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Agricultural Land Suitability Analysis for Yen Khe Hills (NgheAn, Vietnam) using Analytic Hierarchy Process (AHP) Combined with Geographic Information Systems (GIS)

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Abstract: Yen Khe commune of NgheAn province, Vietnam is a hilly area where physical and environmental conditions limit the development of agriculture. For proper planning and management of this hilly terrain, land suitability analysis has been done using Analytic Hierarchy Process (AHP) method combined with GIS based multi criteria decision making approach. Satellite images and Digital Elevation Model (DEM) were used in conjunction with field data for the development of land suitability maps. Pairwise comparison matrix was used to determine weight of the parameters. Results of the AHP-GIS method showed that 12.33 per cent of land surface is highly suitable for agriculture, 20.33% moderately suitable, 29.26 per cent marginally suitable, and 38.08 per cent unsuitable. In this study, the areas where further agriculture development can be done have been suggested within the limitation of land development laws of Vietnam, considering socio-economic requirement and maintaining tradition of local inhabitant. AHP-GIS approach adopted in this study for the development of land suitability map would be helpful for agriculture development in the hilly area of Vietnam and also other part of the world with proper land use management.

***Keywords*:** Agricultural land suitability analysis, Analytic hierarchy process (AHP), Geographic information systems (GIS), Vietnam, Multi-criteria decision analysis (MCDA)

Rational and optimum use of land resources to develop agricultural production is an appropriate approach for sustainable agricultural development, especially under the pressures of rapid population growth, urbanization, and land use change in all developing countries. Land suitability analysis aims at determining favorable land surface for crops and other agricultural land use types. It is an important stepping stone to land use planning (Ahmed et al 2016). Topography, Soil, drainage, agriculture, land use and other thematic data can be easily integrated and analyzed through Geographic Information Systems (GIS) for land suitability analysis to properly plan and manage land for the development of agriculture, especially in hilly area (Collins et al 2001, Malczewski 2004). GIS study can help in providing alternative uses of land for precision farming to improve crop yields (Shalaby et al 2006, Maris et al 2008, Jafari and Zaredar 2010, Feizizadeh and Blaschke 2013).

Determining physical condition of land, soil type and climate help farmers to decide what crops will grow best in that area. Some crops can grow only in specific environment requiring specific nutrient in soil and proper drainage. Therefore, the development of land suitability maps considering physical parameters, soil type and climate is important for the development of crops in the area. Pramanik (2016) used seven different such criteria for land suitability analysis using Analytic Hierarchy Process (AHP) and Weighted Overlay Method (WOM). A combination of GIS and quantitative models of Multi Criteria Decision Analysis (MCDA) enhances degree of accuracy of land suitability analysis. The model requires both spatial and non-spatial data and scored weights of the importance of interested factors (Prakash 2003). Perveen et al (2007) used GIS based AHP (GIS-AHP) to identify arable land surfaces for paddy rice. Chandio et al. (2013) conducted a systematic review for GIS-AHP application in land suitability analysis. GIS-AHP was applied to agricultural land suitability assessment in Tuscany (Italy) (Rovai and Andreoli 2018), Hinglo river basin (India) (Roy and Saha 2018), Kuala Langat (Malaysia) (Nourqolipour et al 2015). GIS-AHP study is considered as one of the most popular and promising multi-criteria evaluation approach for land suitability analysis. However, there are so many risks involved in the crop production including extreme temperatures, droughts, and extreme rainfall events with soil erosion, which may limit the agriculture yield despite best selection of site.

The paper considers a research question: How does a combination of GIS and AHP promote the identification, comparison and multi-criteria decision-making analysis of agricultural land use? Therefore, the main objective of the paper is to apply the GIS-AHP in analyzing the suitability of agricultural land at Yen Khe commune (NgheAn province, Vietnam). The AHP method determines the importance of factors used in land suitability analysis whereas GIS application will help in spatial analysis and development of land suitability maps.

MATERIAL AND METHODS

Study area: Yen Khe commune is located in the Western Nghe An area of Vietnam which is a part of the Pu Mat National Park in the middle of the Annamite Range (Fig. 1). The commune have an area of 5,245 ha and a total population of 5,643 habitants. This commune has been selected as the study area as the development of agriculture in this area is a challenge due to hilly terrain and agriculture is priority for the economic development of the area. Most of the villages in this area are occupied by forest-dwelling ethnic minorities whose livelihoods mainly depend on forest products. Potential cultivation of this foothill areas are tea, orange and annual plants. Due to rapid development of this very small area, proper agriculture development is priority for livelihood of the local population considering local needs. The elevation of this area is between 18 and 960 m. Drainage in the hill area is of dendritic type. The average winter and summer temperature is 15°C and 27°C, respectively. The climate of the area is tropical monsoon type. Average annual rainfall is 1800- 2000 mm. Geology of the area consists of sedimentary, metamorphic and volcanic rocks and alluvium formation. The hill is composed mainly of sedimentary rocks and the plain area is occupied by alluvial soil. The ferralitic soil occupy major part of the study area and alluvial soil along flood plains of rivers and streams.

Data collected and used: Remote sensing, geology, soil, agriculture and meteorological data have been collected from various sources (Table).Thematic maps such as elevation (ELE), slope (SL), soil (S), soil moisture (SM), geology (GO), aspects (AS), and distance from rivers (DR), and distance from road (DRO) were converted in the same standardized units for the analysis. Vector thematic layers were converted to raster layers. They were reclassified to the standardized value and used as parameters to build agricultural land use maps.

Spatial analyst of data: The Aster Digital Elevation Model (DEM) was used to create elevation, slope and aspect maps (Fig. 2, 3, and 4). Geological map was prepared based on the petrology and litho logy of the formations (Fig. 5). Soil map was prepared from the spatial data obtained from the soil database of NgheAn province which was combined with the field data of Yen Khe commune in GIS environment (Fig. 6). Drainage (river system) was extracted from DEM and validated from Google Earth Image. Roads were extracted from Vietnam National Atlas and modified from Google Earth Image. Inverse Distance Weighting (IDW) interpolation method was used to create the distance buffer map from rivers and roads (Fig. 7 and 8). The Normalization Differential Water Index (NDWI) map was generated from Landsat 8 Image using standard formula and classified into five classes for the analysis (Fig. 9). Land cover map as prepared from the Landsat 8 image by adopting supervised classification and modifying it with Google Earth Image (Fig. 10).

Analytic Hierarchy Process (AHP) method: In the present study, AHP method was used to determine the important coefficient of parameters which were evaluated by designing a hierarchy of main criteria and sub-criteria. Multi-criteria decision problems were solved by establishing the pair wise comparison matrix, which reflect the relationship between the components of a level with properties of a higher level. This technique was implemented in a comparison matrix with two criteria at a time. The comparison of the selected parameters was determined for calculating weight of multi-criteria in Yen Khe commune (Table 2). The matrix classification is based on 1-9 scale relative importance of pairwise criteria, where level 1 represents an equally important and level 9 shows extreme importance (Saaty 1977, Feizizadeh and Blaschke 2013). Then Saaty method

Table 1. Information of collected data

Data	Sources	Characteristics	Collected date
Topography	Digital Elevation Model (DEM)	3-ARC (90 meters)	2000
Land cover	Landsat 8 (OLI)	USGS satellite images (30 m)	2018
Soil moisture	Landsat 8 (OLI)	USGS satellite images (30 m)	2018
River and transport	Digitized feature	Open map	2017
Petrography, stratigraphy, Soil	Digitized feature	NATMO and GSI, North Central Vietnam Geological Division	2015

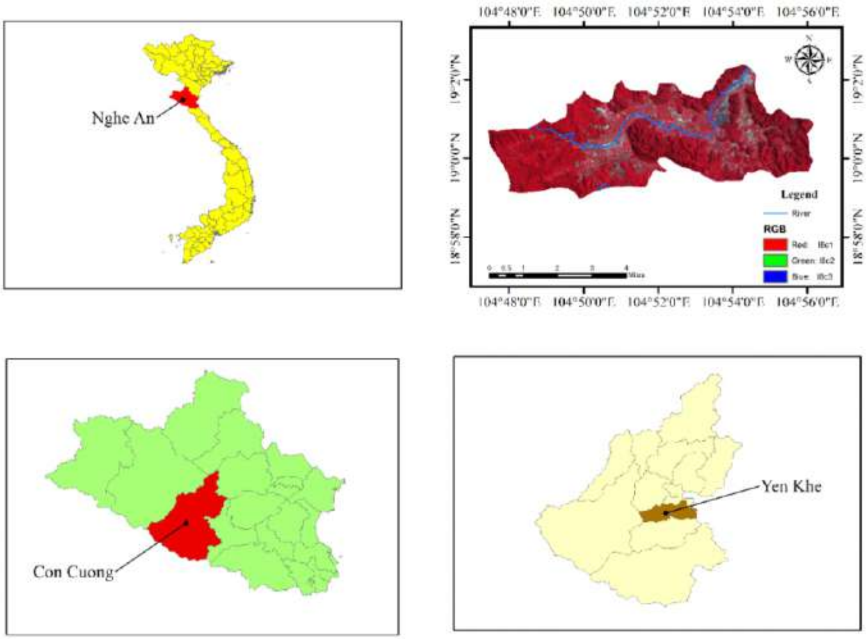

Fig. 1. Location of Yen Khe commune in Con Cuong district, NgheAn province of Vietnam

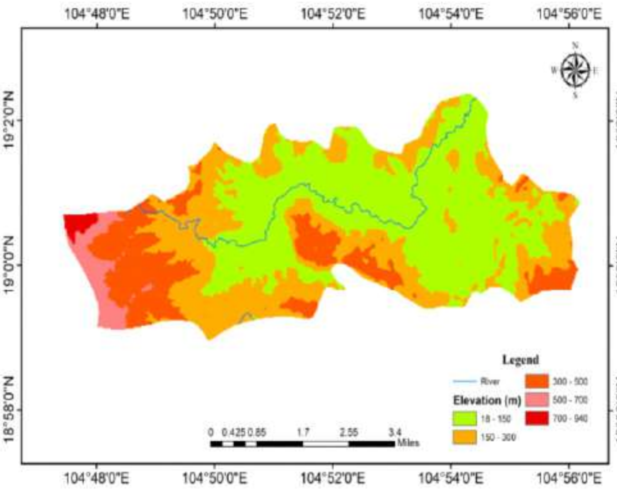

Fig. 2. Map of elevation at Yen Khe commune

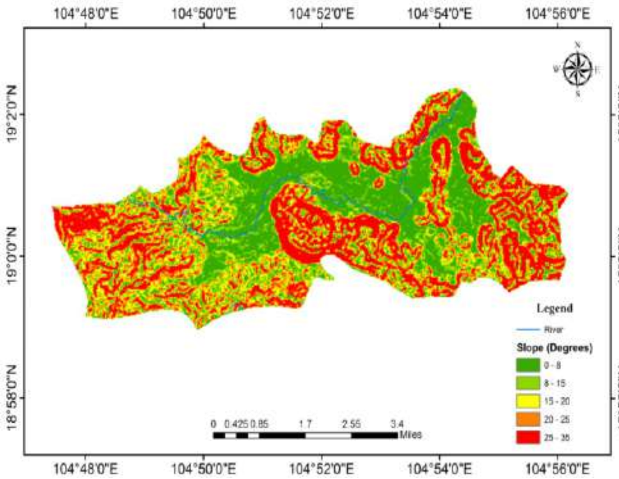

Fig. 3. Map of slope at Yen Khe commune

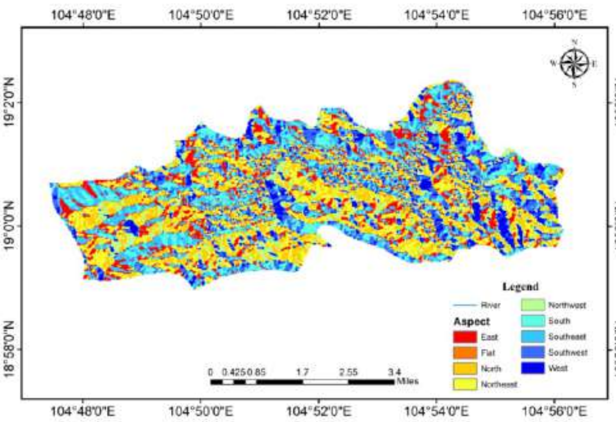

Fig. 4. Map of aspect at Yen Khe commune

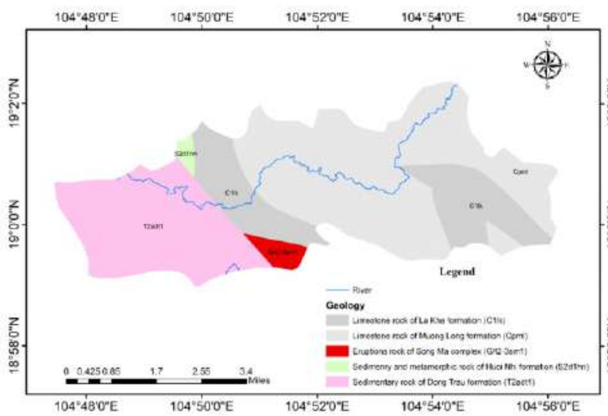

Fig. 5. Map of geology at Yen Khe commune

was applied to calculate weights and Eigenvalues (Table 3 and 4). The efficiency criteria of AHP was evaluated by consistency relationship (CR) which is measured by equation CR = CI/RI where CI represents consistency index and RI represents random index (Feizizadeh and Blaschke 2013).

The suitability of land for agricultural development is determined by using weighted overlay techniques based on the AHP method and multi-criteria decision-making analysis. The AHP was applied to determine the influential factors in the hierarchy and all created thematic layers were combined in GIS for the application of weighted overlay techniques. Each pixel on a raster data layer contains a specified value. Selected raster layers were overlaid by recognizing their cell values to the same scale, giving a weight value to individual criterion and integrating the weight cell values together. When overlaying raster data layers at the same scale, the cell value of each pixel was multiplied by their weight value using Arc GIS software. Processes and methods are shown in Figure 11.

RESULTS AND DISCUSSION

Reclassified criteria layers: All parameters were divided into 5 different categories for the development of map. The sub-criteria were divided into 5 different scales corresponding to scores 2, 4, 6, 8, and 10. Score '2' is the lowest values and score '10'indicates the highest values (Table 5).

Table 2. Matrix results of parameters compared pair wise in Yen Khe commune

Criteria	SL	ELE	SM	DR	S	GEO	AS	RO
SL	1	2	2	4	2	6	6	7
ELE	1/2	1	1	3	1/2	4	5	6
SM	1/2	1	1	2	1/2	4	4	4
DR	1/4	1/3	1/2	1	1/2	2	1	2
S	1/2	2	2	2	1	4	3	3
GEO	1/6	1/4	1/4	½	1/4	1	2	1
AS	1/6	1/5	1/5	1	1/3	½	1	1
RO	1/7	1/6	1/6	½	1/3	1	1	1

Table 3. Estimated weight of criteria

Criteria	SL	ELE	SM	DR	S	GEO	AS	RO	Weight
SL	0.31	0.29	0.28	0.29	0.37	0.27	0.26	0.28	0.292
ELE	0.15	0.14	0.14	0.22	0.09	0.18	0.22	0.24	0173
SM	0.15	0.14	0.14	0.15	0.09	0.18	0.17	0.16	0.148
DR	0.08	0.05	0.07	0.07	0.09	0.09	0.04	0.08	0.070
S	0.15	0.29	0.28	0.15	0.18	0.18	0.13	0.12	0.187
GEO	0.05	0.04	0.04	0.04	0.05	0.04	0.09	0.04	0.038
AS	0.05	0.03	0.03	0.07	0.06	0.02	0,.04	0.04	0.051
RO	0.04	0.02	0.02	0.02	0.06	0.04	0.04	0.04	0.041

Table 4. RI index with n = 10

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.57	0.88	1.14	1.23	1.33	1.41	1.45	1.48

Site suitability maps for potential agriculture: The highly suitable area for agricultural production is 645.81 ha (12.33%), moderately suitable is 1064.72 ha (20.33%); marginally suitable land is 1532.76 ha (29.26%); currently unsuitable land for agricultural production is 1357.67 ha (25.92%) and permanently unsuitable is 637.24 ha (12.17%) (Fig. 12).

High suitability area: Land in this category falls on gentle slopes (0°– 8°) at relatively low elevation(<300m), where soil moisture is high, soil is good and also good irrigation facility is available. Valleys in the central of study area part of the study are highly suitable for cultivation especially of rice. However, where surface moisture is less, irrigation facilities are to be provided.

Moderate suitability area: About 1064 ha land (20.33%) falls in this category. Characteristics of this area are gentle to moderate slopes (8°–15°), medium soil moisture, lower elevation, ferralitic soil and moderate water supply. This area can be used for farming with proper soil erosion prevention method especially during rainy season.

Marginally suitable area: About 1532.76 ha (29.26%) land falls in this category. Characteristics of this area are moderately high slope (15°–20°), less soil moisture, moderately higher elevation. In this area, possibility of erosion of soil is more during monsoon. However, natural water supply in this area is less due to elevation. Therefore, this area is less suitable for agricultural production because of its moderate height, slope and distance of water source and distance from the road. Investment in the development of irrigation systems or extension of roads would be difficult and expensive.

Currently not suitable: About 1357.67 ha (25.92%) land falls in this category. Characteristics of this area are high slope, dry soil, barren land, rocky soil, lack of water supply

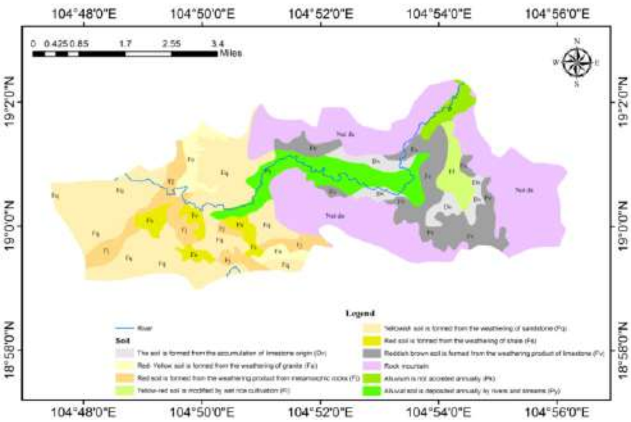

Fig. 6. Soil characteristics map at Yen Khe commune

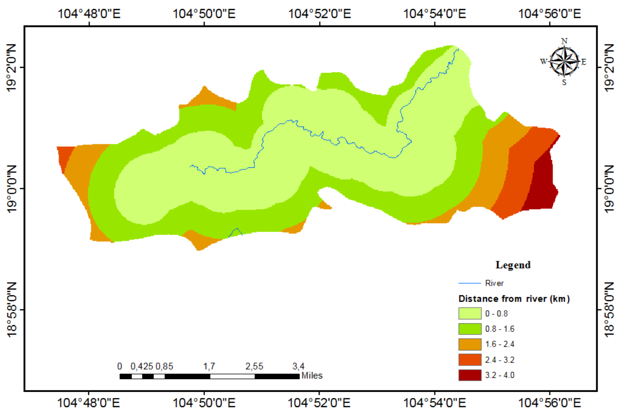

Fig. 7. Distance map from rivers at Yen Khe commune

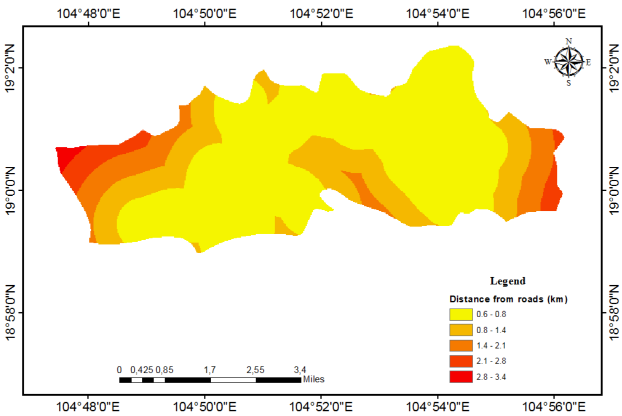

Fig. 8. Distance map from roads at Yen Khe commune

capacity. These areas are currently unsuitable for agriculture production. At present, these high altitude areas are covered with dense vegetation, mainly planted forests. Thus, this type of land is not providing revenue to indigenous people from cultivation.

Permanently not suitable: About 637.24 ha (12.17%) land

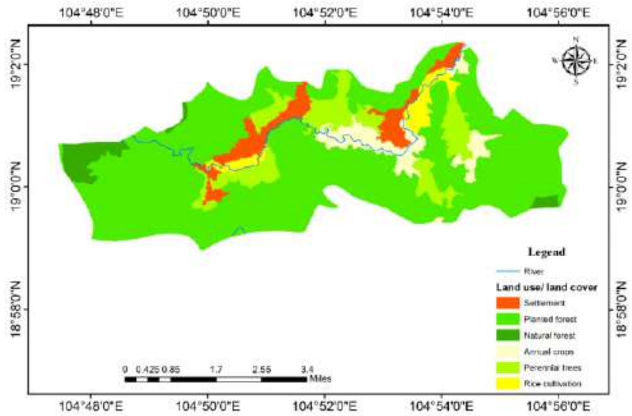

Fig. 10. Land use land cover map at Yen Khe commune

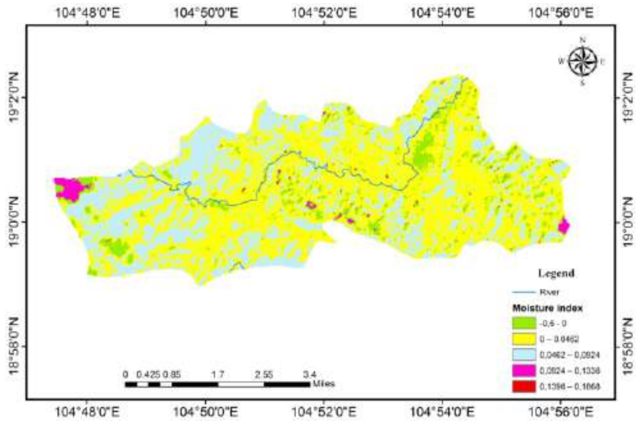

Fig. 9. Map of moisture index at Yen Khe commune

falls in this category. This area has high slope, dry soil, poor soil and water condition. Land in this area is mainly under natural forest inhabited by a few local people. Most of the land is rocky and barren not suitable for the agriculture. Relatively large parts of watershed of Kem stream and Thoi Stream (Yen Khe commune) are occupied by this type of land. At present, these areas are within the protected core zone and buffer zone of Pu Mat National Park.

Geology, soil type, elevation, slope, aspects, drainage and distance from rivers are selected for agricultural land suitability analysis as ecological limitation criteria (Akıncı et al 2013). Agriculture requires favorable climate, topography, suitable soils and irrigation facility. For selling the agriculture produce good transport system is required in the area. In accordance with Food and Agricultural Organization (FAO), land suitability for agriculture can be classified into five levels: 1. Highly suitable agricultural land, 2. Moderately suitable agricultural land, 3. Marginally suitable agricultural land, 4. Currently not suitable for agriculture, and 5. Permanently not suitable for agricultural production. Less suitable areas can

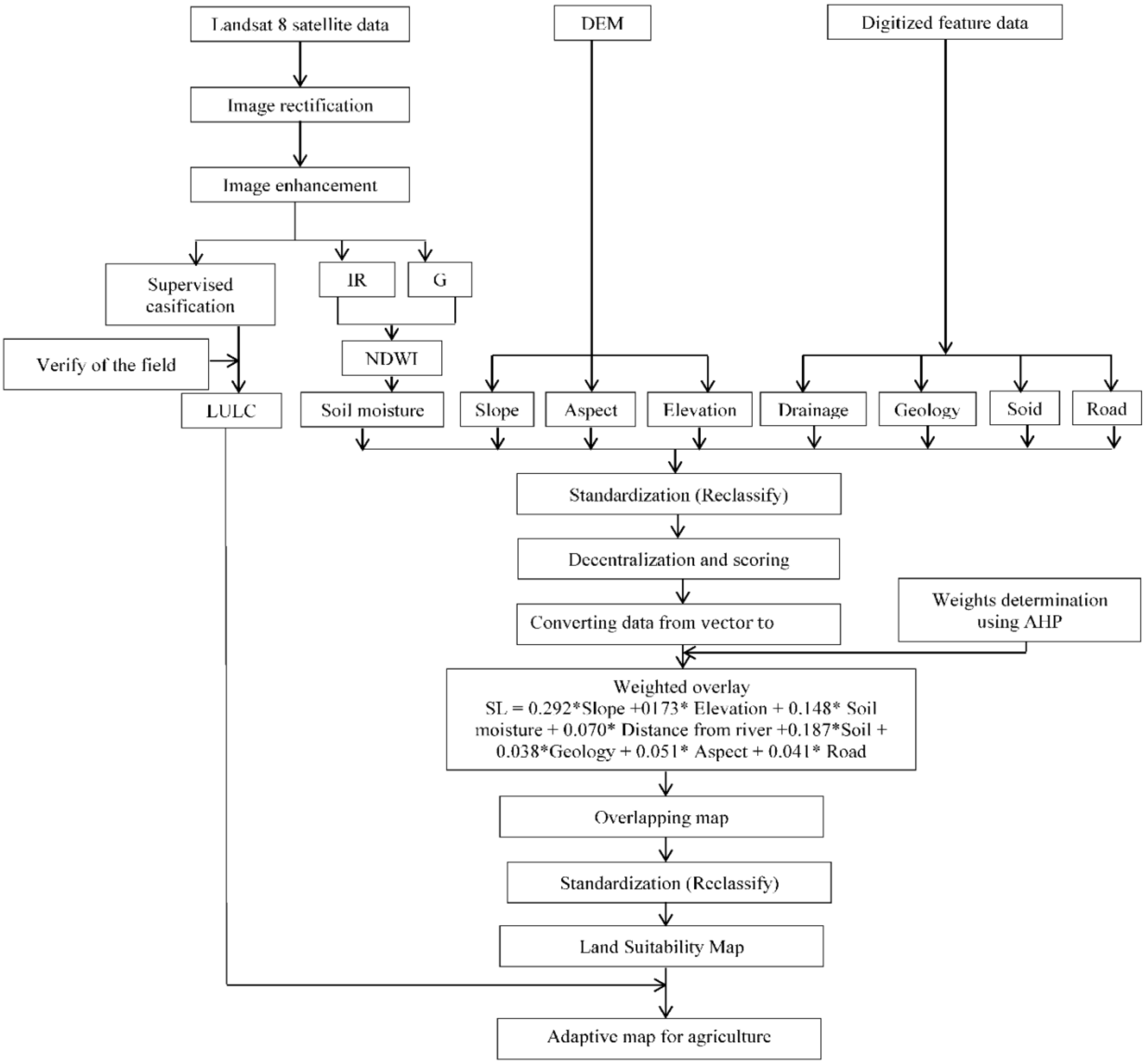

Fig. 11. Flow chart of methodology

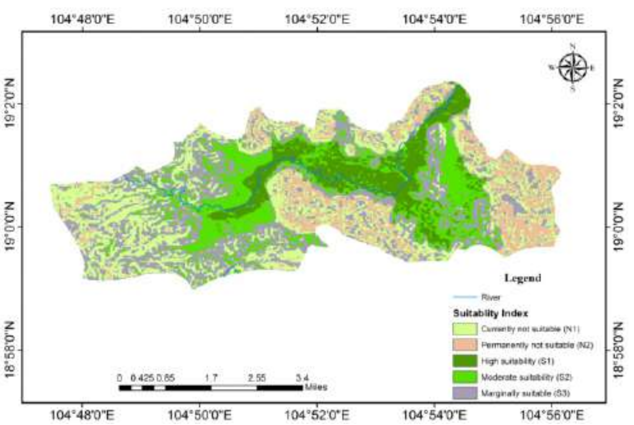

Fig. 12. Site suitability map for agriculture in Yen Khe commune

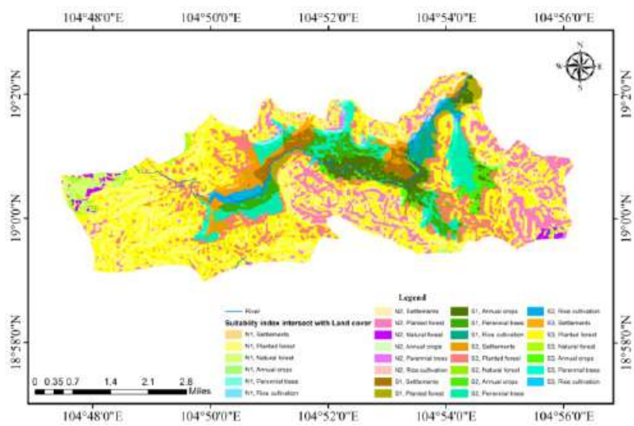

Fig. 13. Map of potential agriculture land use in Yen Khe commune

Table 5. Scores of the main criteria and sub-criteria

Main criteria	Sub-criteria	Area (ha)	Area (%)	Score
Slope (°)	0–8	1354.74	25.86	10
	8–15	1036.55	19.79	8
	15–20	726.29	13.87	6
	20–25	667.75	12.75	4
	25–69	1452.85	27.74	2
Elevation (m)	18–150	2460.052	46.96	10
	150–300	1706.76	32.58	8
	300–500	838.15	16.00	6
	500–700	191.91	3.66	4
	700–940	41.33	0.79	2
Soil moisture	-0.6-0	1704.14	32.53	2
	0–0.0462	3097.71	59.14	4
	0.0462–0.0924	370.22	7.07	6
	0.0924–0.1336	65.70	1.25	8
	0.1396–0.1868	0.43	0.008	10
Distance from river (km)	0–0.084	563.68	10.76	10
	0.084–0.141	1262.42	24.10	8
	0.141–0.197	1036.03	19.78	6
	0.197–0.254	872.71	16.66	4
	0.254–0.3118	1503.37	28.70	2
Soil	Yellow-red soil is modified by wet rice cultivation (Fl)	133.9044	2.56	6
	Reddish brown soil is formed from the weathering product of limestone (Fv)	547.5969	10.48	8
	Alluvium is not accreted annually (Pk)	94.1476	1.8	10
	The soil is formed from the accumulation of limestone origin (Dv)	213.7758	4.08	8
	Alluvial soil is deposited annually by rivers and streams (Py)	403.0224	7.71	10
	Red soil is formed from the weathering product from metamorphic rocks (Fj)	388.4654	7.43	4
	Red soil is formed from the weathering of shale (Fs)	355.2053	6.79	4
	Red- Yellow soil is formed from the weathering of granite (Fa)	160.0799	3.06	2
	Yellowish soil is formed from the weathering of sandstone (Fq)	1095.215	20.93	2
	Rock mountain	1846.8	35.26	0
Geology	Limestone rock of La Khe formation.	1097.20	20.95	2
	Limestone rock of Muong Long formation Cp*ml*	2554.00	48.76	4
	Sedimenry and metamorphic rock of HuoiNhi formation (S_2d_1hn)	44.49	0.85	6
	Eruptions rock of Song Ma complex ($G/t_{2-3}sm_1$)	104.21	1.99	8
	Sedimentary rock of Dong Trau formation (T_2adt_1)	1438.31	27.46	10
Aspect	SW, flat	590.92	11.28	10
	S, SE	1460.95	27.89	8
	E, W	1311.06	25.03	6
	NW, NE	1506.97	28.77	4
	N	368.31	7.03	2

be developed for agricultural production, by preventing soil degradation with proper land use management (Bocco et al 2001, Prato 2007).

Site suitability and agriculture potential maps of the Yen Khe commune were developed based on the AHP-GIS methods (Fig. 13 & 14). Area having natural forest cover is mostly unsuitable for agriculture. This is consistent with the reality as these types forests exist in areas with rugged terrain at high altitude. In the planted forest cover, there is 17 per cent of area suitable for agricultural cultivation. This is an area that can be converted from forestation to fruit trees or other agricultural crops. In the annual crop area, there is still 38 % of area inappropriate for agriculture due to limited availability of irrigation water and less soil fertility. This area can be converted to growing perennial trees, fruit trees with a more appropriate irrigation facility and use of fertilizers.

In the covered by perennial trees, only 28 per cent area is highly suitable for agriculture, and 48 per cent area is moderately suitable for agriculture. Thus, remaining 24 per cent area can be considered for another type of land use. Plantation of forest can be done in this area in view of the steep slopes. About 53 per cent of rice cultivation (paddy rice) area of Muong Qua, Thai Son and Thai Hoa fieldsis valued for high revenue generation. But about 31 per cent of this area lack water supply during dry season. Therefore, adequate irrigation facility is required in this area, which is suitable for rice production. Moreover, drought-resistant rice varieties can be considered for this area besides food crops. The remaining 14 per cent of the area is not suitable for wet rice cultivation due to physical limitations and soil composition.

Changes in land use for agriculture production in the future may be less due to limited availability of land and legal

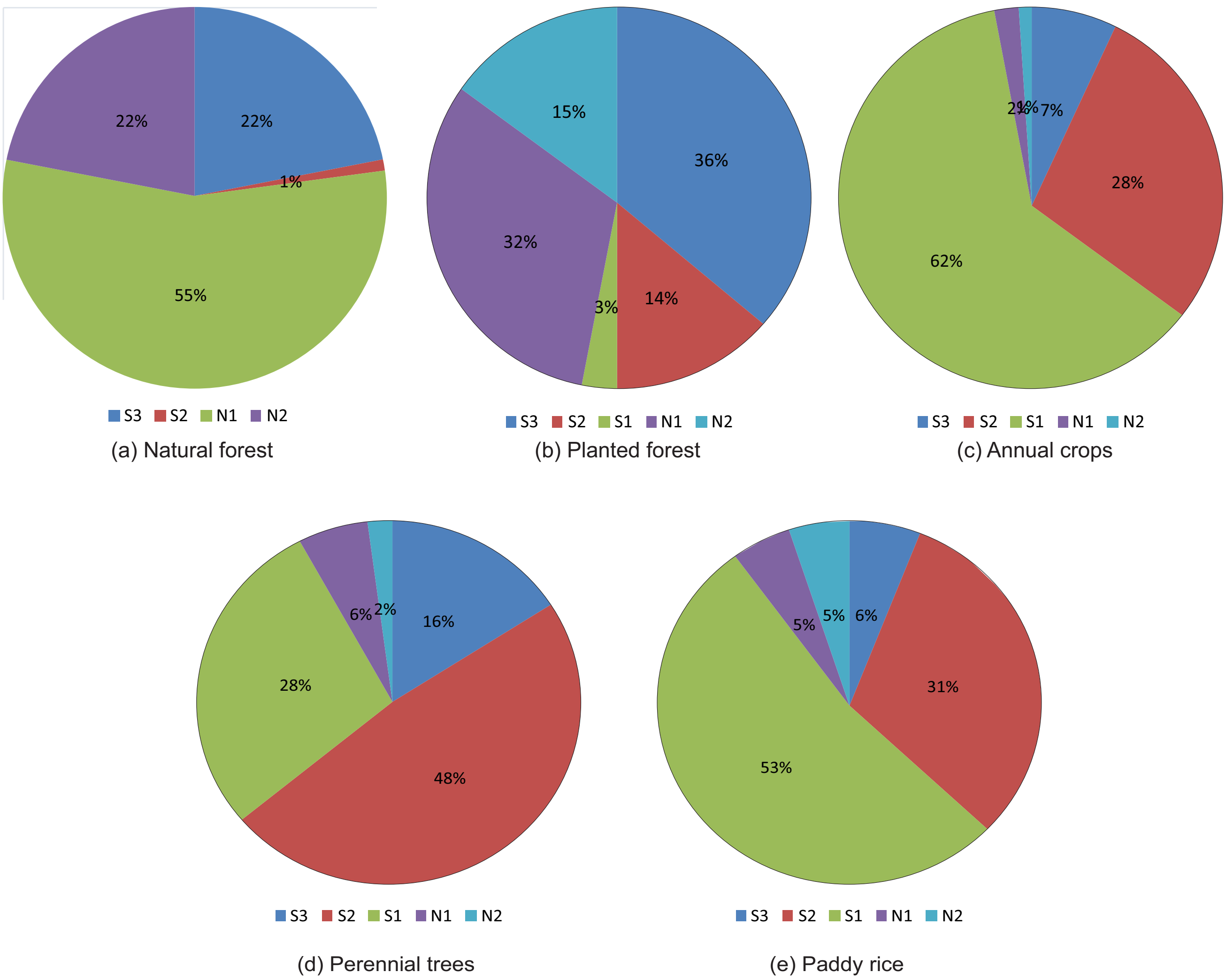

Fig. 14. Land suitability levels in each type of current land use indicated in Figure 13

restrictions (Zarkesh et al 2010). Farmers in mountainous areas are being encouraged by the government to convert less effective annual crops into permanent grasslands or plantations. The priority of land use in some units is determined by legal requirements, and cannot be changed, such as military or protective land (Pierce et al 2005). In some cases, many other uses can be proposed such as afforestation, perennial crops or fruit trees because they meet the requirements (Vlek et al 2017). According to FAO, time variability of meteorological variables like temperature, rainfall and wind over long periods could give severe limitations for crops that should be considered in the classification scheme by means of suitable climatic indexes [FAO].

CONCLUSION

GIS-AHP method was applied to evaluate the suitability of land for agriculture use in Yen Khe commune, Con Cuong district, NgheAn province, Vietnam. The relatively large area 1994.91 ha (38.09%) is not suitable for agriculture activity. Only 645.81 ha (12.33%) study area falls in mostly suitable category for agricultural production. In Vietnam, natural forest land cannot be allocated for other purposes including agricultural production. In the suitability analysis, such restricted areas were considered for exclusion: 2.62 ha (0.05%) of natural forest overlapping with marginally suitable land class and 36.82 ha (0.7%) natural forest coinciding with moderately suitable agricultural land class. Land suitability maps developed from GIS-AHP method indicate that highly suitable land for agriculture use is located in the central area of Yen Khe which is only 12.33 per cent of the total study area. In this part of the area favorable conditions for agriculture production such a slow slope, availability of water and good quality soil exist. The present approach of AHP-GIS applied in this study area can also be of help in the development of other hilly areas also for suitable land use planning and thus enhancement of agriculture and other crop production. However, this study has some limitations of suitability of selection of criteria for land use planning depending on the local condition and variation in climatic condition. Local people have properly managed about 155 ha area, which falls under unsuitable category (slope greater than 25°, higher elevation about 1000m and dry soil). This land area is being used for the production of food crops (rice, maize), tea, and oranges with the application of improved simple farming techniques. In the land use planning, tradition of local forest-dwelling people may also have to be taken in account while evaluating land suitability for agriculture considering social, point of view besides economic and environment.

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REFERENCES

Ahmed GB, Shariff ARM, Balasundram SK and Bin Abdullah AF 2016. Agriculture land suitability analysis evaluation based multi criteria and GIS approach. *IOP Conference Series: Earth and Environmental Science*. IOP Publishing. p 012044

Akıncı H, Özalp AY and Turgut B 2013. Agricultural land use suitability analysis using GIS and AHP technique. *Computers and electronics in agriculture* **97**: 71-82.

Bocco G, Mendoza M and Velázquez A 2001. Remote sensing and GIS-based regional geomorphological mapping-A tool for land use planning in developing countries. *Geomorphology* **39**: 211-219.

Chandio IA, Matori ANB, WanYusof KB, Talpur MAH, Balogun A-L and Lawal DU 2013. GIS-based analytic hierarchy process as a multicriteria decision analysis instrument: a review. *Arabian Journal of Geosciences* **6**: 3059-3066.

Collins MG, Steiner FR and Rushman MJ 2001. Land-use suitability analysis in the United States: historical development and promising technological achievements. *Environmental Management* **28**: 611-621.

Feizizadeh B and Blaschke T 2013. Land suitability analysis for Tabriz County, Iran: a multi-criteria evaluation approach using GIS. *Journal of Environmental Planning and Management* **56**: 1-23.

Jafari S and Zaredar N 2010. Land Suitability Analysis using multi attribute decision making approach. *International Journal of Environmental Science and Development* **1**: 441.

Malczewski J 2004. GIS-based land-use suitability analysis: a critical overview. *Progress in planning* **62**: 3-65.

Maris N, Mansor S and Shafri H 2008. Apicultural site zonation using GIS and multi-criteria decision analysis. *Pertanika Journal of Tropical Agricultural Science* **31**: 147-162.

Nourqolipour R, Shariff ARBM, Balasundram SK, Ahmad NB, Sood AM, Buyong T and Amiri F 2015. A GIS-based model to analyze the spatial and temporal development of oil palm land use in Kuala Langat district, Malaysia. *Environmental Earth Sciences* **73**: 1687-1700.

Perveen F, Nagasawa R, Uddin MI and Delowar HK 2007. Crop land suitability analysis using a multicriteria evaluation and GIS approach. *5th International Symposium on Digital Earth Berkeley*, USA: The University of California. pp 1-8.

Pierce SM, Cowling RM, Knight AT, Lombard AT, Rouget M and Wolf T 2005. Systematic conservation planning products for land-use planning: interpretation for implementation. *Biological Conservation* **125**: 441-458.

Prakash T 2003. Land suitability analysis for agricultural crops: a fuzzy multicriteria decision making approach. *ITC.*

Pramanik MK 2016. Site suitability analysis for agricultural land use of Darjeeling district using AHP and GIS techniques. *Modeling Earth Systems and Environment* **2**: 56.

Prato T 2007. Evaluating land use plans under uncertainty. *Land use Policy* **24**: 165-174.

Roberts M, Randolph J and Chiesa J 1979. A land suitability model for the evaluation of land-use change. *Environmental Management* **3**: 339-352.

Rovai M and Andreoli M 2018. Integrating AHP and GIS Techniques for Rural Landscape and Agricultural Activities Planning. *Multicriteria Analysis in Agriculture*.Springer, pp 69-98.

Roy J and Saha S 2018. Assessment of land suitability for the paddy cultivation using analytical hierarchical process (AHP): A study on Hinglo river basin, Eastern India. *Modeling Earth Systems and Environment* **4**: 601-618.

Saaty TL 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology* **15**: 234-281.

Shalaby A, Ouma Y and Tateishi R 2006. Land suitability assessment for perennial crops using remote sensing and Geographic Information Systems: A case study in northwestern Egypt. *Archives of Agronomy and Soil Science* **52**: 243-261.

Vlek P, Azadi H, Bhaduri A, Bharati L, Braimoh A, Martius C, Sunderland T and Taheri F 2017. The trade-offs in multi-purpose land use. Land degradation and the Sustainable Development Goals: Threats and potential remedies. *International Center for Tropical Agriculture (CIAT)*, Nairobi, Kenya.

Zarkesh MK, Ghoddusi J, Zaredar N, Soltani MJ, Jafari S and Ghadirpour A 2010. Application of spatial analytical hierarchy process model in land use planning. *Journal of Food, Agriculture & Environment* **8**: 970-975.

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Modelling Dissolved Oxygen Concentration Using Artificial Neural Networks

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Abstract: An attempt was made to study the suitability of water for drinking based on various water quality parameters in Guntur, Andhra Pradesh, India. Parameters that were considered for water quality assessment includes pH, turbidity (T), electrical conductivity (EC), salinity (S), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH),chloride (Cl) and dissolved oxygen (DO). All the above parameters were modelled using artificial neural network (ANN)and multiple linear regression (MLR) techniques to compute DO. The performance of the ANN models was assessed based on root mean squared error (RMSE), mean absolute error (MAE), coefficient of determination (R^2), and Willmott index (WI). The results of the analysis showed that the pH, EC, S, TDS, DO are within BIS permissible range as compared to TA, TH, and Cl. It was found that the DO values computed by the ANN model were in close agreement with their respective observed values as compared to MLR.

***Keywords*:** Alkalinity, Dissolved oxygen, Water quality, ANN, Guntur

Water with 71 per cent of the Earth's coverage is the most important resource in shaping the land and regulating the climate. Groundwater, surface water (rivers, streams and ponds), atmospheric water (rain water, snow and hail) and springs are the main sources of water available. On Earth, 97.5 per cent of the water is inaccessible to the human being; whereas only 2.5 per cent of fresh water is used for human, agriculture and industries. Most of fresh water bodies all over the world are getting polluted due to rapid industrialization and indiscriminate use of chemical, fertilizers and pesticides in the agriculture sector, thus decreasing the portability of water. Furthermore, due to increase in population, industrialization and urbanization, large quantities of sewage and industrial wastewater are discharged into water bodies, that have significantly contributed to the pollution of water. Once the water is contaminated, its quality cannot be restored back easily. It is therefore necessary to check the quality of available water sources at regular intervals of time. To maintain good health however, water should be safe to drink and meet the local standards and international standards in taste, odour and appearance. To monitor the water resources and ensure its sustainability, water quality standards based on various parameters by national and international criteria and guidelines were established American Public Health Association (APHA 2002) and Bureau of Indian Standards (BIS 2012). Quality of any kind of water for its various purposes depends on a large number of physico-chemical properties assessment. Determination of these parameters using conventional methods is often tedious and time consuming.

Artificial Neural Networks (ANNs) are suitable models to overcome the limitations of conventional methods (Malik et al 2017, Malik et al 2018a, Malik et al 2018b, Singh et al 2018, Malik et al 2019). ANNs are data dependent models that work on the principle of learning and memorizing the patterns in data, which extract a relationship between model inputs and outputs with a minimum data requirement (Adamala et al 2014). Various investigations on modelling water quality and predicting various physico-chemical water parameters were studied by (Dogan et al 2009, Basant et al 2010, Gazzaz et al 2012, Heydari et al 2013). Analysing various physico-chemical properties of water becomes an important criterion for the assessment and management of water quality. This necessitates the collection of various water samples from different places in Guntur district. The objectives of this study are to analyse the quality in terms of physico-chemical parameters of different water samples in Guntur region and to model DO using ANN.

MATERIAL AND METHODS

Study area: Geographically, Guntur lies between 15°30' N and 17° 00' N latitude, 79° 10' E and 80° 50' E longitude. Study area experiences an average annual rainfall of 906 mm and average temperature of 28.5°C. It lies at an elevation of 30 m above mean sea level. It has a tropical climate and is one of the industrial corridors of Andhra Pradesh. Soils of the study area are red gravel, black cotton, sand alluvial and saline swamps. Water samples from 20 different locations in the study area during 2017-2018 were collected to test the water quality (Fig. 1). Samples at each location were taken seven times during the study period.

Physico-chemical parameters: Water quality parameters analyzed from the collected samples were pH, electrical conductivity (EC, µS/cm), salinity (S, ppt), total dissolved solids (TDS, ppt), turbidity (T, NTU), total alkalinity (TA, ppm), total hardness (TH, ppm), chloride (Cl, ppm) and dissolved oxygen (DO, ppm). The pH, EC, S, T, TDS of water samples were determined using water quality analysis kits with the standard procedure of the equipment. The chemical analysis of collected samples was performed to estimate TA, TH, DO and Clas per the American Public Health Association (APHA2002) and the American Water Work Association (AWWA 1979) procedures.

Artificial neural networks (ANN): ANN is an artificial model works on the principle of the biological nervous system. ANNs consists of input (*i*), hidden (*j*), and output (*k*) layers, which are processes by weights, *w*. These layers are interconnected by a large number of processing elements called 'neurons'. Figure 2 shows a typical architecture of three-layer ANN with the interconnection weights w_{ij} and w_{jk} between layers of neurons. ANNs are trained with the popular back-propagation (BP) algorithm in about 80 to 90 per cent of practical modelling applications (Adamala et al 2015). In a forward pass, the BP learning updates the weights in the direction in which the performance function decreases most rapidly and the error between observed and predicted is computed. The error is propagated from the output layer to the input layer for updating the weights of connections. Detailed information about the ANNs is found in McCulloch and Pitts (1943). The mathematical form of ANN is expressed as:

$$y = \phi\left[\sum_{i=0}^{n} w_{ij} x\right] \qquad (1)$$

Where *x* = input vector; *y* = output vector; *w* = set of adaptive parameters (weights); *n* = number of elements in the input vector; and Ø= sigmoidal activation function.

developing ANN models, the code was written using MATLAB 7.0 programming language (The Math Works, Inc., Natick, Mass.). If the input data is of different dimensions, the normalization of input data is essential to achieve all variables into the same magnitude and to avoid the rejection of smallest magnitude variables. A MATLAB built-in function 'mapstd' is used to normalize the input and output data so that it's mean and standard deviations were to 0 and 1, respectively. The output is converted back into the same unit by denormalization procedure.

ANN modelling is achieved by dividing the dataset into two sets: training and testing. The ANN was trained and validated with 70 and 30 per cent of the data sets respectively. DO based ANN models were developed with different input combinations varying from eight inputs to one output. The results pertaining to eight inputs were only discussed here due to their superior performance as compared to other input combinations. The input layer of ANN model consists of 8 nodes such as pH, EC, T, S, TDS, TA, TH, and Cl and the output layer consists of one node such as DO. Sigmoidal and linear activation functions were employed in the hidden layer and output layer neurons, respectively. In order to reach optimum hidden layer nodes, nodes from 1 to 20 were tested on a trial-and-error basis. The optimum neural network can be selected based on criteria such that the node at which model has minimum error and maximum efficiency (Malik and Kumar 2015, Malik et al 2018a). Within this range, the ANN architecture having one hidden layer and 12 nodes gives the best choice. Two important parameters during network training are the learning rate and the momentum, which were fixed as 0.6 and

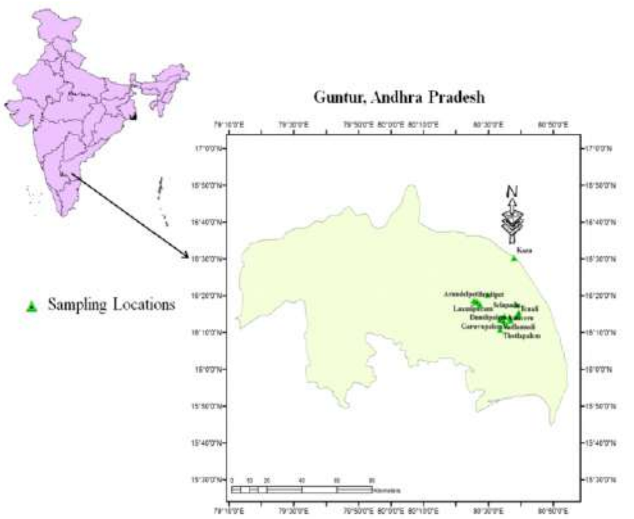

Fig. 1. Sampling locations of study area

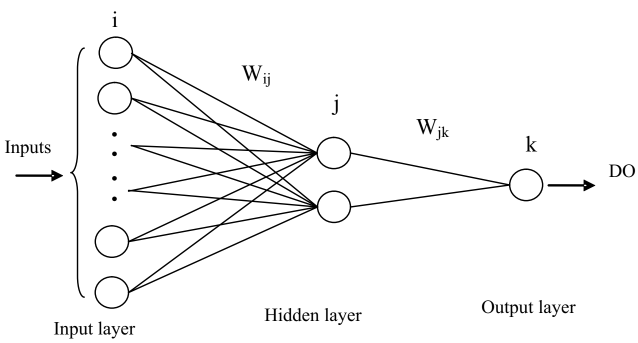

Fig. 2. A three layer feed-forward ANN model

0.87, respectively after the number of trial and error procedures. The final set of weights after training was stored for future prediction using new input data.

Multiple linear regression (MLR) model: MLR is a conventional approach in the statistical modelling, which models the relationship between one dependent and number of independent variables. The general form of the MLR model is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ...+ \beta_{n-1} x_{n-1} + \beta_n x_n \qquad (2)$$

where *y* = dependent variable (predictant) that is represented as a function of *n* independent variables (predictors), *x*; β_0 = unknown intercept; β_1, β_2,... , β_{n-1}, β_n = partial regression coefficients of the function.

Evaluation of models: In order to evaluate the performance of the developed ANN and MLR models, statistical analysis involving the root mean squared error (RMSE), mean absolute error (MAE), coefficient of determination (R^2), and Willmott index (WI) were conducted. The expressions for the aforementioned statistical parameters are described below.

$$\text{Root Mean Squared Error (RMSE)} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(T_{ii}-O)^2} \qquad (3)$$

$$\text{Mean Absolute Error (MAE)} = \frac{1}{n}\sum_{i=1}^{n}|T_{ii}-O| \qquad (4)$$

$$\text{Coefficient of determination } (R^2) = \frac{\left[\sum_{i=1}^{n}(O_i-\bar{O})(T-\bar{T}_i)\right]^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2\sum_{i=1}^{n}(T_i-\bar{T})^2} \qquad (5)$$

$$\text{Willmott index (WI)} = 1-\left[\frac{\sum_{i=1}^{n}(O_i-T_i)^2}{\sum_{i=1}^{n}\left(|O_i-\bar{O}|+|T_i-\bar{T}|\right)^2}\right] (0 < \text{WI} \le 1) \qquad (6)$$

Where T_i and O_i = observed and predicted values; n = number of data points, $\bar{O}$ and $\bar{T}$ = average of observed and predicted values.

RESULTS AND DISCUSSION

Table 1 shows the mean values of nine physico-chemical parameters from 20 sampling locations along with their permissible limits as per BIS (2012). All six parameters (pH, EC, S, TDS, DO, and T) were found within the permissible range for all sampling locations as per BIS(2012) standards for drinking water. However, the TH and Cl concentrations were found lesser than the BIS (2012)permissible range for most of the locations. The TA concentration was high for six locations and low for one location as compared to BIS (2012) standards. The crossing of permissible range for the above three parameters for most of the locations depicts the existence of heavy metals in the water body. ANN and MLR models' performance was evaluated using RMSE, MAE, R^2, and WI. The results of ANN and MLR estimated DO during training and testing are shown in Table 2. ANN based DO model gave the RMSE (ppm) values of 0.375 and 1.211 during training and testing, respectively. Similar results can be depicted with the MAE, R^2 and WI from Table 2.ANN based models for DO prediction performed superior as compared to MLR models in terms of low RMSE and MAE and high R^2 and WI indices. Overall comparison of results showed that the ANN model gave reasonable estimates for the DO prediction.

Time series plots of observed and ANN predicted DO is shown in Figure 3. The observed and ANN predicted DO values of were exactly matches for most of the sampling locations except sample numbers 15, 17 and 19 (Laxmipuram, Pedakakani and Brodipet). However, a small deviation in prediction was observed for nine (Vadlamudi) and 11 (Valiveru) samples (Fig. 3). Figure 4a and 4b are the scatter plots of observed and ANN predicted DO during training and testing periods, respectively. The scatter plots in Fig. 4 confirm the R^2 statistics given in Table 2 (training and testing). ANN estimated DO agree well with the observed DO and were distributed evenly on both sides of the 1:1 line during training. Comparison of Fig. 4a and Fig. 4b revealed that the spread of ANN estimated DO around 1:1 line was less than that of the observed DO during testing as compared to training. The ANN estimated DO were well agreed with the observed DO values with high values of R^2(>0.632).

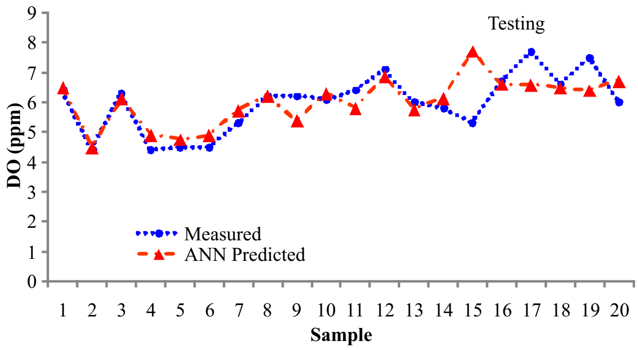

Fig. 3. Time series plots of ANN estimated DO with respect to observed data during training and testing

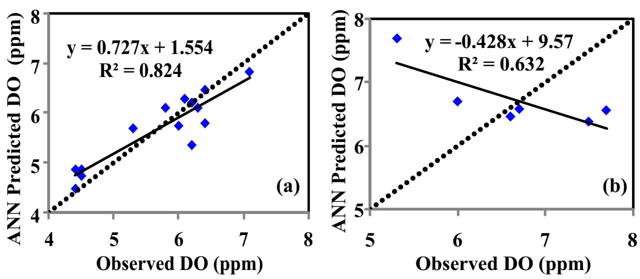

Fig. 4. Scatter plots of ANN estimated and observed DO during (a) training and (b) testing

Table 1. Mean value of physico-chemical parameters of water samples

Sampling location	No.	pH	EC (μS cm^{-1})	S (ppt)	TDS (ppt)	DO (ppm)	T (NTU)	TH (ppm)	TA (ppm)	Cl (ppm)
Permissible range (BIS 2012)		6.5-8.5	0-300	1-2	0.5-2	< 20	1-5	300-600	200-600	250-1000
Tenali	1	7.01	5.62	1.7	1.67	6.4	2	475	575	*92.7*
Nandivelugu	2	7.76	1.52	1.3	1.00	4.4	2	330	*850*	282
Angalakuduru	3	6.85	3.66	1.9	1.41	6.3	2	*270*	390	*79*
Dundipalem	4	7.42	1.97	1.6	1.29	4.4	3	*245*	*775*	265
Edlapalli	5	7.07	2.35	2.0	1.56	4.5	2	*255*	600	531
Sangam Jagarlamudi	6	6.75	1.68	1.4	1.10	4.5	3	525	*650*	318
Garuvupalem	7	7.76	0.26	0.2	0.17	5.3	1	*250*	*175*	*153*
Vadlamudicross road	8	7.2	1.12	0.9	0.73	6.2	3	320	350	283
Vadlamudi	9	6.62	0.75	0.6	0.5	6.2	2	*220*	475	*215*
Penugudurupadu	10	6.67	0.65	0.5	0.43	6.1	2	*220*	275	*220*
Valiveru	11	6.57	1.59	1.3	1.04	6.4	3	455	475	390
Thotlapalem	12	6.64	1.28	1.1	0.86	7.1	3	*200*	300	*167*
Selapadu	13	6.55	2.04	1.7	1.36	6	2	*260*	*725*	290
Chavavaripalem	14	7.41	0.78	0.6	0.51	5.8	3	*275*	275	274
Laxmipuram	15	7.25	0.68	0.6	0.45	5.3	3	*245*	300	*206*
Chinakakani	16	7.08	0.9	0.7	0.6	6.7	1	*255*	600	*141*
Pedakakani	17	6.9	1.5	1.3	1	7.7	3	335	525	300
Kaza	18	7.23	0.73	0.60	0.48	6.6	3	300	500	*113.2*
Brodipet	19	7.3	0.73	0.06	0.48	7.5	2	*275*	325	*124*
Arundelpet	20	7.3	2.42	1.4	1.58	6.0	2	300	*750*	318

Table 2. Performance analysis of ANN based DO models

Performance indicator	ANN		MLR	
	Training	Testing	Training	Testing
R^2	0.824	0.632	0.682	0.5634
RMSE	0.375	1.211	0.489	1.6096
MAE	0.307	0.934	0.403	1.0500
WI	0.946	0.741	0.894	0.675

CONCLUSION

The physic-chemical properties of water samples in Guntur region were assessed for their suitability for drinking. The analysis showed that the concentration pH, EC, S, TDS, DO, T of the entire water samples were well within permissible limits. However, TH, TA and Cl values of most of the water samples were not within permissible limits. Further, ANN and MLR models were applied to predict the relationship between the eight water quality parameters as input and DO as output. The performance of the developed ANN based DO models were evaluated by RMSE, MAE, R^2 and WI indices. The comparison results showed that the ANN model provided reasonable better estimates for the DO prediction as compared to MLR.

REFERENCES

Adamala S, Raghuwanshi NS, Mishra A and Tiwari MK 2014. Evapotranspiration modeling using second-order neural networks. *Journal of Hydrologic Engineering* **19**(6): 1131-1140.

Adamala S, Raghuwanshi NS and Mishra A 2015. Generalized quadratic synaptic neural networks for ETomodeling. *Environmental Processes* **2**(2): 309-329.

APHA 2002. Standard methods for the examination of water and wastewater. *American Public Health Association*, Washington D.C.

AWWA 1979. Committee report: Viruses in drinking water. *Journal of the American Water Works Association* **71**: 441-444.

Basant N, Gupta S, Malik A, Kunwar P and Singh K 2010. Linear and nonlinear modeling for simultaneous prediction of dissolved oxygen and biochemical oxygen demand of the surface water-a case study. *Chemometrics and Intelligent Laboratory Systems* **104:** 172-180.

BIS 2012. Indian standard for drinking water specification – 10500. Bureau of Indian Standards, New Delhi, p 16.

Dogan E, Sengorur B andKoklu R 2009. Modeling biological oxygen demand of the Melen River in Turkey using an artificial neural network technique. *Journal of Environmental Management* **90**: 1229-1235.

Gazzaz NM, Yusoff MK, Aris AZ, Juahir H and Ramli MF 2012. Artificial neural network modeling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors. *Marine Pollution Bulletin* **64**: 2409-2420.

Heydari M, Olyaie E, Mohebzadeh H and Kisi Ö 2013. Development of a neural network technique for prediction of water quality parameters in the Delaware river, Pennsylvania. *Middle East*

Journal of Scientific Research **13**(10): 1367-1376.

Malik A and Kumar A 2015. Pan evaporation simulation using daily meteorological by soft computing techniques and multiple linear regression. *Water Resources Management* **29**(6): 1859-1872.

Malik A, Kumar A and Rai P2018a. Weekly pan-evaporation simulation using MLP, CANFIS, MLR and climate-based models at Pantnagar. *Indian Journal of Ecology* **45**(2): 292-298.

Malik A, Kumar A and Kisi O 2017. Monthly pan-evaporation estimation in Indian central Himalayas using different heuristic approaches and climate based models. *Computers and Electronics in Agriculture* **143**: 302-313.

Malik A, Kumar A and Kisi O 2018b. Daily pan evaporation estimation using heuristic methods with gamma test. *Journal of Irrigation and Drainage Engineering*. DOI: 10.1061/(ASCE) IR.1943-4774.0001336.

Singh A, Malik A, Kumar A and Kisi O 2018. Rainfall-runoff modelling in hilly watershed using heuristic approaches with gamma test. *Arabian Journal of Geosciences* **11**(11): 1-12. DOI.org/10.1007/s 12517-018-3614-3.

Malik A, Kumar A, Kisi O andShiri J 2019. Evaluating the performance of four different heuristic approaches with Gamma test for daily suspended sediment concentration modeling. *Environmental Science and Pollution Research* DOI.org/10.1007/s11356-019-05553-9.

McCulloch WS and Pitts W 1943. A logical calculus of the ideas imminent in nervous activity. *Bulletin of Mathematical Biophysics* **5:** 115-133.

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Use of Fuzzy Logic in Modeling Gully Erosion for Modified Bergsma using Remote Sensing Data and Geographic Information Systems Zarkatah Valley, Erbil, Iraq

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Abstract: Study concluded the digital techniques in calculating high-resolution of the erosion locations, and while creation a spatial database to determine the risk of gully erosion. Providing the possibility of creation a three-dimensional model that simulates the reality of the research region to determine the behavior of rivers and reduce their effects in erosion and sedimentation. The possibility of statistical spatial analysis and mathematical treatment of spatially derived Basin data, in case of non-erosion this value is neglected, as the value will be (0) or (1); zero indicates that the condition did not been met and that the element did not belong to the required group or considered as an expression of an inappropriate location. The value (1) indicates full belonging to the values, and all requirements shall be met.

Keywords: Fuzzy logic, Modeling Gully Erosion, Modified Bergsma, Remote sensing, Geographic information, Zarkatah Valley, Erbil, Iraq

The gully erosion is one of the most dangerous processes on the surface of the earth of sensitive for ecosystems, because of the negative effects on the impact of soil thickness, which reflect the effects on its productive capacity. Most of the mountainous and semi-mountainous terrain in the world is affected by this phenomenon, (and Gómez 2016). This erosion is being developed by the gullies that resulted from the integration of the meander and the small streams by the river piracy, so that it is has more capacities and length. Accordingly, the amount of running water increases and increases its ability to erosion (Ndifelani and Mararakanyeab 2017). These gullies in the region are represented as rank in the river (5) and their cross section is in the shape of a letter (V) (Fig. 1), for the activity vertical erosion in their streams. The gully erosion has negative effects on agricultural activity in the region as it erodes large areas of arable land.

Cross sections of the basin show the attitude of gully erosion (Hirt et al 2010). Therefore, the researchers rely on basic criteria in the detection and measurement of this phenomenon in terms of drainage, (Bastola et al 2018). It is observed that 1982 ergsma equation is prevalent in the application of many studies. The equation is summarized by dividing the total length of the watercourses in the unit of area (m) over the unit of area (m2). It provides several levels of classification of erosion in the region (Abir Ben Slimanea et al 2018). By technical progress and the availability of the types of spatial data in the spatial form derived using different software, it provides spacial information. Thus, it was based on the equation's spatial adjustment and its application so it gave high-accuracy results. The objective of the study is to measure the gully erosion by using the digital satellite data for the real water drainage system with mapping the erosion. Furthermore, this study shows the real location of the erosion levels, because it takes the spatial shape and not the linear reality. The importance of constructing an equation that reveals and simulates the real spatial distribution of the gully erosion regarding the drainage depending on the spatial data, and the modern technology provided by GIS and RS software, and to create a spatial database to determine the dimensions of this environmental problem. By the availability of spacial information of high-accuracy spacial images and DEM data which show that the watercourses are not a linear hypothesis but a surveyor one and provide an adjustment to this equation to give more accurate results and simulate the actual reality in determining the risk of this type of erosion. The equation that measures the gully erosion is considered as an experimental hypothesis. The study presented simulates the fact that rivers take a spatial function not linear one; and is more reflective the function concerning the magnitude of the phenomenon and it spatial and actual existence with easy-to-measure by software applications such as ARC GIS 10.2 (1) and its accessories.

MATERIAL AND METHODS

Study area: Zarkatah valley basin is of Soran District within the Erbil province in the north of Iraq. It runs from north and northwest to the south and flows into the Great Zab River in the north of Erbil. (General Directorate of Survey1982) Zarkatah valley basin is an area of 79, 19 km^2, located between longitudes (45° 69' 89” E- 45° 85' 11” E), and two Circles of latitude ((36° 35' 18” N- 36° 55' 06” N),ranges in altitude between (776- 1580 m) above sea level (Fig. 2). It is located within the unstable impulsive region of the high mountains affected by the strength of the orogeny movement (Alps), (Saad 2006). It is due in its originate back to the marine environment and the shallow-water environment with some coastal and volcanic influences and reflect the difficult, rocky and cracked soil as well as its climate is affected by the Mediterranean climate (CS) (Qusay Abdul Majid al-Samarrai 2006). This region is within the wet land and also rain land, which has a total rainfall of more than 650 mm annually and the mean temperature, is 22° C.

Experimental details: The research was based on the technical analysis style and the method of analysis in GIS on two phases. The first phase is derivation of the water drainage from the data of DEM using ARC Gis10.2 and extension Arc hydro. The second phase includes analysis of the water drainage of the basin and the division of the basin into units of areas with 1 km^2 dimensions. The data used include DEM digital elevation data 4 meters cadastral units, satellite images of the moon (65m.) sensor satellite Quick Bird north of Arbil for 2010, space images 2013 Landsat8 row34 196 bath, topographic maps from General Directorate of Iraqi Survey. The ArcGIS software including arc map 10.2 for processing and presentation, basing layers of information and extracting results in maps, shapes and tables. Catalog Arc: to create a geographic information base. Arc Scene: for 3D display and the creation of cumulative cartographic layers, Toolbox Arc - to perform the working steps and geostatistical analyst for spatial statistical Processing.

Working procedures: This includes:

- Derivation of the water network from the digital elevation data (5)
- Create the composite space image and deduction the region
- Divide the area of the Basin into a grid of squares (100 m ×100 m) of map 1 /100000 In the Arc program
- GISl0.2, through Toolbox Arc - Management Data - class feature - Fishnet Create
- Each cadastral unit is assigned a special code indicating its position on the map
- Using the Extension - Toolbox Arc Analysis-identity, Figure (3)
- Calculating the Average of gullies by dividing the area of gullies m / cadastral units Km^2

$$AE = \frac{\sum A\omega}{A} \times 100$$

AE = Average rate of gully erosion of m / km,

ΣAω= The total area of the gully valleys m × cadastral unit

A= Area of the cadastral unit Km

RESULTS AND DISCUSSION

The number of squares that covered the Basin was 8160 square, the area of the square (10000) m^2 dimensions (100 m × 100 m). The number of squares that included gully erosion was 4141 and the rate of was 50.747 per cent. The area of the Basin was 17, 79 km^2 and the area of the squares that included the gully erosion was 41.373 km^2 of the Basin area. Through Figure (1) and Figure (4) for gully erosion, it is show that the gully erosion was 16.554 km^2 and accounted for 20.9 per cent of the total area of the Basin and the rate of (40.01 %) of the area of squares that include gully erosion (Table 2).

Most of the erosion is in the bottom of the Basin (Rank. 1-2-3) with the confluence of the valleys with each other to form widening gullies as the number of watercourses increases basic on deepening the drainage and destroying it vertically (Aykut Akgüna and Necdet Türk 2011). There is possibility of digital techniques in calculating high-resolution of the erosion locations with the abundance of digital satellite data, while creation a spatial database to determine the risk of gully erosion. Providing the possibility of creation a three-

Table 1. System of classification of gully erosion

Degree E	Type E	E Rate m^2/ km^2	Type E
1	None erosion	Less than 20	None detectable erosion area
2	Slight erosion	20.01 - 40	Slight erosion area
3	Moderate erosion	40.01 – 60	Moderate erosion area
4	High erosion	60.01 - 80	High erosion area
5	Very severe erosion	More than 80.01	Very severe erosion area

Source: The Bergsma equation, in accordance with the cadastral equation

Table 2. Area and rate of gullies of the Basin

Number of locations	Total of the gullies' area / km^2	Rate of the gully erosion (%)
1340	2.704	16.334
940	3.58	21.626
967	5.23	31.60
613	3.5	21.232
251	1.54	9.302
4141	16.554	100

Source: Figure (4) degrees of gully erosion

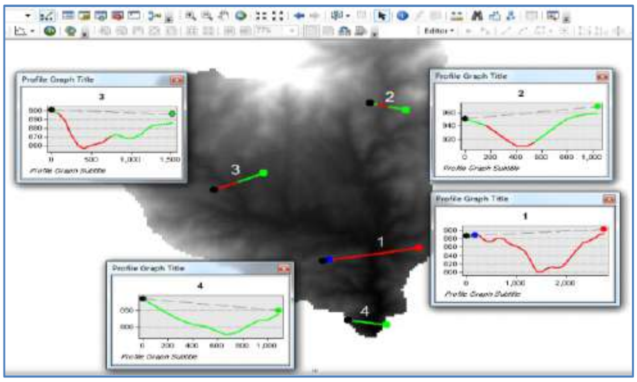

Fig. 1. Cross section of basin

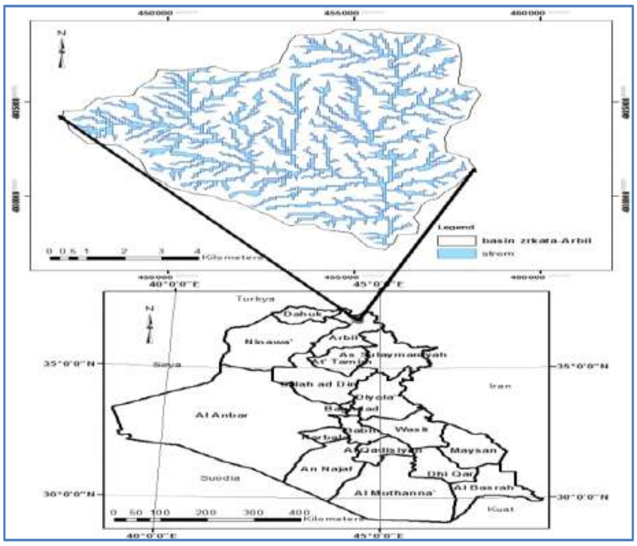

Fig. 2. Location of studied region

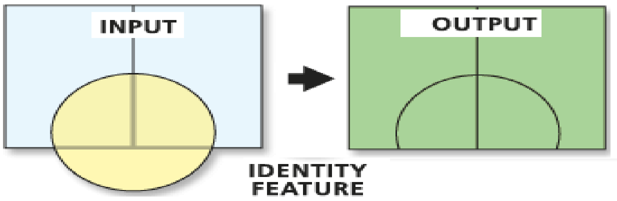

Fig. 3. Identity feature

Image. 1. The River

Source: Field study on 2013/6/11

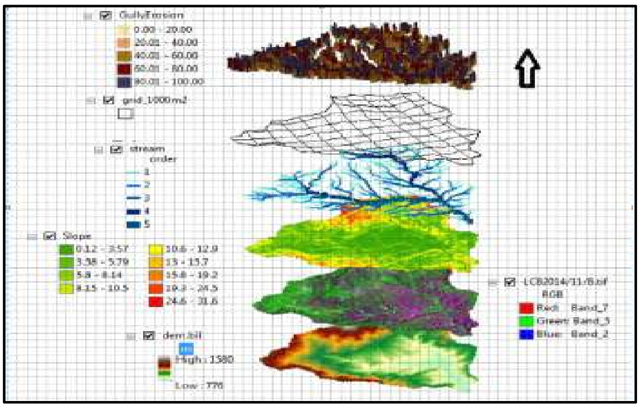

Fig. 5. Analysis of the natural database of the Basin

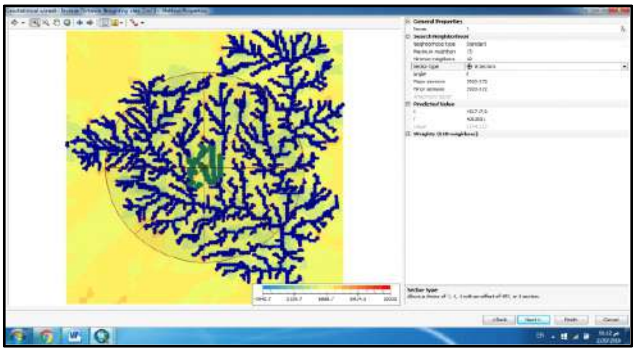

Fig. 6. Statistical analysis of spatial distribution of gully erosion in the Zarkatah Basin Using the ArcGIS geostatistical analyst

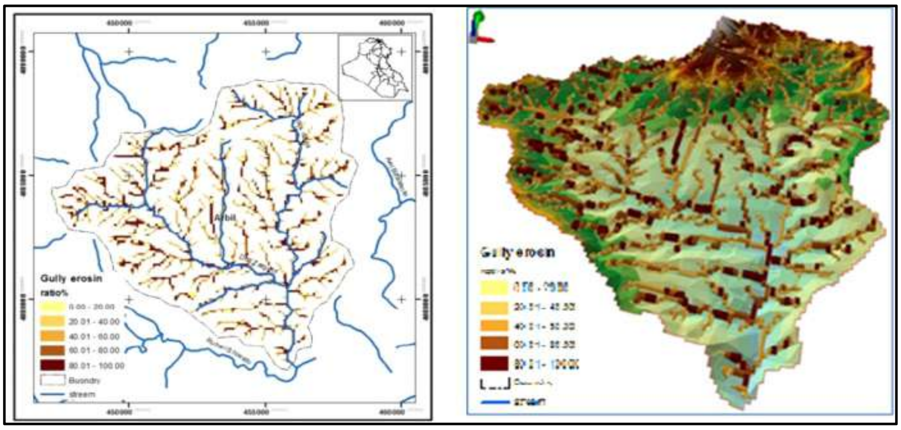

Fig. 4. Degrees of gully erosion in the Basin

dimensional model that simulates the reality of the research region to determine the behavior of rivers and reduce their effects in erosion and sedimentation (Fig. 5) (Federica et al 2011, Dubea et al 2014, Mohsen et al 2018). The possibility of statistical spatial analysis and mathematical treatment of spatially derived Basin data is as in Figure 6.

CONCLUSIONS

The use of digital data for high-resolution spatial images achieved good results for detection of spatial gully erosion and spatial risks. Software for information systems provides the possibility of creation a realistic information base with precise standards closer to reality than experimental standards in terms of the spatial drainage network not assumed that networks are linear.

REFERENCES

Abir BS, Damien RH, Rebaid YL, Bissonnaisb OP and Fethi B 2018. Combining field monitoring and aerial imagery to evaluate the role of gully erosion in a Mediterranean catchment (Tunisia).*CATENA* **1:** 73-83.

Al-Samarrai QAM 2008. *Climate and Climate Regions*, Arab Printing Press, Dar Al Yazourdi Scientific Publishing and Distribution, Amman, Jordan. pp 305-309.

Aykut ANT 2011. Mapping erosion susceptibility by a multivariate statistical method: A case study from the Ayvalık region, NW Turkey. *Computers & Geosciences* **37**(9): 1515-1524.

Bastola SA, Dialynas YG, Bras RL, Noto LV and Istanbulluoglu ED 2018. The role of vegetation on gully erosion stabilization at a severely degraded landscape: A case study from Calhoun experimental critical zone observatory. *Geomorphology* **308**(1): 25-39.

Bergsma EKO 1983. Rainfall erosion surveys for conservation planning. *ITC Journal* **1**(1): 166-174.

Received 09 August, 2019; Accepted 21 August, 2019

Castilloa C and Gómez JA 2016. A century of gully erosion research: Urgency, complexity and study approaches, Earth-Science Reviews **160**(2): 300-319.

Dubea F, Nhapial, Murwirab A, Gumindogaa W, Goldinc J and Mashaurid DA 2014. Potential of weight of evidence modelling for gully erosion hazard assessment in Mbire District Zimbabwe. *Physics and Chemistry of the Earth*, Part A, B, C. **67**(2):145-152.

Federica LM and Conforti GR 2011. Comparison of GIS-based gullying susceptibility mapping using bivariate and multivariate statistics: Northern Calabria, South Italy, *Geomorphology* **134**(4): 297-308.

General Directorate of Survey, Topographic Map 1/20000 Arbil, Iraq, 1982.

Hirt C, Filmer MS and Featherstone WE 2010. Comparison and validation of recent freely-available ASTER-GDEM ver1, SRTM Ver4.1 and GEODATA DEM-9S ver3 digital elevation models over Australia. *Australian Journal of Earth Sciences* **57**(3): 212-217.

Ibrahim SM 1995. Mapping gully erosion around Sulaimani city using aerial 3 photographs. *Journal of AL-Bohoath AL-Tachaniya* **29**(2): 316-321.

Leonardo V, Notoa S, Bastolab Y, Dialynasb G, Elisa AR and Brasb L 2017. Integration of fuzzy logic and image analysis for the detection of gullies in the Calhoun Critical Zone Observatory using airborne LiDAR data. *ISPRS Journal of Photogrammetry and Remote Sensing* **126**(1):209-224.

Mohsen ZF, Mirchoolia AM, Abdulvahed KD, Hamid RP, Mohamad AZ and Fatemeh S 2018. Spatial modeling of gully erosion in Mazandaran Province, northern Iran, *CATENA* **161**(1):1-13.

Ndifelani P and Mararakanyeab SD 2017. Gully erosion: A comparison of contributing factors in two catchments in South Africa. *Geomorphology* **288(**1): 99-110.

Olivier Dewitteabc Mohamed Daoudid Claudio Boscoe Miet Van Den Eeckhaut 2015. Predicting the susceptibility to gully initiation in data-poor regions, *Geomorphology* **228**(1):101-115.

Saad ZJ and Jeremy CG 2006. *Geology of Iraq published* by Dolin, Prague and Maravian Museum, Brno, Czech Republic **19**(2):18-22.

Indian Journal of Ecology (2019) 46(3): 464-469

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Application of Remote Sensing and GIS in Conventional Weightage Modelling for Landslide Hazard Zonations (LHZ) in Nilgiri District, Tamil Nadu, India

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Abstract: In India, landslide is one of the most significant hazard in mountainous region includes 10 hilly states of Himalayas, North East India, Nilgiri, Eastern Ghats and Western Ghats. In the present study, Landslide Hazard Zonation (LHZ) of Coonoor Ghat section was carried out by adopting conventional weightage modelling with an application of geospatial technology. The LHZ map was executed on the basis of geo-environmental influencing factors such as Geology, Geomorphology, Land use and Land cover, Slope aspect, Lineament buffer, Drainage Buffer, Relative Relief and Soil cover. The final LHZ map was revealed that 66.66 per cent existing landslides were coming under High to Very High Hazard, 24.69 per cent were in Moderate Hazard and 8.65 per cent were in Low Hazard zones.

Keywords: Weightage rating method, Landslide Hazard Zonation, Geoenvironmental factors, Remote sensing and GIS

Landslides are one of the most vulnerable hazards in the hilly terrains and draw a special attention throughout the world because it causes extensive damages to property and loss of life. Mitigation of landslides can be successfully adopted, once detailed study/knowledge that provides the expected frequency and magnitude of landslides that will occur in that area in the near future. Hence, it is necessary to identify landslide prone areas for carrying out speedy recovery, safety migration which would also be very much useful for future planning in the area. In the natural hazards, landslides have represented 4.89 per cent that occurred worldwide every year between 1990 and 2005 (Kanungo et al 2006) and the trend is continuously increasing due to unplanned urbanization, development and deforestation activities. Any approach adopted towards Landslide Hazard Zonation (LHZ) requires different parameters which lead to landslides through thematic mapping of these conditions. In India, landslides are one of the most significant hazards that affect the different mountainous region every year during all rainy seasons. In India landslides are highly risky natural hazard at ten hilly states such as Himalayas, North East India, Nilgiris, Eastern Ghats, Western Ghats with including union territory of Pondicherry (Mahe) which causes wide spread damages to property, infrastructure as well as human loss every year (Sharda 2008).

The Nilgiri district of Tamil Nadu is one of the highly landslide prone area in India (Ganapathy et al 2010). In the year of 2009, within 5 days more than 1150 landslides were occurred in the Nilgiri district. Hence, it is necessary and urgency to study habitat safety of this area. The evaluation of landslide hazard is a complex phenomenon because it depends upon many factors. In the last few decades, several landslide hazard zonation maps have been prepared by manual integration of thematic maps by using qualitative and quantitative methods. In the Qualitative method, the landslide area is divided into number of zones and expert can assess the hazard prone areas by identifying similar geological and geomorphic conditions in the zones (Ayalew et al 2004). The Quantitative method is adopted through statistical and geotechnical methods for evaluation of the Landslide Hazard Zonation (LHZ) (Davis et al 2002, Suzen 2002, Ohlmacher et al 2003, Lee 2005). Geographic Information System (GIS) is the most powerful tool to evaluate the landslide hazard zonation by incorporation of various thematic maps and field prediction. By Remote sensing and GIS technology, it is highly possible for effective collection of data, manipulation and integration of different spatial data with different causative factors (geology, structure, surface cover, slope characteristics etc) that are responsible for occurrence of landslides. Integration of these thematic maps in a GIS environment leads to generation of Landslide Susceptible Zonation (LSZ). The main objective of the present study is to evaluate landslide hazard zonation by utilization of weightage evidence model through GIS technology by incorporating of geo-environmental factors (geological, geomorphologic and climatic data).

Study area: The Coonoor Ghat section (Fig. 1) is situated at the eastern part of Nilgiri district, located in the western part of

Tamil Nadu (Coonoor taluk of Nilgiri district). The study area lies between latitudes 11°19'00"N and 11°23'00"N and longitudes of 76°47'00"E and 76°54'00"E occupy an area of 40.34 Km^2 approximately falls in the survey of India toposheets (1:25000) 58 A/15 SE and 58 A/15 SW. The minimum and maximum altitudes are 327 and 2091 m above the mean sea level respectively. Subtropical high land type of climatic condition persists in the study area. This Ghat section is also called as "Kallar Ghat Section" which follows the valley of Kallar and Coonoor river and receives an average rainfall of 1435.73 mm during South West monsoon and 2934.07 mm during North East monsoon. The average annual rainfall is 2184.90 mm. The rain fall pattern is seasonal and maximum expected in October to December .

MATERIAL AND METHODS

The Landslide Susceptibility analysis is carried out by using different resulted layer maps which are derived from various sources and techniques. The Landslide Susceptibility Zonation can be evaluated from various thematic maps through preparation of different database. The compilation of the different database is consisting of three important processes such as digitization, data correction (modification of old data and information from satellite imageries, aerial photographs) and detailed field survey for validate the thematic maps. The fundamental database is derived from Survey of India (SOI) toposheets (1:25000 scale), aerial photographs, and IRS LISS – III satellite imagery. The extensive field work is carried out in the entire study area for collection of information like landslide locations, slope characteristics, geometrical analysis of each individual landslide points and thickness of soil cover. Field verification is also done for validating of land use and land cover in the study area. The entire spatial database constructed by using GIS techniques, where different layer maps are prepared by using field information such as geology, geomorphology and soil cover. Slope aspect, elevation, 30 m contours, drainage map and geomorphologic units are extracted from Digital Elevation Model (DEM) 30 m resolution data. The land use and land cover map is derived from IRS-ID LISS –III satellite imagery, aerial photographs, google maps, and NRSC Bhuvan maps, whereas the lineament map is extracted from the aerial photographs and satellite imageries. The care was taken for assigning of weight and rating values representing the relative importance of factors which responsible for landslides. In the weighting scheme, the factors and categories are assigned a numerical values (between 0 and 9) based upon field experts. These numerical values assigned to each categories of each factor, based upon the probability of landslide occurrences.

Computation of Landslide Hazard Index (LHI): The classes of different layers are assigned corresponding value as attribute information (Table 1) in ArcGIS. For each class, these attribute data are calculated with the corresponding weightage and yield Landslide Hazard Index (LHI) for each class (Equ.1). This systematic method was adopted on the basis of influences of landslide triggering factors.

Landslide Hazard Index (LHI) = Σ (Weighting X different layer attributes)...........Equ.1

Geology: The Mettupalayam to Coonoor ghat section is coming under Coonoor block which is the part of Nilgiri ranges with deep valleys and some flat terrains. The study area is mainly composed of most prevalent rock type called "Charnockite" and presently is coming under "Sargur Schist" (Fig. 2). In some places very small patches of charnockite "Sargur Schist" groups of rocks and pyroxene granulite is covered together and popularly known as "Nilgiri Massif". The charnockite rock mass is showing shallow to deep weathering condition with thickness of 40 m lithomass. The entire study area is covered with Archean rock type called charnockite, capped with lateritic soil without any regular soil cover.

Geomorphology: The study area is an active and young mountainous terrain. In the valley sides, tributaries extend from valley towards main distributaries which connects to Coonoor river. Coonoor River flows west – east direction in the study area and having V shaped valleys with steep gradient and high run off with different geomorphic units such as, hill top weathered , truncated spur, valley region, undulated terrain, undulated plain upland, structural hills, bajada formation, and flood plain (Fig. 3).

Land use and land cover: Land use and Land cover (LULC) is also one of the important factor responsible for landslides. Hence, it is necessary to take up a detailed study for potential landslides. Land use and land cover (LULC) of the study area was prepared by the help of IRS LISS –III imagery, Bhuvan and Google maps. Initially, the study area is masked and taken for Land use and Land Cover (LULC) classification. With the help of Bhuvan and Google maps, supervised classification method is adopted for LULC map preparation. The supervised classification is adopted with maximum likelihood classification. Nine major Land use and Land Cover (LULC) units are identified in the study area such as Agriculture Plantation, Agriculture Crop land, Build up area urban, Build up area Rural, Barren lands, Evergreen forest, Deciduous forest, plantation forest and forest swamp (Fig. 4). The final LULC map is taken for verification of field survey and the final map is prepared at an accuracy of 82.4 per cent and Kappa coefficient is varied between 0.76 and 0.81 for each and every individual class which is acceptable.

Slope aspect: The direction of slope and orientation of slope was measured clockwise in degrees from 0 to 360, where 0 is north-facing, 90 is east-facing, 180 is south-facing, and 270 is west-facing. This aspect map is divided into ten classes which are N - class I (1-22.5); NE - class II (22.5-67.5); E - class III (67.5-112.5); SE - class IV (112.5-157.5); S - class V (157.5-202.5); SW - class VI (202.5 – 247.5); W - class VII (247.5-292.5); NW - class VIII (292.5 – 337.5); NNW - class IX (337.5 – 360) and flat - class X (0-1) (Fig. 5).

Lineament Buffer: Lineaments are large linear structural features and zone of weakness. Lineaments are linear tectonic structures and very highly responsible for geological hazards. Lineaments were identified from the IRS-ID LISS–III satellite imagery and aerial photographs. The overall lineaments pattern in the study area is exhibiting more or less similar trend to the drainage patterns. Generally landslides are associated with proximity distance from lineaments. Distance from the lineaments (lineament buffer) are categories into 5 classes such as interval I (0 – 125); class II (126 – 250); class III (351 – 375); class IV (376 – 500) and class V (> 500) (Fig. 6).

Drainage Buffer: Drainage pattern in the study area is highly dendritic pattern in nature. The drainage pattern is mostly associated with structural features (lineaments) of the study area. Drainage system of the study area is digitized from the available toposheets and also developed from 30 m DEM with the help of GIS techniques. Initially, the proximity of drainage system prepared with the buffer interval of 100 m and this map is spatially correlated with the spatial distribution of landslides. The maximum numbers of slides are coming under the 150 m buffer zones. Hence, it is decided to consider for six buffer zones at 50 m intervals and extended up to 300 m. Thus a lineament buffer layer is consisting of 6 categories such as class I (0 – 50); class II (51 – 100); class III (101 – 150); class IV (151 – 200); class V (201 – 250) and class VI (251 – 300) (Fig. 7).

Relative Relief: Based upon the relative relief the area is divided into number zones such as very low (< 300 m); low relative relief (301-600 m); Moderate relative relief (601 - 900 m); high (901 - 1200 m) and very high relative relief (> 1201 m) (Fig. 8).

Soil cover: The entire study area is made of sandy clay, sandy clay loam, gravel sand clay and outcrop of lateritic soil (Fig. 9).

RESULTS AND DISCUSSION

Conventional rating system is adopted for preparation of Landslide Hazard Zonation (LHZ) and is based upon the relative importance of various causative factors through field expert from the field conditions. From the field condition,

Table 1. Weights and rating for thematic layers and their categories

Categories	Weights	Ratings
Land use and land cover (LULC)		
Agriculture, Plantation	9	9
Forest, Evergreen		8
Built up urban		5
Agriculture, Crop land		3
Built up Rural		1
Forest, Deciduous		1
Forest, plantation		0
Forest, swamp		0
Barren Land		0
Drainage buffer		
< 50 m	8	8
51- 100 m		7
101 – 150 m		5
151 – 200 m		4
201 – 250 m		1
251 – 300 m		2
Lineament buffer		
< 125 m	7	8
126- 250 m		3
251 – 375 m		4
376 – 500 m		4
> 500 m		3
Soil cover		
Gravel, Sand and clay	6	9
Sandy clay		4
Lateritic Soil (Outcrops)		2
Sand, clay loam		1
Relative relief		
> 1200 m	5	8
901 – 1200 m		6
601 – 900 m		3
301 – 600 m		1
0 – 300 m		0
Slope Aspect		
Flat	4	0
North		0
Northeast		2
East		4
Southeast		9
South		5
Southwest		5
West		1
Northwest		1
N-Northwest		1
Geomorphology		
Hill top weathered	3	1
Bajada Formation		0
Truncated spur		1
Valley region		9
Undulated terrain		1
Undulated plain upland		3
Structural Hills		1
Flood plain		0
Lithology		
Charnockite	2	1

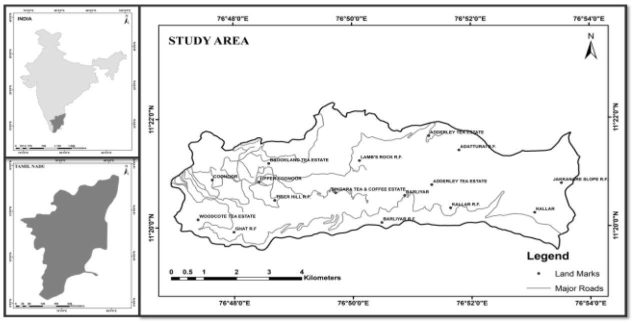

Fig. 1. Location map

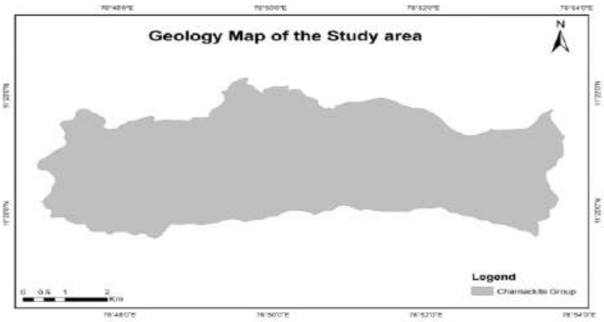

Fig. 2. Geology map

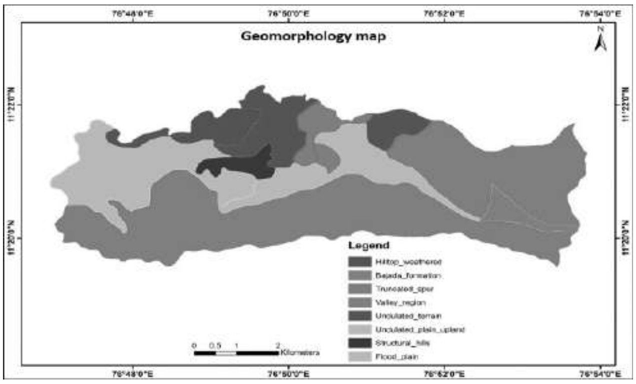

Fig. 3. Geomorphology map

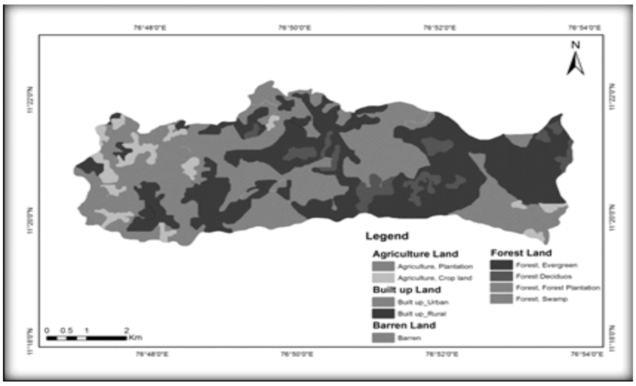

Fig. 4. Land use and land cover map

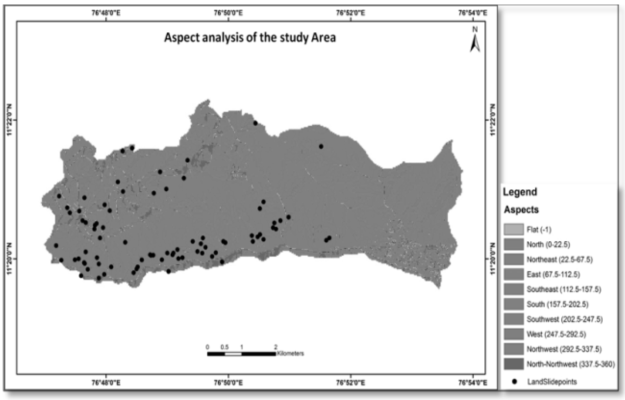

Fig. 5. Slope aspect map

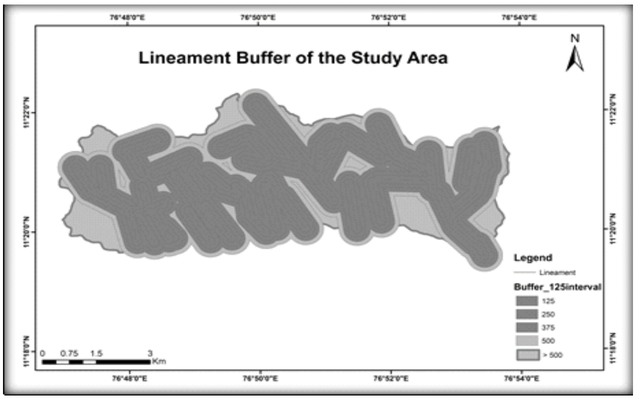

Fig. 6. Lineament buffer map

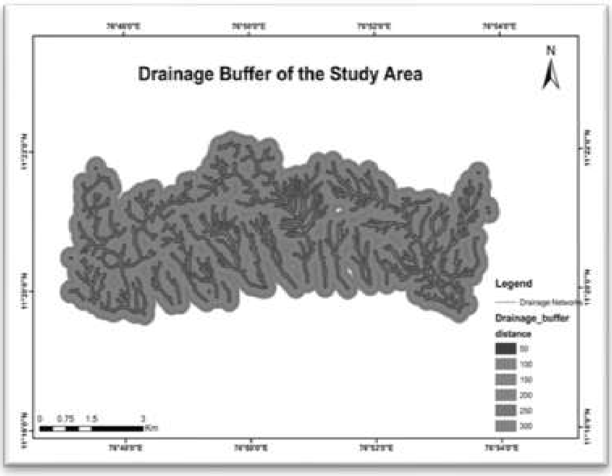

Fig. 7. Drainage buffer map

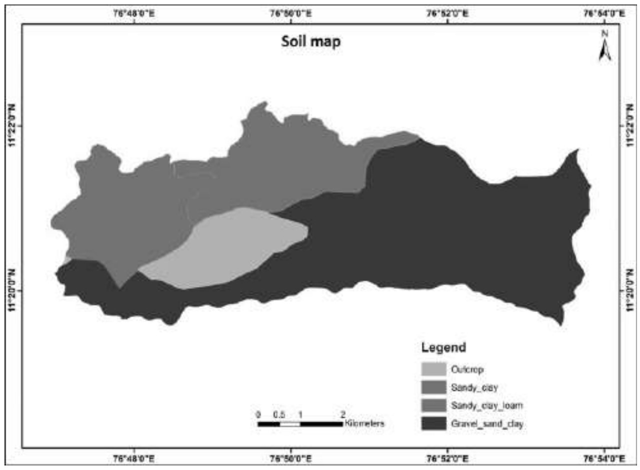

Fig. 8. Soil map

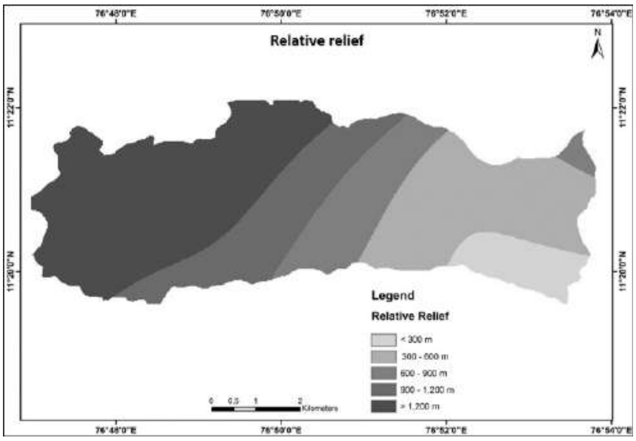

Fig. 9. Relative relief map

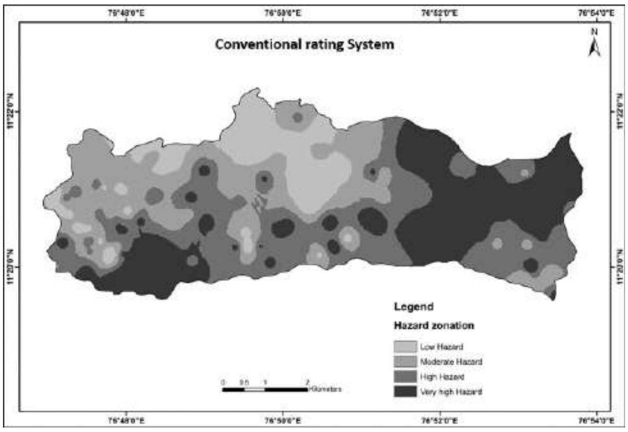

Fig. 10. Landslide hazard zonation map

weightage values are awarded for each category between 9 and 2 based upon their importance to Landslides. In the present study, a maximum weightage value are awarded 9 for LULC and followed by 8 for drainage buffer, 7 for lineament buffer, 6 for soil cover, 5 for relative relief, 4 for slope aspect, 3 for geomorphology and 2 for lithology and also Ratings were rewarded between 0 and 9 based upon the importance of their landslide significance for each class.

In the land use and land cover (LULC) map, higher rating value awarded for Agricultural plantation, followed by Evergreen forest, Build up area urban, Agriculture Crop land, Build up area Rural, Deciduous forest, Plantation forest, Forest swamp and Barren lands. For drainage buffer and lineament buffer, higher ratings are awarded for closest buffer zone because maximum number of slides occurred near to drainage buffer and lineament buffer. In the case of soil cover, higher rating is awarded for sandy gravel and clay soil due to different behaviour of soil under the water saturation conditions which led to landslides. Relative relief and slope aspect maps, the maximum rating is awarded for high relief and south, south east and south west directions due to maximum number of slides presence in these directions. In the geological factors such as geomorphology maps, the maximum rating is awarded for valley regions due to presence of drainage pattern. For lithology map, lower rating is awarded due to hard rock in nature. Here landslides preferred only in different weathering conditions. Landslide Hazard Index (LHI) varied between 153 and 344. These LHI values are characterized to produce landslide hazard zonation (LHZ) classes. The standard classification procedure is adopted for LHZ (Sarkar et al 1995).

Landslide hazard zonation (LHZ): The landslide hazard index frequency diagram used for preparation of landslide hazard zonation (LHZ). By adopting the slicing method for frequency distribution curve, the landslide hazard index threshold values are obtained. These values are classified into 195, 250 and 290. A landslide hazard zonation map is prepared by showing four zones such as low (LH), moderate (MH), high (HH) and very high hazard (VHH) (Fig. 10).

Validation of landslide hazard zonation (LHZ): The various landslide points are identified by the help of GPS and landslide inventory maps are prepared through overlay analysis by comparison between existing landslides and Landslide hazard zonation maps. The results obtains from comparison of percentage of landslide incidents with landslide hazard zones in the study area clearly indicates that, very high hazard and high hazard exhibits 34.56 per cent and 32.10 per cent frequency of landslides in the study area. Furthermore, the moderate hazard zones which constitute 24.69 per cent of the landslide occurrences and low hazard constitute 8.65 per cent landslides population in the study area.

CONCLUSION

The distribution of landslides is largely governed by various geo-environmental conditions such as geology, geomorphology, Land use and Land cover (LULC), Slope aspect, Drainage buffer, Lineament buffer, Relative relief and Soil cover. The slope map of the study area has good correlation between landslide activity and slope aspects. In general landslides are preferred in one direction such as south east which can correlate with the lineaments directions. Most of the lineaments are presence in the direction of SE in the study which is showing the direction of weakness. In the validation of the landslide hazard maps with landslide points clearly indicates that 66.66% landslides are coming under high to very high hazard zones. The remaining 33.34% of landslides occurs due to local condition of instability in the region. The remote sensing and GIS tools are incorporated with geo-environmental parameters by weightage rating system which gives excellent results in the landslide hazard zonation maps.

REFERENCES

Ayalew L, Yamagishi H and Ugawa N 2004. Landslide susceptibility mapping using GIS – based weighted linear combination, the case in Tsugawa area of Agano River, Nilgata Prefecture, Japan. *Landslides* **1**: 73-81.

Davis JC and Ohlmacher GC 2002. *Landslide hazard prediction using generalized logistic regression*. Proceeding of IAMG.

Ganapathy GP, Mahendran K. and Sekar SK 2010. Need and urgency of landslide risk planning for Nilgiri district, Tamil Nadu State, India. *International Journal of Geometric and Geosciences* **1**(1): 29-40.

Kanungo DP, Arora MK, Sarkar S and Gupta RP 2006. A comparative study of conventional, ANN block fox, Fuzzy and combined neural an fuzzy weighting procedures for landslide susceptibility zonation in Darjeeling Himalayas. *Engineering Geology* **85**: 347- 366.

Received 14 May, 2019; Accepted 31 July, 2019

Lee S 2005. Application and cross-validation of spatial logistic multiple regression for landslide susceptibility analysis. *Geosciences* **9**(1): 63–71.

Ohlmacher GC and Davis JC 2003. Using multiple logistic regression and GIS technology to predict landslide hazard in northeast Kansa, USA. *Engineering Geology* **69:** 331-343.

Sarkar, S, Kanungo DP and Mehrotra GS 1995. Landslide hazard zonation: A case study in Garhwal Himalaya, India, *Mountain Research and Development* **15**(4): 301-309.

Sharda YP 2008. Landslide studies in India, Glimpses of Geoscience Research in India. The Indian report to IUGS 2004-2008. *Indian National Science Academy, Silver Jubilee Volume*: 98-101.

Suzen ML 2002. *Data driven landslide hazard assessment using geographical information systems and remote sensing*, M.E.T.U. Ph.D. Thesis, Unpublished: 196 pp.

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Crop Acreage and Crop Yield Estimation using Remote Sensing and GIS Techniques, Bulandshahr District

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Abstract: Present study was conducted in the Bulandshahr district, Uttar Pradesh, India, for land use land cover changes, density of vegetation, difference vegetation index and estimation of crop yield for the year of 2000 and 2014. Remote sensing and geographical information system techniques were used in this study. Five land use land cover classes were identified such as built-up land, open land, crop land, and natural vegetation and water bodies through supervised classification with an accuracy of 97.9 and 99.5 per cent for the year 2000 and 2014, respectively. Increment in built-up land, open land and crop land were observed while natural vegetation was decline up to 15.6 per cent in fourteen years. Highest NDVI values for 2000 and 2014 were 0.4141 and 0.4166 while lowest were -0.4127 and -0.4166. In the crop yield estimation, an average of 3.7×10^6 ton ha^{-1} crop production was estimated. Overall, the study showed that the use of remote sensing and GIS in crop yield estimation was better as compared to traditional techniques.

Keywords: Crop yield estimation, Difference vegetation index, Geographical information system, Normalised difference vegetation index, Remote sensing

The information on crop area statistics is backbone of agricultural statistical system and reliable and timely information on crop area is of great importance to planners and policy makers. This information is useful for efficient and timely agricultural development and making important decisions with respect to procurement, storage, public distribution, export, import and other related issues. Crop production forecasts/estimates are generally portrayed as the product of two components: area to be harvested and expected yield per unit area (You et al 2014). Most parts of the country are having detailed cadastral survey maps, frequently updated land records and institutions like permanent village reporting agency for providing reliable and continuous data on crop area. However with more emphasis on local area planning, there is further need for the availability of crop area, irrigation availability and the soil type which can go a long way in rapid development of an area. Making timely and accurate regional predictions of crop yield is of great importance for agricultural management and food security warning purposes (Mo et al 2009, Piao et al 2010, Fritz et al 2018). Applications of remote sensing technique in crop acreage estimation has becoming increasingly dominating in India (Mosleh et al 2015) due to low cost and this approach with combination of ground truth data will retrieve the best area estimate. Several techniques have been adapted for crop estimation using aerial photographs and satellite images, including: pixel count (Gallego et al 2014), supervised classification (Kussul et al 2017), Bayesian/fuzzy classification and spectral un-mixing (Mann and Joshi 2017) and area frame sampling (Pradhan 2001, Boryan et al 2017). Wu and Li (2012) studied crop planting and type proportion method for crop acreage estimation of complex diverse agricultural landscapes. Goswami et al (2012) documented use of remote sensing and geographic information system (GIS) based wheat crop acreage estimation of Indore district, Madhya Pradesh, India. Previous studies had done their work in different parts of India but because of diversity of crops, there is a need to apply remote sensing and GIS techniques in those areas which have not yet been estimated in terms of crops. Therefore, the objectives of this research work are to analyze land use and land cover changes for the year of 2000 and 2014 of the Bulandshahr district, Uttar Pradesh, India using remote sensing and GIS and to estimate vegetation density and crop production.

MATERIAL AND METHODS

Study area: The geographical location of Bulandshahr district is 28.4°N and 77.85 °E. The total area of the district is 4,441 km^2 with an elevation of 237.44 m above mean sea-level and located between Ganges and Yamuna rivers. The soil in the district of Bulandshahr is alluvial which is an important grain producing agricultural district.

Data source: The Landsat 5 TM images of 8th October 2000 and 21st September 2014 were downloaded from USGS website. From September to October is the period of *Kharif* crops at mature stage of their growth.

The radiometric correction of landsat images was employed for detecting changes of surface reflectance, using a relative radiometric correction method. The images of two dates were rectified by taking ground control points and projected to a common Universal Transverse Mercator (UTM) coordinate system of World Geodetic System (WGS 84). Image enhancement techniques such as contrast stretching and ratio images were worked out to improve the visual interpretability of the image. A ratio image effectively compensates for the brightness variation caused by varying topography and emphasized the color content of the data. As per the aims of the study, four methods were used. First, supervised classification for making land use and land cover (LULC) maps. Second, normalized difference vegetation index (NDVI) to estimate crop yield. Third, correlation coefficient method to calculate accuracy of NDVI. Fourth, difference vegetation index (DVI) for the identification of crops.

Supervised classification: For supervised classification, the software Erdas Imagine 9.3 was used. The pixels of different categories of LULC on the basis of spectral signature were identified. For each category of LULC, ten training areas (belongs to homogeneous pixels) were selected. Similar signatures of particular category of LULC were merged which results new spectral signature of that category. For the supervised classification of LULC, maximum likelihood method was selected and performed in Erdas Imagine. Similarly this classification technique was applied on three years landsat data to obtained changes in LULC categories and LULC maps of the year 2000, 2014 were obtained (Fig. 1).

Accuracy assessment: The accuracy assessment of land use land cover changes was done by relative deviation method in which variations between actual area and estimated area of crop were calculated. The relative deviation method formula is given by:

$$\frac{X_i - X}{X_i} \times 100 \qquad (2.1)$$

Where X_i is the actual area and X is the estimated area.

Normalised difference vegetation index (NDVI): For the identification of the crop is done with the help of vegetation index model. Image is taking for maximum growth stage in the model. In this study NDVI model is applied for two spectral bands from landsat TM data i.e. red band (band 3) and near Infrared (NIR) band (band 4). The equation is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

After this the values are stretched by the following equation

$$\frac{DN_{in} - DN_{\min}}{DN_{\max} - DN_{\min}} \times 255$$

The density slicing technique was used on the NDVI image for differencing the different land use classes on the basis of digital numbers (DN) or brightness value of the image. The higher brightness (DNmax) values are taken as crops due to the maximum growth period. Moderate are taken as other vegetation and lower is taken for non-vegetation cover.

Difference vegetation index (DVI): This technique was used for agricultural land use mapping. DVI models was applied for two spectral bands from Landsat TM data i.e. Red band (band 3) and NIR band (band 4). The equation is as follows:

DVI = NIR - R

where, DVI= difference vegetation index, NIR= Near infra-red band andR = Red band.

RESULTS AND DISCUSSION

Built-up land and water bodies: In the year 2000 per cent built-upland was 9.9 and in 2014 15.45 with an increment of approximately 5.5 per cent. Natural vegetation was converted into built-up land as urban population is increasing continuously in the Bulandshahr district. People migrated from rural areas to urban area in the search of employment, business, and medical facilities for better life conditions. Highways and roads are built in both urban and rural areas. Whereas, water bodies in 2000 was 0.44 and in 2014 it was 0.57 per cent and approximately remained same. It was slightly increased due to the increase in the black river catchment area.

Open land: In the year 2000 open land was 10.7 and in 2014 13.01 percent and increased by nearly 2.3 per cent because natural vegetation converted in barren land and due to some unauthorized activities, natural vegetation was converted into an open land.

Natural vegetation: The natural vegetation was 24.6 and 8.99 per cent in 2002 and 2014 with decrement of 15.6

percent and due to rapidly cutting down of trees and converted into the built-up land and the open land.

Crops: In the year 2000 crops area was 54.22 and in 2014 was 61.9 per cent and crops increased by 7.6 per cent. Crops land was increased because land area from natural vegetation was converted into crops.

Accuracy assessment: The overall accuracy of the year 2000 image is 97.9 per cent and in 2014 was 99.5 per cent and this indicate that the accuracy level was very fine and reliable.

As for the individual classes like crop, water bodies, natural vegetation and open bodies ranged between 97.9 and 100.0 but form crop was low (74.6 %) in 2000. Similar trend was observed but for crop improved to 100 per cent (Table 2 and 3).

Normalised difference vegetation index (NDVI) and differential vegetation index (DVI): The red color shows variation of low value from -0.4127 to -0.4166, yellowish color shows zero value and green color shows high value of the NDVI from 0.4141 to 0.4166 in the year 2000 and 2014. In 2000 the production was 14.95 t ha^{-1} with 0.4141 NDVI values and in 2014 production was 15.79 t ha^{-1} with 0.4166 NDVI values. High DVI values ranges from 91 to 93 for 2000 and 2014 respectively while lowest DVI values ranges from -81 to -85 for the year of 2000 and 2014, respectively. The DVI values also supporting the crop production increment in fourteen years due to increase in crop land (Fig. 2).

Yield estimation: Crop yield (t ha^{-1}) derived from NDVI value is lower than the crop yield (t ha^{-1}) derived from DVI value (Table 4). Total average production of Kharif crop in Bulandshahr district of Uttar Pradesh was 3.7 x 10^6 t with the yield 15.45 t ha^{-1}.

The natural vegetation decline in fourteen years up to 15.6 per cent which converted into built-up land open land

Table 1. Land use pattern

Land use/ Land cover classes	2000		2014	
	Area (ha)	Percentage	Area (ha)	Percentage
Built up	36794.0	9.9	57390.3	15.4
Open land	40076.0	10.7	48348.8	13.0
Natural vegetation	91450.3	24.6	33420.1	8.9
Crops	201366.0	54.2	230076.0	61.9
Water bodies	1667.2	0.4	2117.9	0.5

Table 2. Land use accuracy assessment for 2000

Land use class	Crop	Water bodies	Built up	Natural vegetation	Open land	Total	User accuracy (%)
Crop	203	0	0	69	0	272	74.6
Water bodies	0	313	0	0	0	313	100
Built up	0	0	1352	0	25	1377	98.1
Natural vegetation	1	1	0	2764	0	2766	99.0
Open land	0	1	17	1	908	927	97.9
Total	204	315	1369	2834	933	5655	
Producer accuracy (%)	99.5	99.3	98.7	97.5	97.3		
Overall accuracy (%)	97.9						

Table 3. Land use accuracy assessment for 2014

Land use class	Crops	Water bodies	Built up	Natural vegetation	Open land	Total	User accuracy (%)
Crops	861	0	0	1	0	862	99.8
Water bodies	0	408	0	2	0	410	99.5
Built up	0	0	1155	0	0	1155	100
Natural vegetation	7	3	0	260	0	270	96.2
Open land	0	0	0	0	88	88	100
Total	868	411	1155	263	88	2785	
Producer accuracy (%)	99.1	99.2	100	98.8	100		
Overall accuracy (%)	99.5						

Table 4. Average production (t ha^{-1})

Derived from NDVI value		Derived from DVI value		Average production	
Yield (tone ha^{-1})	Total production	Yield	Total production	Yield	Total production
14.95	3.6 x 10^6	15.95	3.8 x 10^6	15.45	3.7 x 10^6

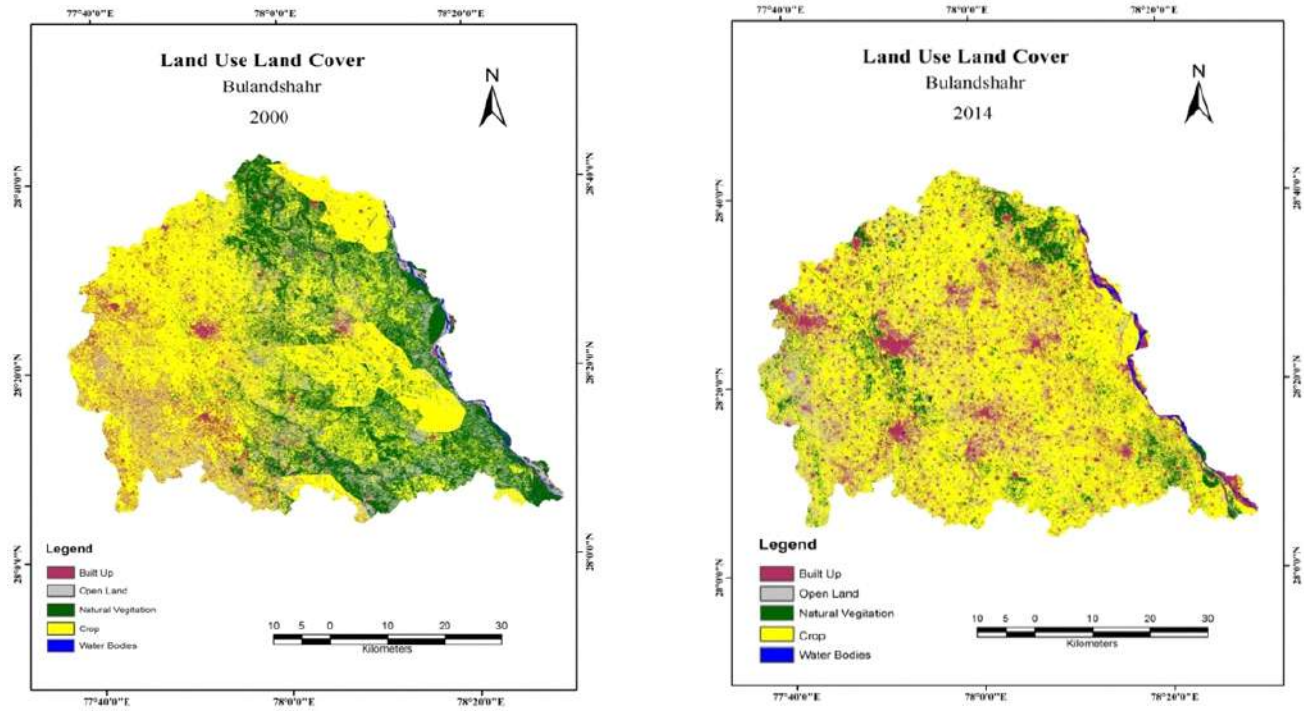

Fig. 1. Land use land cover map 2000 and 2014

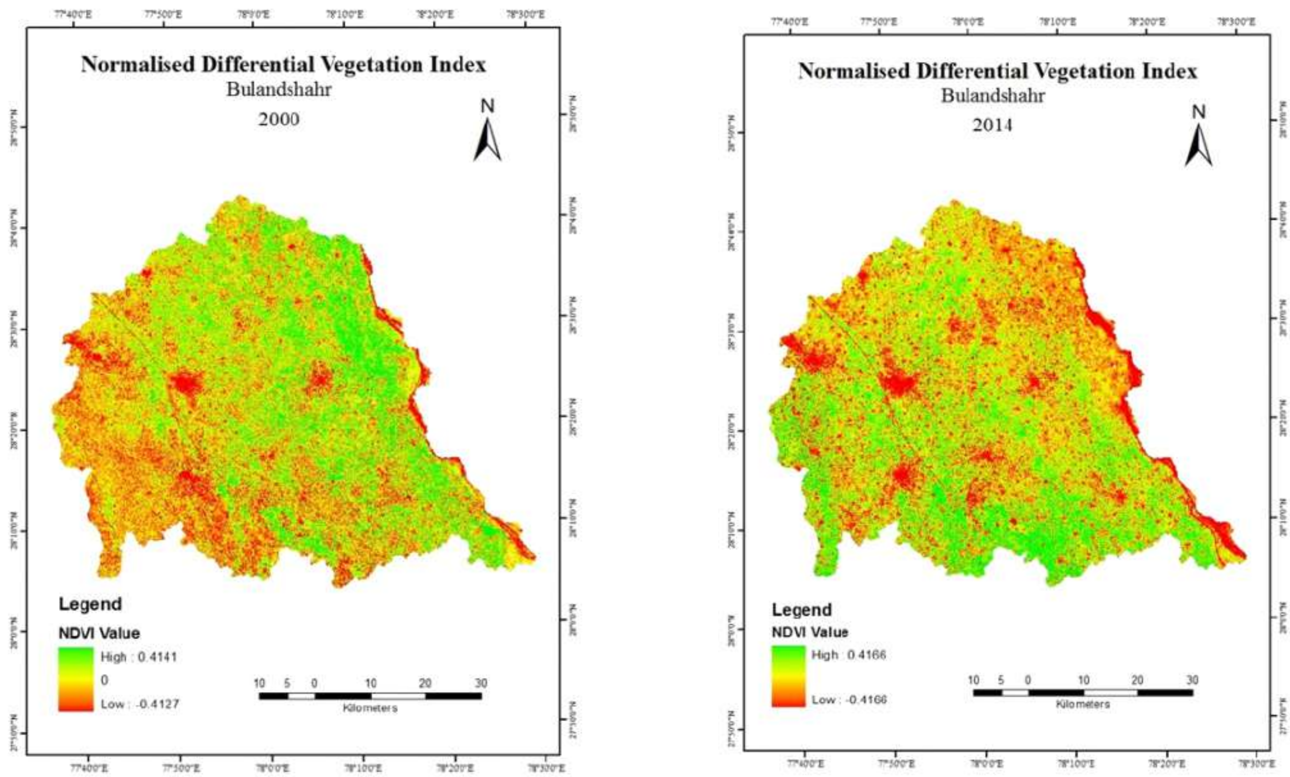

Fig. 2. Normalised difference vegetation index 2000 and 2014

and crop land. The main disadvantage of this conversion could be more soil loss because of the exposure of soil which comes under direct rainfall hit condition. The accuracy assessment of supervised classification was showing good accuracy which i.e. 97.9 and 99.5 per cent for the year of 2000 and 2014, respectively. Normalised difference vegetation index (NDVI) values were highest in the year of 2014. The possible reason for the increment of NDVI values would be increasing crop land and the timings of landsat imageries were the peak growth time of *Kharif* crops. The reason of increasing NDVI values in fourteen years due to increment of crop land is also supported by the crop production values. The crop production in the year of 2000 was 14.95 t ha^{-1} while it increased in 2014 up to 15.79 t ha^{-1}. Overall, a good relationship between the increment in crop production and crop land area and declination of natural vegetation land area was observed. The remote sensing and GIS successfully analyzed land use land cover changes and estimated crop production. Furthermore, the remote sensing and GIS techniques can also be used for future crop production estimation.

REFERENCES

Basu S, Michaelis A, Votava P, Wang W, Ganguly S, Nemani R and Kumar U 2017. Unmixing algorithms: A review of techniques for spectral detection and classification of land cover from mixed pixels on NASA earth exchange. *Large-Scale Machine Learning in the Earth Sciences* Chapman and Hall/CRC**:** 131-173.

Boryan CG, Yang Z, Willis P and Di L 2017. Developing crop specific area frame stratifications based on geospatial crop frequency and cultivation data layers. *Journal of Integrative Agriculture* **16**(2): 312-323.

Fritz S, See L, Bayas JCL, Waldner F, Jacques D, Becker-Reshef I, Whitcraft A, Baruth B, Bonifacio R, Crutchfield J and Rembold F 2018. A comparison of global agricultural monitoring systems and current gaps. *Agricultural Systems* **168**: 258-272.

Gallego FJ, Delince J and Rueda C 1993. Crop area estimates through remote sensing: Stability of the regression correction .*International Journal of Remote Sensing* **14**(18): 3433-3445

Gallego FJ, Kussul N, Skakun S, Kravchenko O, Shelestov A and Kussul O 2014. Efficiency assessment of using satellite data for crop area estimation in Ukraine. *International Journal of Applied Earth Observation and Geoinformation* **29**: 22-30.

Gallego J and Bamps C 2008. Using corine land cover and the point survey LUCAS for area estimation. *International Journal of Applied Earth Observation and Geoinformation* **10**(4): 467-475.

Gorte B and Stein A 1998. Bayesian classification and class area estimation of satellite images using stratification. *IEEE Transactions on Geoscience and Remote Sensing* **36**(3): 803-812.

Goswami SB, Saxena A and Bairagi GD 2012. Remote Sensing and GIS based wheat crop acreage estimation of Indore district, M.P. *International Journal of Emerging Technology and Advanced Engineering* **2**(3): 200-203.

Kussul N, Lavreniuk M, Skakun S and Shelestov A 2017. Deep learning classification of land cover and crop types using remote sensing data. *IEEE Geoscience and Remote Sensing Letters* **14**(5): 778-782.

Li Hand Wu J. 2004 Use and misuse of landscape indices. *Landscape Ecology* **19**(4): 389-399.

Mann D and Joshi PK 2017. Evaluation of image classification algorithms on hyperion and ASTER data for land cover classification. *Proceedings of the National Academy of Sciences, India Section A: Physical Sciences* **87**(4): 855-865.

Mosleh M, Hassan Q and Chowdhury E 2015. Application of remote sensors in mapping rice area and forecasting its production: A review. *Sensors* **15**(1): 769-791.

Ozdogan M and Woodcock CE 2006. Resolution dependent errors in remote sensing of cultivated areas. *Remote Sensing of Environment* **103**(2): 203-217.

Piao S, Ciais P, Huang Y, Shen Z, Peng S, Li J and Friedlingstein P 2010. The impacts of climate change on water resources and agriculture in China. *Nature* **467**(7311): 43.

Pradhan S 2001 Crop area estimation using GIS, remote sensing and area frame sampling. *International Journal of Applied Earth Observation and Geoinformation* **3**(1): 86-92.

Quarmby NA, Townshend JRG, Settle JJ, White KH, Milnes M, Hindle TL, and Silleos N 1992. Linear mixture modelling applied to AVHRR data for crop area estimation. *International Journal of Remote Sensing* **13**(3): 415-425.

Sabbah and Salman 2015. *Crop acreage estimation of Bulandshahr, Uttar Pradesh P.G. Diploma Dissertation*. Department of geography, JMI, New Delhi, India

USDA-NASS C. 2009 *Census of Agriculture*, February

Wu B and Li Q 2012. Crop planting and type proportion method for crop acreage estimation of complex agricultural landscapes. *International Journal of Applied Earth Observation and Geoinformation* **16**: 101-112.

You L, Wood S, Wood-Sichra U and Wu W 2014. Generating global crop distribution maps: From census to grid. *Agricultural Systems* **127**: 53-60.

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Morphometric Analysis of Song Watershed: A GIS Approach

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Abstract: The present study conducted in Dehradun district of Uttarakhand state advocates that remotely sensed data and GIS based approach in evaluation of drainage morphometric parameter was more appropriate than the conventional methods. Various linear, aerial and relief aspects were taken into consideration to analyze the morphometry of the study area and digital elevation model (DEM) and slope map of the catchment area were generated from ASTER data of 30 m resolution. The drainage patterns were mainly dendritic to sub dendritic. The slope of the study area had been divided into five equal intervals viz. gentle (0º to 13º), moderate (14º to 26º), moderately steep (27º to 39º), steep (40º to 52º), and very steep (53º to 65º). The order of stream of the study area ranged from 1st order to 6th order. The variation in stream length ratio might be due to difference in slope and topographic conditions. The variation of bifurcation ratio in the catchment area was ascribed to the difference in topography and geometric development. The drainage density was 2.03 km^2 which was moderate. The drainage texture was 8.75 which shows that the lithology is not so complex.

Keywords: Digital Elevation Model (DEM), Morphometric analysis, Remote sensing, Geographic information system, Sub-watershed

Water demand is growing as the world population is growing and more and more urbanization is taking place worldwide. On the other hand, water resources are limited, increasing demand for various water uses and decreasing access to good-quality water as most of the nearby and good-quality sources have already been over exploited (Diwakar and Thakur 2012, Sappa et al 2015). Land, water and soil are limited natural resources and their wide utilization with increasing population was a major area of concern. In order to mitigate the demand and supply gap between resources and ever increasing demand, it was of prime importance to conserve the natural resources with proper prioritization for its sustainable development. In this context, the advent of remote sensing technology and geographical information system (GIS) tools opened new path in morphometric analyses. These techniques were used for natural resources planning and management for the past few decades. In other ways, GIS and remote sensing applications had been used by many scientists in mapping groundwater potential zone, monitoring of command area, modelling of rainfall run off and many other applications (Ebrahimi et al 2016, Singh et al 2017, Sahoo et al 2017).

Morphometric analysis of a watershed provides a quantitative description of a drainage system. It is an important aspect of watershed characterization. The watershed development programme has tremendous potential to render socio-economic justice, attain self-reliance and a balanced development (Rahmati et al 2016, Rana 2018) and programme not only protects and conserves the environment, but also contribute to livelihood security. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Rai et al 2017). Rahaman et al (2015) carried out morphometric analyses of river basins by using remote sensing and geographic information system (GIS) techniques. Shrimali et al (2001) conducted a study on the Sukhana lake catchment in the Shiwalik hills for the delineation and prioritization of soil erosion areas. Ratnam et al (2005) and Khanday and Javed (2016) carried out studies on check dam positioning by prioritization of micro watersheds using the sediment yield index (SYI) model and morphometric analysis. Therefore, the purpose of this study was to analysis Song watershed, Dehradun using remote sensing and GIS techniques. The aims of this study were to identify the drainage system and its interaction with nature, to recognize the morphometric parameters and their behaviour in the area and to analysis the watershed through morphometric parameters.

MATERIAL AND METHODS

Study Area: The study area is located in the sub-tropical, humid and temperate type of climate, latitudinal extends are

30º2'23” to 30º27'37” N and longitudinal extends are 77º57'24” to 78º17'7” E of Dehradun district in Uttarakhand with an elevation of 437 m above mean sea level. The forest area account for near about 1477 km^2 of area, around 47.8% of the total area of the district (Fig.1).

Pre-processing: In pre-processing, the mosaicked DEM satellite images were combined with topographic map which were rectified and geo-referenced under the GIS environment. A boundary of Dehradun district was digitized from the topographic map. The digitized shape file was used to extract Dehradun district from DEM.

Linear aspect: The mean stream length (Lsm) was calculated by dividing the total stream length of order 'u' by the number of stream segments of order 'u' and the values of mean stream length for each stream order in this study was also calculated (Table 1). The length of the valley was calculated through the measuring tools in ArcGIS10 software. The shortest distance between the source and mouth of the river is the maximum aerial distance (Adm). It was calculated through special tools in ArcGIS 10 software. Drainage density was the computation of the total stream length in a given basin area to the total area of the basin and was classified into five different classes of drainage texture, i.e. less than 2 indicates very coarse, between 2 and 4 is coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. It was calculated by dividing the stream frequency with the drainage density and expressed into km-1.It can be calculated in ArcGIS 10 Software through special measuring tools. Basin shape (Bs) is the ratio of square of basin length (Lb) to the area of the basin (A). The form factor (Rf) points out the shape or outline form of a drainage basin capable of being understood which affects stream discharge behaviors. Circularity ratio is the ratio of an area of basin to an area of circle having same circumference as the perimeter of basin. This ratio is prominently relevant to the length and frequency of streams, geological structures, land use/ land cover, climate, relief and slope of the basin.

Drainage mapping and morphometric analysis: The drainage map of the study area was delineated through the processes of fill, flow direction and flow accumulation in (Fig. 2). The order of the stream was designated according to the Horton law designating an un-branched stream as first order stream, when two first order streams joined it was designated as second order (Rai et al 2017). Two second order steams joined together to form third order and so on. The number of streams of each order were counted and recorded. Based on stream orders, the sub watershed boundary was delineated (Table 1).

RESULTS AND DISCUSSION

Linear Aspect: The total basin area was 782.27 km^2 and the number of streams gradually decreases with the increment of stream order and the stream segment of any given order will be fewer than the next lower order but more numerous than the next higher order. There are 1523 streams linked with 6th order of streams sprawled over an area of 782.27 km^2.

The count of stream channel in given order is termed as stream number and the first order stream contains the highest stream number whereas the least stream number is of sixth order. The number of streams in the first, second, third and fourth order stream counts 1157, 281, 66 and 2 streams and finally the number of stream in sixth order is only 1 (Table 1). The mean length of channel segments is 8.26 of a given order was greater than that of the next lower order but was less than the next higher order is 29.70. As a general principle, mean length of channel segments of a given order was greater than that of the next lower order but less than the next higher order.

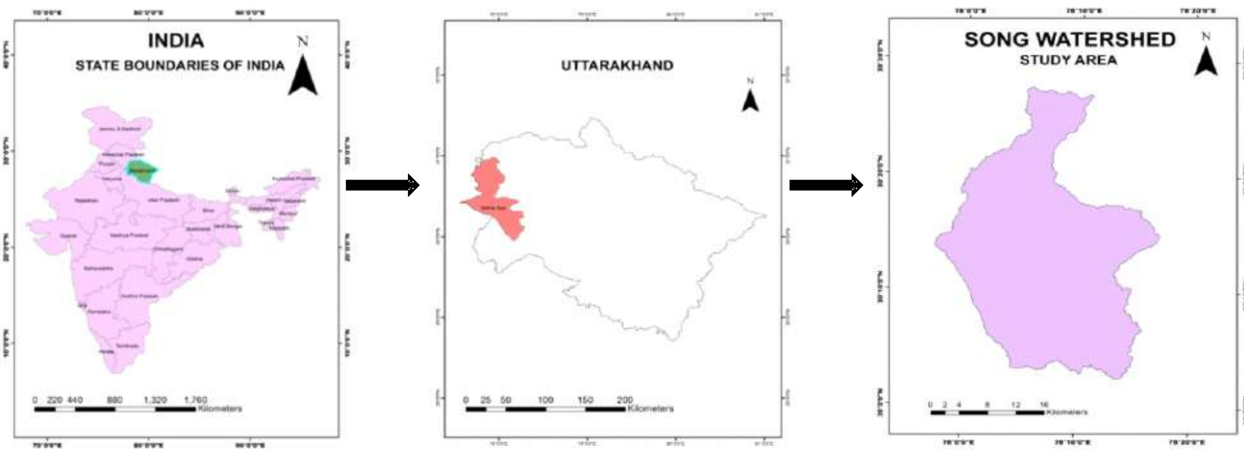

Fig. 1. Location map of the study area

Table 1. Computation of morphometric parameters

Morphometric parameters	Formula	Reference
Stream order (Su)	Hierarchal rank	Strahler (1964)
Stream length (Lu)	Length of streams	Horton (1945)
Mean stream length (Lsm)	Lsm = Lu / Nu Where, Lsm = Mean stream length Lu = Total stream length of order 'u' Nu = Total no. of streams segments of order 'u'	Strahler (1964)
Stream length ratio (RL)	RL = Lu / Lu1 Where, RL = stream length ratio Lu = total stream length of order 'u' Lu1 = Total stream length of its next lower order	Horton (1945)
Bifurcation ratio (Rb)	Rb = Nu / Nu1 Where, Rb = Bifurcation ration Nu = Total no. of stream segments of order 'u' Nu1 = No. of segments of the next higher order	Schumn (1956)
Mean bifurcation ratio (Rbm)	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
Relief ratio (Rh)	Rh = H / Lb Where, Rh = Relief ratio H = Total relief (Relative relief) of the basin (km.) Lb = Basin length	Schumn (1956)
Drainage density (D)	D = Lu / A Where, D = drainage density Lu = Total stream length of all orders A = Area of the basin (Km2)	Horton (1932)
Stream frequency (Fs)	Fs = Nu / A Where, Fs = Stream frequency, Nu = Total no of streams of all orders, A= Area of the basin (km2)	Horton (1932)
Drainage texture (Dt)	Dt= Nu / P Where, Rt = drainage texture, Nu = Total no. of streams of all orders, P = Perimeter of the basin (km)	Horton (1945)
Form factor (Rf)	Rf = A / Lb2 Where, Rf = form Factor, A = area of the basin (km2) Lb2 = Square of the basin length	Schumm (1956)
Circularity ratio (Rc)	Rc = 12.57 A / P2 Where, Rc = Circularity ratio, A = area of the basin (km2), P = Perimeter of the basin (km)	Horton (1932)
Elongation ratio (Re)	Re = (2 / Lb)*√(A / P) Where, Re = Elongation ratio, Lb = Basin length A= Area of the basin (km2), P= perimeter of the basin (km)	Strahler (1964)

In this study area, there is a variation in the stream length ratio. There is a change from one order to another order indicating their late youth stage of geomorphic development. This variation might be due to change in slope and topography. The geological structures do not affect drainage pattern as the bifurcation ratio is in between 3.0 to 5.0. When bifurcation ratio is low, there will be high possibilities of flooding as water will tend to accumulate rather than spreading out. Human intervention plays an important role to reduce bifurcation ratio which in turn augment the risk of flooding within the basin**.** Higher values of bifurcation ratio indicate strong structural control on drainage pattern. The Song watershed shows a bifurcation ratio of 4.50 which can be obtained from the total bifurcation ratio that was 22.50 divided by the number of stream order, which was five stream order. The length along the longest water course from the outflow point of Song basin to the upper limit to the basin boundary. The main channel length was computed using ArcGIS10 software, which was 62.31 km. The valley length was 41.27 km. The channel index of this study is 1.29. The channel index of the study area is 0.85. The maximum aerial distance is 48.35 km (Table 2).

Aerial Aspect: Aerial aspects include form factor, elongation ratio, stream frequency, drainage density, drainage texture, basin shape and circularity ratio (Table 2). The value of drainage density was 2.03 km/km^2 indicating high drainage density which may be attributed to the region which has impermeable subsurface materials and mountainous relief (Table 3).

The value of drainage texture was 8.75 indicating that the Song water shade was very fine texture. The drainage intensity of watershed was 0.96 km^{-1}. The computed stream

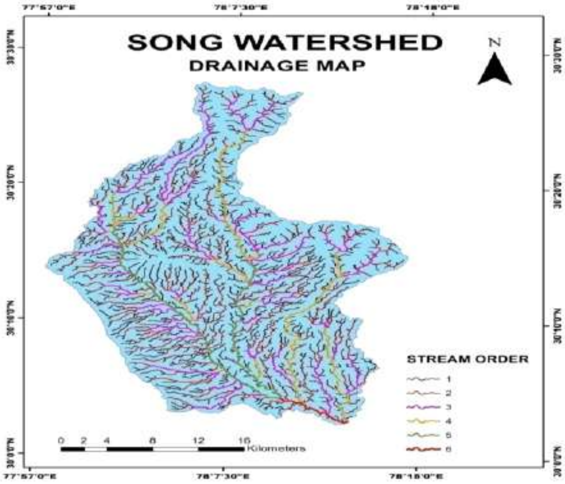

Fig. 2. Drainage map showing the stream order of Song watershed

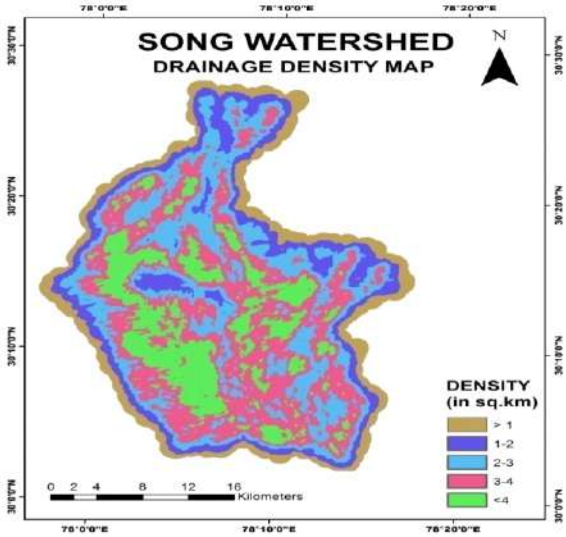

Fig. 3. Drainage density map of the Song watershed

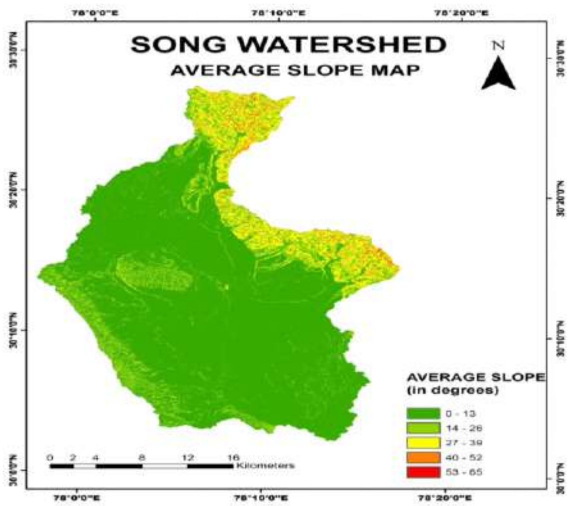

Fig. 4. Average slope of Song watershed

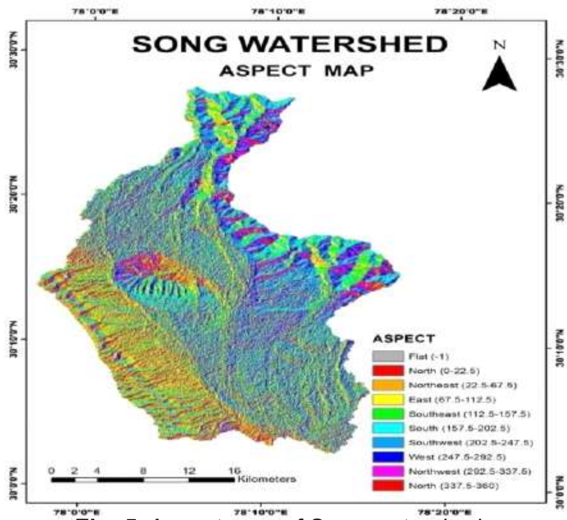

Fig. 5. Aspect map of Song watershed

Table 2. Results of morphometric analysis showing linear aspects for the Song watershed

Linear Aspect	Results						References
Stream order (Su)	1st	2nd	3rd	4th	5th	6th	Miller (1953)
No. of streams (Nu)	1157	281	66	16	2	1	Horton (1945)
Stream Length (Lu) in Km	782.61	425.11	201.32	109.10	59.39	7.48	Strahler (1964)
Mean Stream Length (Lsm)	0.68	1.51	3.05	6.82	29.70	7.84	Horton (1945)
Stream Length Ratio (RL)	-	2.24	2.02	2.24	4.36	0.26	Strahler (1964)
Bifurcation Ratio (Rb)	4.12	4.26	4.13	8	2	-	Strahler (1964)
Mean Bifurcation Ratio (Rbm)	4.50						Strahler (1964)
Main Channel Length (Cl) Kms.	62.31						Horton (1945)
Valley Length (Vl) Kms.	41.27						Strahler (1964)
Maximum Areal Distance (Adm) Kms	48.35						Horton (1945)
Channel Index (Ci)	1.29						Horton (1932)
Valley Index (Vi)	0.85						Horton (1932)

Table 3. Results of morphometric analysis showing areal aspects for this study area

Areal aspects	Method	Result
Drainage Density (D) (km/km^2)	D=Lu/A	2.03
Drainage Texture (Dt)	Dt=Nu/P	8.75
Drainage Intensity (Di) ($km^{-1)}$)	Di=Fs/D	0.96
Stream Frequency (Fs) (km^{-1})	Fs=Nu/A	1.95
Basin Length (Lb) km	ArcGIS 10 Software	45.76
Basin Area (A) km^2	Arc GIS 10 Software	782.27
Basin Perimeter (P) km	ArcGIS 10 Software	174.07
Basin Shape (Bs)	$Bs=Lb^2/A$	2.7
Form Factors (Rf)	$Rf=A/Lb^2$	0.37
Circularity Ratio(Rc)	$Rc = 12.57 A / P^2$	0.32
Elongation Ratio (Re)	Re = (2 / Lb)*√(A / P)	0.69
Length of Overland Flow (Lg) (km)	Lg = 1 / D*2	1.0
Constant Channel Maintenance (C)	C = 1/D	0.5

Table 4. Average slope classes

Slope class range (in degree)	Slope class category
0-13	Gentle
14-26	Moderate
27-39	Moderately Steep
40-52	Steep
53-65	Very Steep

Table 5. Morphometric analysis showing relief aspects

Relief aspect	Method	Result
Relief (R)	Vertical distance between the lowest and highest points of	2279
Relief Ratio (Rh)	Rh=R/Lb	49.80
Ruggedness Number (Rn)	Rn=R/D	4626.37

frequency value was s 1.95 km^{-1} which was attributed to low stream frequency value (Table 3). Basin length was 45.76 km (Table 3) and basin area was 782.27 km^2 (Table 3). The basin perimeter was 174.07 km and basin shape was 2.67. The form factor would always be less than 0.7854 (for a perfectly circular basin). The form factor for the Song watershed was observed to be smaller i.e. 0.37 indicating that the watershed is an elongated drainage basin in shape with flat peak flow for longer duration. The circularity ratio was 0.32 which indicates that the catchment area is less circular in shape having low to moderate relief and a few structurally controlled drainage system. The elongation ratio generally varies from 0.6 to 1.0 over a wide range of climatic and geologic types and were ramified into 3 categories, i.e. circular (>0.9), oval (0.9 to 0.8) and less elongated (<0.7).The value of elongation ratio for the Song watershed was calculated as 0.69 showing that the catchment area is less elongated in shape while having moderate relief. The length of overland flow of the Song watershed is 1.0 km indicating low surface runoff in the catchment area. In Song watershed, the value of constant channel maintenance was 0.50 (Table 3). It indicates that on an average 0.50 $feet^2$ surface was required in the catchment area for creation of one linear foot of the stream channel.

Relief aspect (AS): The relief aspects was divided into five categories of very low slope, low slope, medium slope, high slope, very high slope. Gentle is between 0˚to 13˚, moderate is between 14˚ to 26˚, moderately slope is between 27˚ degree to 39˚, steep slope falls under 40-52˚and lastly very steep slope is under 53-65˚ as shown in (Fig. 4 and Table 4).

In this study, it has been divided into 10 categories which are Flat (-1), North (0-22.5), Northeast (22.5-67.5), East (67.5-112.5), Southeast (112.5-157.5), South (157.5-202.5), Southwest (202.5-247.5), West (247.5-292.5), Northwest (292.5-337.5), North (337.5-360) in (Fig. 5). The maximum elevation was at 2584 meters and the lowest is at 305 meters. Hence, the relief of the catchment area is 2279 meters. Relief ratio normally increases with decreasing drainage area and size. The relief ratio of this study is 49.80.The calculated Song watershed has the ruggedness number of 4626.37.

CONCLUSION

This study demonstrates that remote sensing techniques and GIS play a vital role for the preparation of updated drainage map and morphometric analysis in a timely and cost-effective manner, in evaluation of drainage morphometric parameter is more appropriate than the conventional methods. The elevation in the study area ranges between 305-2584 m above mean sea level which indicates that the area is highly elevated. The major part of the study area falls under gentle and moderate slope (0º to 13º) and (14º to 26º) respectively, while some portion falls under moderately steep and steep slope and very little portion is under steep slope in the northern direction. The stream order ranged from 1st order to 6th order. The variation in stream length ratio might be due to difference in slope and topographic conditions. The variation of bifurcation ratio in the catchment area is ascribed to the difference in topography and geometric development. The drainage density was moderate. The mean bifurcation ratio falls under normal basin category. High bifurcation ratio determines that the region was subjected to strong structural control which influences the drainage. The circularity shows that the watershed is less circularity in shape and is elongated and drainage texture was litho logy not so complex.

REFERENCES

Diwakar J and Thakur JK 2012. Environmental system analysis for river pollution control. *Water, Air& Soil Pollution* **223**(6): 3207-3218.

Ebrahimi H, Ghazavi R and Karimi H 2016. Estimation of groundwater recharge from the rainfall and irrigation in an arid environment using inverse modelling approach and RS. *Water Resources Management* **30**(6): 1939-1951.

Horton RE 1932. Drainage-basin characteristics. *Eos, Transactions American Geophysical Union* **13**(1): 350-361.

Horton RE 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin* **56**(3): 275-370.

Khanday MY and Javed A 2016. Prioritization of sub-watersheds for conservation measures in a semi-arid watershed using remote sensing and GIS. *Journal of the Geological Society of India* **88**(2): 185-196.

Miller VC 1953. Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. *Technical Report (Columbia University. Department of Geology)* **65**(1): 112-113.

Rahaman SA, Ajeez SA, Aruchamy S and Jegankumar R 2015. Prioritization of Sub Watershed Based on Morphometric Characteristics Using Fuzzy Analytical Hierarchy Process and Geographical Information System–A Study of Kallar Watershed, Tamil Nadu. *Aquatic Procedia* **4**: 1322-1330.

Rahmati O, Haghizadeh A and Stefanidis S 2016. Assessing the accuracy of GIS-based analytical hierarchy process for watershed prioritization; Gorganrood River Basin, Iran. *Water Resources Management* **30**(3): 1131-1150.

Rai PK, Mishra VN and Mohan K 2017. A study of morphometric evaluation of the Son basin, India using geospatial approach. *Remote Sensing Applications: Society and Environment* **7:** 9-20.

Rai PK, Mohan K, Mishra S, Ahmad A and Mishra VN 2017. A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India. *Applied Water Science* **7**(1): 217-232.

Rana NK 2018. Analysis of Mahananda River Basin Using Geospatial Data. *The Indian Rivers, Springer***,** *Singapore,* pp 239-250.

Ratnam KN, Srivastava YK, Rao VV and Murthy KSR 2005. Check dam positioning by prioritization of micro-watersheds using SYI model and morphometric analysis remote sensing and GIS perspective. *Journal of the Indian Society of Remote Sensing* **33**(1): 25.

Sahoo S, Dhar A, Kar A and Ram P 2017. Grey analytic hierarchy process applied to effectiveness evaluation for groundwater potential zone delineation. *Geocarto International* **32**(11): 1188-1205.

Sappa G, Ergul S, Ferranti F, Sweya, Lukuba N and Luciani G 2015. Effects of seasonal change and seawater intrusion on water quality for drinking and irrigation purposes, in coastal aquifers of Dar es Salaam, Tanzania. *Journal of African Earth Sciences* **105**: 64-84.

Schumm SA 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin* **67**(5): 597-646.

Shrimali S, Aggarwal SP and Samra JS 2001. Prioritizing erosion-prone areas in hills using remote sensing and GIS-A case study of the Sukhna Lake catchment, Northern India. *International Journal of Applied Earth Observation and Geoinformation* **3**(1): 54-60.

Singh LK, Jha MK and Chowdary VM 2017. Multi-criteria analysis and GIS modeling for identifying prospective water harvesting and artificial recharge sites for sustainable water supply. *Journal of Cleaner Production* **142:** 1436-1456.

Strahler AN 1957. Quantitative analysis of watershed geomorphology. *Eos, Transactions American Geophysical Union* **38**(6): 913-920.

Strahler AN 1964. Part II. Quantitative geomorphology of drainage basins and channel networks. *Handbook of Applied Hydrology: McGraw-Hill, New York* **39**(4): 4-76.

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Use of GIS For Hypsometric (Area-Elevation) Analysis of Gagas Watershed (Uttarakhand)

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Abstract: The hypsometric curve (HC) and integral (HI) of 13 sub-watersheds (SW) of Gagas watershed located in upper Ramganga River basin, India, was done using digital elevation model (DEM) of Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) and geographical information system (GIS). The HI value of 13 sub-watersheds varied from 0.324 to 0.495, which indicates that 32.4 to 49.5 per cent of the original rock masses still exist in these sub-watersheds. The two geological stages of erosion cycle i.e. monadnock and mature were identified in the study area. The study could be useful for planning and constructing soil and water conservation structures at appropriate locations in the sub-watersheds of Gagas watershed.

Keywords: Hypsometric curve, Hypsometric integral, Naula watershed, GIS, Uttarakhand

Hypsometric analysis of a watershed is important for integrated planning and management of watershed resources. Hurtrez et al (1999) stated that a watershed is stabilized with convex hypsometric curves and un-stabilized (susceptible to erosion) with concave hypsometric curves. In recent years, a number of studies have been conducted by various researchers in different part of the world on estimation of erosion status of watersheds or river basins using hypsometric (area-altitude) analysis and watershed morphometric parameters (Sharma et al 2016, Kandpal et al 2018a, Singh and Singh 2018, Malik et al 2019a). Markose and Jayappa (2011) evaluated hypsometric parameters and prepared hypsometric curves for 20 sub-basins of Kali River, Uttara Kannada district of northern Karnataka, India and observed that 13 sub-basins were under the young stage with high HI values and subjected to recent tectonic activities, the remaining seven sub-basins were under the mature stage and subjected to more erosion and less influenced by recent tectonic activities. Gajbhiye *et al.*(2014) estimated HI values for eight sub-watersheds ranged between 0.47 and 0.51 and identified the mature stage of erosion cycle in eight SW of Shakkar watershed located in Madhya Pradesh, India. Walia et al (2018) observed the hypsometry (HC and HI) in ArcGIS 10.3 and Microsoft Excel environment in four micro-watersheds draining into Patiala-Ki-Rao river, Punjab, India, for accessing and comparing the erosion status under different management practices. In this study, hypsometric (area-altitude) analysis of 13 sub-watersheds of Gagas watershed located in upper Ramganga River basin, India, was carried to study runoff generation potential and planning for appropriate soil and water conservation measures in the watershed.

MATERIAL AND METHODS

Study area: The Gagas watershed, lies in the middle and outer range of Himalaya located between 79°20'36” to 79°33'15” E longitudes and from 29°51'55” to 29°35'49” N latitudes with an area of 514.84 km^2on Ramganga River basin in the South-Western Almora region of Uttarakhand, India. The altitude of the region varies from 2742m to 726m above the mean sea level. The mean yearly rainfall fluctuates from 903 to 1281 mm, with a mean of 1067mm. Roughly, over 80 per cent of the yearly rainfall in the region occurs from the South-West monsoon, which begins in the third wek of June and can last till mid-October.

Data collection and methodology: The digital elevation model (DEM) of Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) with 30m x 30m resolution (https://earthexplorer. usgs.gov) was used to delineate the boundary and stream network of the watershed, which was further sub-divided into 13 sub-watersheds (Fig. 1) using ArcGIS 10.2 environment.

Plotting of the hypsometric curve: Hypsometric curve was derived for fourteen sub-watersheds of Naula watershed from ASTER DEM of 30m x 30m resolution. The hypsometric curve is obtained by plotting the relative area (a/A) on the abscissa (x-axis) and relative elevation (h/H) on the ordinate (y-axis). The relative area is the ratio of horizontal cross-sectional area (a) to entire basin area (A), while the corresponding relative height is the ratio of the height of a

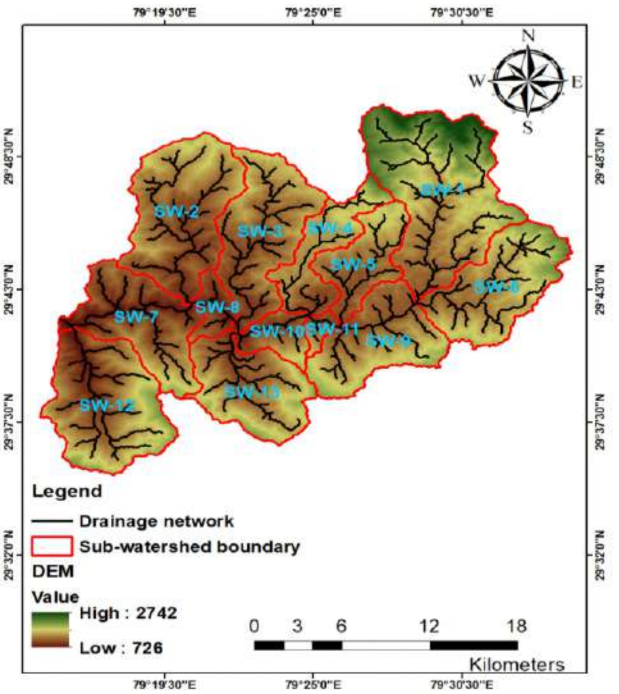

Fig. 1. DEM and drainage network map of the sub-watersheds of Gagas watershed

given contour (h) to the total basin height (H) as shown in Fig. 2 (a and b). This provided a measure of the distribution of landmass volume remaining beneath or above a basal reference plane (Strahler 1952, Singh et al 2008)

Estimation of hypsometric integral: Hypsometric integral (HI) is obtained from the hypsometric curve and provides information about the geologic stages of development and erosion susceptibility of the watershed. Pike and Wilson (1971) developed an elevation-relief ratio method for estimating the HI as:

$$HI = \frac{\text{Mean elevation} - \text{Minimum elevation}}{\text{Maximum elevation} - \text{Minimum elevation}} \quad (1)$$

After obtaining hypsometric integral of individual sub-watersheds and comparing it with the typical hypsometric curves (Fig. 2c), the geological stages of development of the sub-watersheds under study are determined with the following criteria (Strahler, 1952):

a) The sub-watershed will be in inequilibrium (youthful) stage when HI ≥ 0.60
b) The sub-watershed will be in equilibrium (mature) stage when 0.35 ≤ HI < 0.60; and
c) The sub-watershed will be in monadnock (old) stage when HI < 0.35

The flowchart of HC and HI estimation in ArcGIS and MS excel environment are demonstrated in Fig. 3.

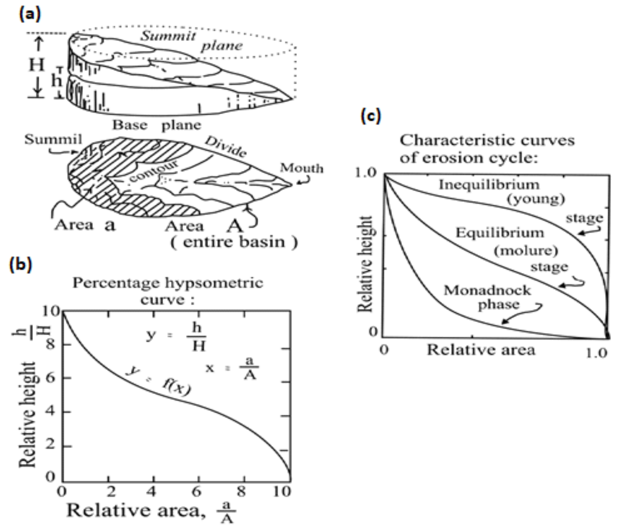

Fig. 2 (a to c). Hypsometric curve and geological stages (Strahler 1952)

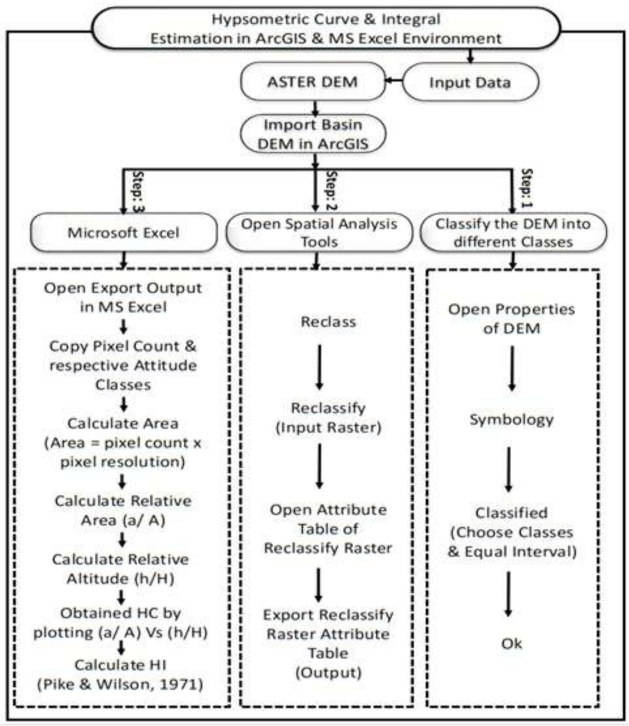

Fig. 3. The flowchart of HC and HI estimation in ArcGIS and MS excel environment

RESULTS AND DISCUSSION

The hypsometric analysis of 13 sub-watersheds of Gagas watershed was carried in ArcGIS 10.2 environment using DEM of ASTER with 30m x 30m resolution. The hypsometric curves revealed that the sub-watersheds have attained monadnock and mature stages (Fig. 4). The SW-1, SW-4, SW-8, and SW-10 attained monadnock stage, the

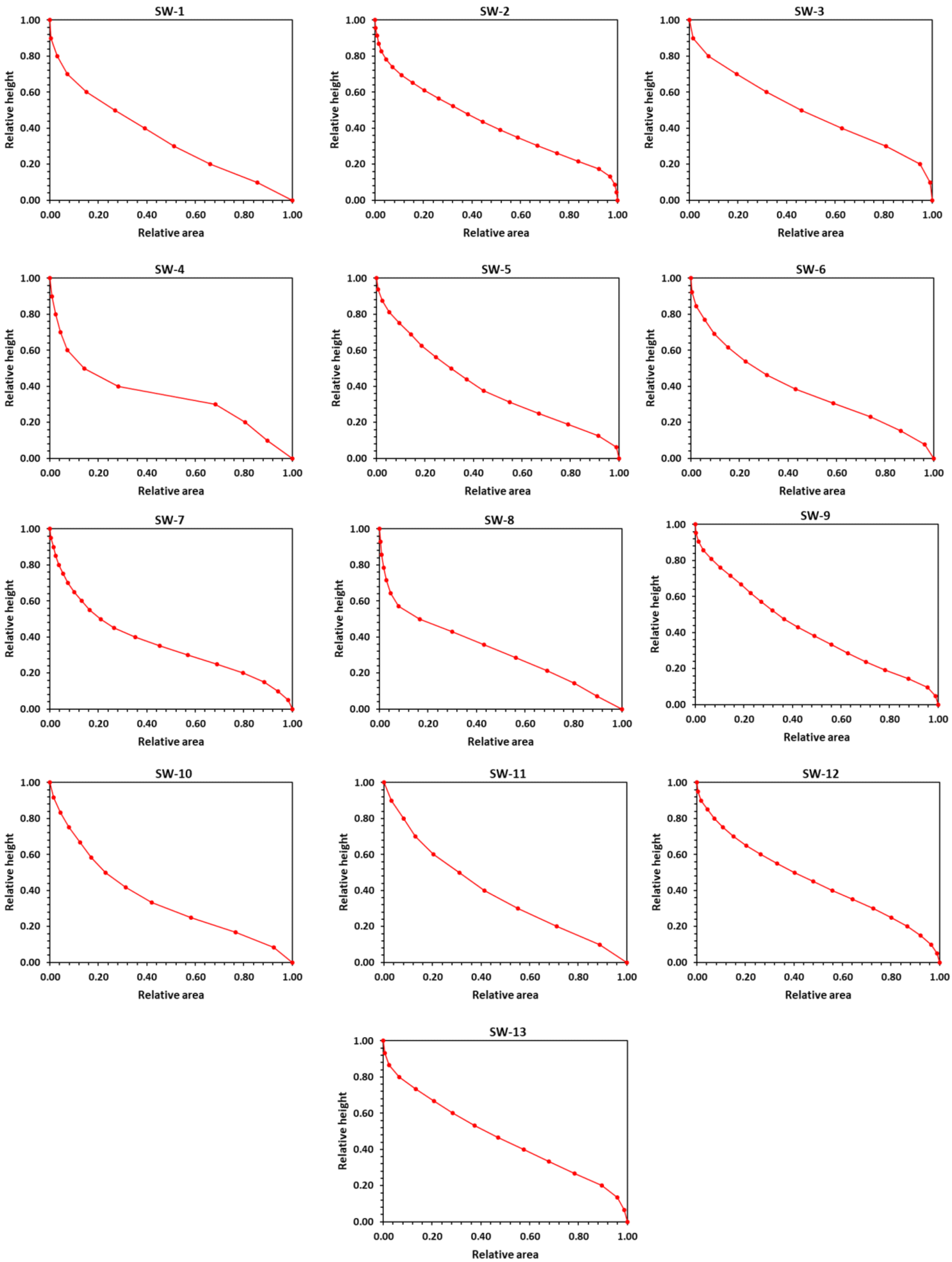

Fig. 4. Hypsometric curves of thirteen sub-watersheds of Gagas watershed

Table 1. Hypsometric integral and geological stage of sub-watersheds Gagas watershed

Sub-watershed number	Area (km^2)	Minimum elevation (m)	Maximum elevation (m)	Mean elevation (m)	Hypsometric integral	Geological stage
SW-1	84.10	1121	2742	1932	0.345	Monadnock
SW-2	61.63	847	1790	1319	0.426	Mature
SW-3	51.87	849	1669	1259	0.495	Mature
SW-4	27.62	975	2225	1600	0.346	Monadnock
SW-5	26.39	1015	1767	1391	0.393	Mature
SW-6	47.72	1111	2125	1618	0.381	Mature
SW-7	44.43	726	1866	1296	0.362	Mature
SW-8	9.22	834	1436	1135	0.324	Monadnock
SW-9	42.04	1012	1915	1464	0.411	Mature
SW-10	12.23	881	1793	1337	0.347	Monadnock
SW-11	4.29	969	1630	1300	0.382	Mature
SW-12	59.40	748	2010	1379	0.452	Mature
SW-13	41.92	889	1948	1419	0.463	Mature

SW-2, SW-5, SW-6, SW-7, SW-9, and SW-11 to SW-12 attained mature stage. There was a combination of convex-concave and S shape of hypsometric curves for 13 sub-watersheds of Naula watershed. This could be due to the soil erosion from these sub-watersheds resulting from the cutting of channel beds, downslope movement of topsoil and bedrock material, washed-out soil mass and cutting of stream banks.

The HI values of 13 sub-watersheds of Gagas watershed are enlisted in Table 1, which revealed that HI = 0.345 under monadnock stage (SW-1), HI = 0.426 under mature stage (SW-2), HI = 0.495 under mature stage (SW-3), HI = 0.346 under monadnock stage (SW-4), HI = 0.393 under mature stage (SW-5), HI = 0.381 under mature stage (SW-6), HI = 0.362 under mature stage (SW-7), HI = 0.324 under monadnock stage (SW-8), HI = 0.411 under mature stage (SW-9), HI = 0.347 under monadnock stage (SW-10), HI = 0.382 under mature stage (SW-11), HI = 0.452 under mature stage (SW-12), and HI = 0.463 under mature stage (SW-13). The hydrologic response of the sub-watersheds attaining the mature stages will have slow rate of erosion. As HI value ranges from 0.324 (SW-8) to 0.495 (SW-3), which indicates that 32.4 and 49.5 per cent of the original rock masses still exist in these sub-watersheds.

Hypsometric curves and integrals were calculated using ASTER DEM for all the sub-watersheds considered in this research and found to be under monadnock and mature stages of geological erosion cycle. Over the recent decade several studies have been conducted on area-altitude and morphometric analysis for knowing the present status of watershed health (Bishop et al 2002, Singh et al 2008, Kusre 2013, Golekar et al 2015, Kandpal et al 2017, Kandpal et al 2018b, Malik et al 2019b). The lower value of HI indicating less erosion from the sub-watersheds of the Gagas watershed.

CONCLUSION

The hypsometric curves and integral values indicated that only two geological stages of erosion cycle i.e., Monadnock and mature were identified out of thirteen sub-watersheds of Gagas watershed. The hypsometric integral value ranges from 0.324 (SW-8) to 0.495 (SW-3), which indicates that 32.4 and 49.5 per cent of the original rock masses still exist in these sub-watersheds. The SW-1 to SW-13 has a lower value of hypsometric integral (i.e., approaching monadnock and mature stages) and need minimum mechanical and vegetative measures to arrest sediment outflow, but may require more water harvesting structures to conserve water at appropriate locations for its conjunctive use in these sub-watersheds.

REFERENCES

Bishop MP, Shroder JF, Bonk R and Olsenholler J 2002. Geomorphic change in high mountains: a western Himalayan perspective. *Global and Planetary Change* **32:** 311–329.

Gajbhiye S, Mishra SK and Pandey A 2014. Hypsometric analysis of Shakkar river catchment through geographical information system. *Journal of Geological Society of India* **84:** 192-196.

Golekar RB, Baride MV, Patil SN and Adil SH 2015. Altimetric and hypsometric analysis for soil and water conservation: A case study of Anjani and Jhiri river basin, Northern Maharashtra, India. *Earth Sciences Research Journal* **19**(1): 51–58.

Hurtrez JE, Sol C and Lucazeau F 1999. Effect of drainage area on hypsometry from analysis of small-scale drainage basins in the Siwalik Hills (Central Nepal). *Earth Surface Processes and Landforms* **24**(9): 799-808.

Kandpal H, Kumar A and Malik A 2018a. Morphometric analysis and prioritization of sub-watersheds in Bino watershed, Uttarakhand: a remote sensing and GIS perspective. *Indian Journal of Ecology* **45**(3): 607-610.

Kandpal H, Kumar A, Reddy CP and Malik A 2017. Watershed prioritization based on morphometric parameters using remote sensing and geographical information system. *Indian Journal of Ecology* **44**(3): 433-437.

Kandpal H, Kumar A, Reddy CP and Malik A 2018b. Geomorphologic parameters based prioritization of hilly sub-watersheds using remote sensing and geographical information system. *Journal of Soil and Water Conservation* **17**(3): 232-240.

Kusre BC 2013. Hypsometric analysis and watershed management of Diyung watershed in north eastern India. *Journal of Geological Society of India* **82:** 262-270.

Malik A, Kumar A and Kandpal H 2019a. Morphometric analysis and prioritization of sub-watersheds in a hilly watershed using weighted sum approach. *Arabian Journal of Geosciences* **12**(12): 1-12.

Malik A, Kumar A, Kushwaha DP, Kisi O, Al-Ansari N, Salih SQ and Yassen ZM 2019b. The implementation of a hybrid model for hilly sub-watersheds prioritization using morphometric variables: Case study in India. *Water* **11**(6): 1-19.

Markose VJ and Jayappa KS 2011. Hypsometric analysis of Kali River Basin, Karnataka, India, using geographic information system. *Geocarto International* **26**(7): 553–568.

Pike RJ and Wilson SE 1971. Elevation- relief ratio hypsometric integral and geomorphic area-altitude analysis. *Bulletin of the Geological Society of America* **82:** 1079-1084.

Sharma SK, Meshram SG, Patil RJ and Tignath S 2016. Hypsometric analysis using geographical information system of Gour river watershed, Jabalpur, Madhya Pradesh, India. *Current World Environment* **11**(1): 56-64.

Singh O, Sarangi A and Sharma MC 2008. Hypsometric integral estimation methods and its relevance on erosion status of north-western lesser Himalayan watersheds. *Water Resources Management* **22:** 1545–1560.

Singh V and Singh SK 2018. Hypsometric analysis using microwave satellite data and GIS of Naina-Gorma river basin (Rewa district, Madhya Pradesh, India). *Water Conservation Science and Engineering* **3**(4): 221-234.

Strahler AN 1952. Hypsometric (area-altitude) analysis of erosional topography. *Bulletin of the Geological Society of America* **63:** 1117-1142

Walia S, Singh S, Loshali DC and Babbar R 2018. Hypsometric analysis of the micro-watersheds with different management practices located on Shivalik foothills. *Arabian Journal of Geosciences* **11:** 1-8.

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Development of One cell or One individual Direct PCR of Protozoan or Metazoan 18S rRNA Gene for Molecular Ecology

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Abstract: The new method for one cell or one individual direct PCR to build a local DNA database of protozoans and metazoans for the molecular ecological studies was developed. At first, we applied a glass capillary method for isolating a protozoan cell and a metazoan individual. The other sources were from wastewater treatment (activated sludge) systems in Nagasaki. The addition of BSA to a water droplet was very useful for the quick isolation of a protozoan cell due to reducing the protozoanmotion. In order to decompose dissolved DNA of other organisms, DNase-I was added to the PCR tube and incubated for 30 min. Then, 70 per cent EtOH of 100 µl was added to the PCR tube .It was sequentially treated by sonication for 30 sec and heated for 2min in a micro wave oven. We applied a nested PCR for 18S rRNA gene of the isolated rotifer individual and a protozoan cell. Finally, we determined the sequence of each PCR amp icon for the rotifer individual or the protozoa. As a result, using the developed new method, we could correctly determine the partial sequence of 18r RNA genes of 17 samples of ciliates and rotifers in 20 samples from natural ponds and activated sludge systems.

Keywords: Protozoan and metazoan, 18S rRNA gene, Molecular ecology, One cell or one individual direct PCR

The morphological identification of protozoan and metazoan in biological wastewater treatment plants have been performed by an operation expert of the plant, because the protozoan and metazoan community relates to water treatment performance (Foissner 2016). However, the morphological identification demands identification expertise; in addition, it is time-consuming (Medlin et al 2006).Hence enough practice was demanded the quick identification. The number of such skilled engineers has been decreasing. However, if a molecular taxonomical method for the identification of protozoan and metazoan was introduced, more accurate and systematic identification can be quickly performed, as well as 16S rRNA gene base molecular taxonomy of bacteria. In particular, the DNA barcoding method using 16S rRNA genes for bacteria already became a popular method using Next Generation Sequencer (Lebonah 2014).

On the other hand, the identification based on 18S rRNA genes was recently started for the diversity study of activated sludge system and coastal ecosystem (Matsunaga 2014, Jung et al 2015). However, DNA clones were frequently identified as unknown species by BLAST search in the studies. Therefore, it is very important for molecular ecological studies to build a local DNA database. In present study, we focused on protozoan and metazoan which can prey on toxic cyanobacteria, because predators are effective organisms for the biological control of toxic cyanobacteria (Iwami et al 2000, Itayama et al 2008). Another goal of our study is to build a local DNA database of protozoan and metazoan in the biological wastewater treatment system. In any case, many species in protozoan and metazoan have to be promptly identified as far as possible. Therefore, it is necessary to develop a more efficient method for building a local DNA database. One of the time-limiting steps is to isolate a moving protozoan cell using a capillary of glass tube under the microscope .

Alternatively, the one cell direct PCR is particularly useful to obtain protozoan and metazoan DNA sequence promptly (Shimano 2008), because it is difficult to find the adequate mass culture condition and the medium for the isolated individuals. However, the one cell direct PCR sometimes resulted in improper DNA sequences. Therefore, we aimed to develop a prompt isolation method and a new protocol to obtain exact sequences of a protozoanora metazoan 18S rRNA genes.

MATERIAL AND METHODS

Study site and sample collection: The samples were collected from two ponds located in Shimabara city of Nagasaki Prefecture (32°51'12.3948"N,130°15'40.1184"E), Tamana city in Kumamoto Prefecture (32°55'41.636"N, 130°33'30.233"E), Japan. Then activated sludge samples were collected from three wastewater treatment facilities in Nagasaki Prefecture and an MBR (membrane bioreactor) in Nagasaki University. The samples were transported to our laboratory at the room temperature within half day.

Isolation and morphological identification: All wells of a 24 well microplate (Iwaki, Asahi Glass co., Ltd.) were filled with sterile BG11 medium (Kratz and Myers 1955, Stanier et al 1971) of 1ml and toxic *Microcystis viridis* (NIES102) cell suspension with $3x10^4$ cells·ml^{-1} of 500 µl. Then each pond water sample of 500 µl was transferred to each well of the 24 well plate to perform an enrichment cultureat room temperature and with dark condition to find out protozoan or metazoan which can prey onthe toxic *Microcysts* cells. After 7 days, one droplet of 100 µl was transferred from each well to a plastic petri dish. Then a moving protozoa cell or a moving metazoan individual was captured using a glass capillary tube of the tipdiameter of 100 umunder the inverted microscope (ECLIPSE TS100, Nikon Co., Japan) with x100~x400 magnifications (Pringsheim 1946).

Furthermore, the isolated individual of protozoan or metazoan was again incubated for 7 days in each well of the 24 multi well plastic plate containing *M. viridis* cell suspension with the same condition. After the incubation, several wells showing shallow green were chosen. One droplet of 100 µl was transferred from each chosen well to a plastic petri dish to perform the morphological identification using the same inverted microscope. BSA (FUJIFILM, Wako Pure Chemical Co.) solution of 100 µl with 20 mg ml^{-1} was added to the drop on the plastic petri dish when we performed the morphological identification under the same inverted microscope. At the same time, the video of the moving protozoan or rotifer was recorded and the still images were captured using a digital camera (Canon EOS Kiss X5). Moreover, in order to directly confirm the predation by each protozoan or rotifer for *M. viridis* cells, the full observation of the protozoan or the rotifer was performed before the addition of the BSA solution. Protozoan and metazoan in the activated sludge systems were directly isolated without enrichment culture. The isolation method was the same as the method for the pond samples described the above.

Cell disruption: The consecutive washing was carried out for each individual or cell on the petri dish after the morphological identification. 5 or more droplets of the same BSA solution of 100 µl were placed on the same petri dish, then the captured individual was transferred to this first water droplet from the original droplet by the same capillary. This washing was repeated more than 5 times. Then, an individual was carefully transferred to a PCR tube. In the first experiment, we followed the conventional direct PCR method (Shimano et al 2008). The 70 per cent ethanol 50 µl was added in the PCR tube to disrupt the cell. We waited until the PCR tube completely dried in an incubator (MD-01N, Major Science Co. Ltd.) of 60 °C for 6 hours.

In the new method, DNase I (Takara Biotechnology Co, Ltd) solution of 2 µl and the buffer solution of 7 µl were added to the PCR tube just after the transfer of the individual. Then the PCR tube was incubated at 37 °C for 30min. Then 70 per cent ethanol of 50 µl was added in the PCR tube. In a microwave oven (NE-EH22, Panasonic Co.), the PCR tube was heated with 500W for 2 min. Ultrasonication (Silent sonic UT-204, SHARP Co. Japan) was sequentially performed with the power density of 2 W/ml for 10 min for ciliate, and 30 min for rotifer (Liang et al 2008). Finally, we waited until the PCR tube completely dried in the same incubator with the same condition. The tube was frozen at -20 °C until PCR amplification.

PCR amplification: After the cell disruption, the nested PCR was applied (Shimano et al 2008). In all PCR amplification, a thermal cycler Veriti™ (Thermo Fisher Scientific Inc.) and TksGflex DNA polymerase (TAKARA BIO INC., Japan) were used, where the enzyme and the buffer composition were followed by the company instruction manual.

For the first PCR, metazoan universal eukaryotic primer set Metaz 2-F and Metaz 5-Rtargeting 18S rRNA gene were used (Machida and Knowlton 2012). The condition of the first PCR amplification (20µl scale) was performed by the following condition: 6pmol of the both primers, the initial denaturation at 94°C for 3min, 50 cycles of 98°C for 10 sec, 52°C for 15 sec, and 68°C for 30 sec, and a final extension step of 72°C for 7 min. The second PCR was performed by a rotifer specific primer-55F (5'-GCCTGGGCTAATA CATGCGA-3') and primer-395R (5'-CTGCTGCCTTCCT TGGAAGT-3'), which were designed by using Primer3 plus and Geneious 8.1.9 (Biomatters Ltd.) in this study. The amplification was performed by the following condition: 6pmol of the primers, the initial denaturation with 94°C for 3 min, 35 cycles of denaturation 98°C for 10 sec, 60.3°C for 15 sec, 68°C for 30 sec, then final extension 72°C for 7 min. For a specific primer of ciliates, Pyro-F and CiliPyro-R (Jung et al 2015) was used for the second PCR. The specificity of the primer set was confirmed by Primer-BLAST (NCBI tool on web site). The amplification for ciliates was performed by the following condition: 6pmol of the primers, initial denaturation at 94°C for 3min, 98°C for 10 sec, 52°C for 20 sec, and 68°C for 1 min, and a final extension step of 72°C for 7 min.

After agarose gel (2.5%) electrophoresis by Mupid®-2plus (TAKARA BIO INC., Japan), the band containing the target amplicon was cut, then it was purified by NucleoSpin®

Gel and PCR clean-up kit (MACHEREY-NAGEL GmbH & Co. KG, Germany).

DNA sequencing and phylogenetic analysis: The obtained amplicon was sequenced by a company service (Fasmac Co., Japan). The sequences of the amplicons were identified by BLAST search. The multiple alignments of sequences were carried out by the Tamura-Nei method, and the phylogenic analysis was conducted by the Neighbor-Joining method using Geneious 8.1.9 (Biomatters Ltd.).

RESULTS AND DISCUSSION

Isolation and morphological identification of protozoan and rotifers from ponds: Because several moving protozoan and rotifers were found in the enrichment culture using toxic *Microcystis viridis* cell suspension, it was considered that the protozoan or the rotifer could graze and assimilate the *M. viridis* cells (Iwami et al 1996). However, it was also possible that the protozoan or the rotifer mainly assimilated bacteria cells in the *M. viridis* cell suspension. Therefore, carried out the second culture of each isolated a protozoa cell or a rotifer individual using the *M. viridis* cell suspension. After 7 days incubation, again confirmed the growth of the rotifer or the protozoa in each well. Then the perseverance full observation was performed to confirm the moment of the predation of *Microcystis* cells by the rotifer or the protozoa. The two kinds of rotifer *Philodina* sp. and *Lepadella* sp. and one ciliate *Euplotes* sp. Were finally chosen (Fig. 1, Table 1, 2), where two illustrated guide books

Table 2. Comparison of the morphological identification and the identification based on 18S rRNA gene using a new method

Sampling site	Sample code	Morphological identification (Phylum, Order, Species)	Molecular identification accession number, similarity %
Natural pond 1 (Nagasaki)	2-1	*Ciliophora, Hypotrichida, Eluplotes* sp.	*Euplotes sp. bLaN1* (LN869991), 100%
Natural pond 1 (Nagasaki)	2-2	*Rotifera, Bdelloidea, Philodina* sp.	*Philodina sp. cmbb21* (MH429976), 99.6%
Natural pond 2 (Kumamoto)	2-3	*Rotifera, Ploima, Lepadella* sp.	*Lepadella patella* (AY218117), 99.7%
MBR, Nagasaki University	2-4	*Ciliophora, Gymnostomatida, Chilodonella* sp.	*Chilodonella uncinata* (KY476314), 99.4%
Wastewater treatment plant 1	2-5	*Rotifera, Ploima, Lepadella* sp.	*Lepadella patella* (AY218117), 100%
Wastewater treatment plant 1	2-6	*Rotifera, Ploima, Lepadella* sp.	*Lepadella patella* (AY218117), 100%
Wastewater treatment plant 1	2-7	*Rotifera, Bdelloidea, Adineta* sp.	*Adineta vaga* (DQ089733), 100%
Wastewater treatment plant 1	2-8	*Rotifera, Bdelloidea, Rotaria* sp.	*Rotaria rotatoria* (KF561104), 99.8%
Wastewater treatment plant 2	2-9	*Ciliophora, Heterotrichida, Spirostomum* sp.	*Spirostomum* sp. *2cLPN1* (LN870108), 100%
Wastewater treatment plant 2	2-10	*Ciliophora, Heterotrichida, Spirostomum* sp.	*Spirostomum* sp. *2cLPN1* (LN870108), 100%
Wastewater treatment plant 2	2-11	*Ciliophora, Heterotrichida, Spirostomum* sp.	*Amoebozoa* sp. *Pugl67W* (KP792398), 99.5%
Wastewater treatment plant 2	2-12	*Ciliophora, Cyrtophorida, Chilodonella*sp.	*Cladosporium* sp. *stain ALEF-C1* (MH015002), 100%
Wastewater treatment plant 2	2-13	*Ciliophora, Cyrtophorida, Prostomatea*sp.	*Prostomatea sp. cLPN2* (LN870114), 98.1%
Wastewater treatment plant 2	2-14	*Ciliophora, Cyrtophorida, Opisthostyla*sp.	*Opisthostyla* sp. (KU363244), 99.7%
Wastewater treatment plant 2	2-15	*Ciliophora, Sessilida, Epistylis*sp.	*Symmetrospora gracilis* (KJ708433), 100%
Wastewater treatment plant 2	2-16	*Ciliophora, Sessilida, Epistylis* sp.	*Epistylis riograndensis* (KM594566), *99.7%*
Wastewater treatment plant 2	2-17	*Ciliophora, Sessilida, Epistylis* sp.	*Epistylis riograndensis* (KM594566), *99.1%*
Wastewater treatment plant 3	2-18	*Ciliophora, Sessilida, Opercularia* sp.	*Opercularia* sp. (KU363267), 99.7%
Wastewater treatment plant 3	2-19	*Rotifera, Ploima, Lepadella* sp.	*Lepadella patella* (AY218117), 99.4%
Wastewater treatment plant 3	2-20	*Rotifera, Bdelloidea, Adineta* sp.	*Adinetavaga (DQ089733), 100%*

Table 1. Comparison of the morphological identification and the identification based on 18S rRNA gene using a conventional method

Sampling site	Sample code	Morphological identification (Phylum, Order, Species)	Molecular identification accession number, similarity %
Natural pond (Nagasaki)	1-1	*Rotifera, Bdelloidea, Philodina* sp.	*Vernalophrysalgivore* (KY852454), 100%
Natural pond (Kumamoto)	1-2	*Rotifera, Bdelloidea, Philodina* sp.	*Poteriospumella* sp. (KX100620), 100%
Natural pond (Kumamoto)	1-3	*Rotifera, Ploima, Lepadella* sp.	*Keratella quadrata* (KX358062), 99.8%
Natural pond (Kumamoto)	1-4	*Rotifera, Ploima, Lepadella* sp.	*Chrysophyceae* sp. (KY464901), 100%

were referred in our morphological identification (Mizuno and Takahashi 2000, Tanaka 2002). *Philodina* sp. was studied for the control of cyanobacteria bloom (Iwami et al 2000, Itayama et al 2008). *Lepadella* sp. was also found in *Microcystis* bloom (Yamamoto 2009). However, could not find a report about the predation for toxic *Microcystis* cell by *Euplotes* sp., though it was reported ciliate *Nassulaaurea* grazed filamentous cyanobacteria collected from three lakes in English Lake District, Cumbria (Hildam et al 1989).

Improvement of isolation method: In the isolation work, the time was mostly consumed to capture moving organisms in a droplet on the plastic petri dish under the microscope. In order to reduce the moving speed, the high viscosity BSA solution was added to the droplet. It succeeded in reducing the time to capture the moving protozoan to 1/2 ~ 1/3 compared to the conventional method. In addition, it also improved the video quality and the photograph. In our local

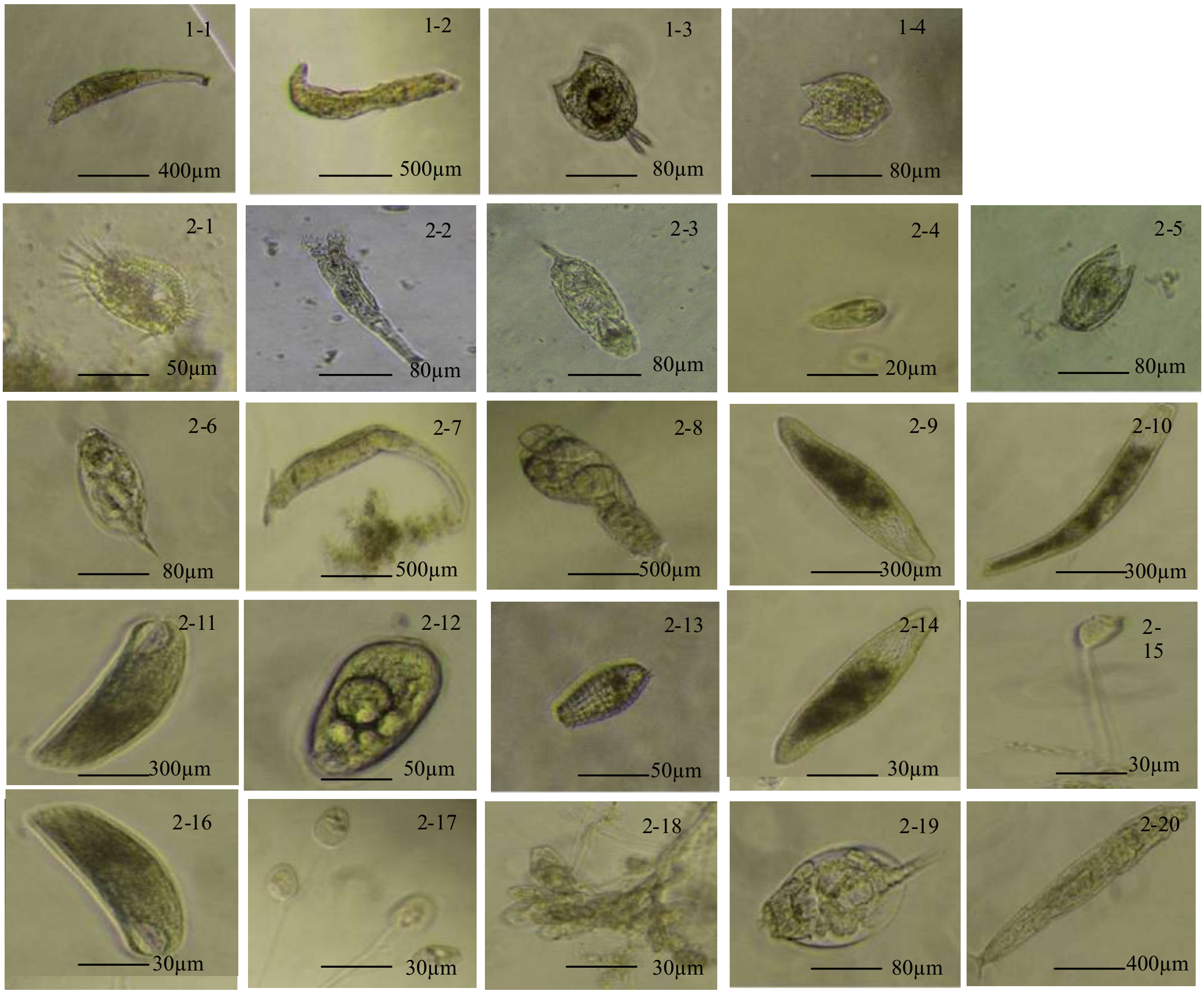

Fig. 1. Photographs of the isolated protozoa and rotifers

DNA database, image data will be very important as a kind of annotation.

It was reported that BSA had any noticeable effect on amplification in the absence of inhibitors (Kreader 1996). The addition of BSA never affected PCR results in our preliminary experiments. However, the addition of BSA into the PCR mixture increases PCR yields from a low purity DNA template, which could be contaminated with PCR inhibitors such as polysaccharides or humic substances (Nagai et al 1998).

Conventional one cell or one individual direct PCR method: The conventional one cell or one individual direct PCR method was applied for two rotifer individuals and one protozoa cell from the pond samples. The result of BLAST search of the sequence of the sample code 1-1 showed amoeba *Vernalophrysalgivore*, which was recently isolated and identified (Gong 2015), though the 1-1 was identified as rotifer *Philodina* sp. by the morphological identification (Table 1). Moreover, the sequence result showed 100 per cent matching. Hence we thought that the DNA template of *V. algivore* was correctly amplified by the conventional method. It was actually high possible that *V. algivore* grew in *Microcystis* cell suspension because *V. algivore* was found as a predator foralgae (Gong 2015). Therefore, it was thought that the extracellular dissolved DNA (free DNA) of *V. algivore* existed in the cell suspension. As a result, it was possible that the free DNA contained to the PCR tube. The result of the BLAST search of the sample 1-2 showed *Poteriospumella*sp. which was a heterotrophic flagellate, though it was morphologically identified as *Lepadella* sp. That of the sample 1-3 and the sample 1-4 showed *Keratella quadrata* and *Chrysophyceae* sp. respectively. Although *Keratella quadrata* is rotifer, the morphology is apparently different from *Lepadella* sp. (Mizuno and Takahashi 2000, Tanaka 2002). Class *Chrysophyceae* include mixotrophic flagellate such as *Ochromonas* sp. Some heterotrophic flagellate and mixotrophic flagellate were known as a predator for *Microsystis* sp. (Zhang and Watanabe 2001, Nishibe, 2002). According torecent research reports, extracellular DNA as environmental DNA commonly exists in the aquatic environment (Salter 2018). When the organisms proliferated in the culture medium, much of extracellular DNA could be released. Hence, speculated that very few free DNA of such organisms was possibly transferred from the culture medium to the PCR tube. Moreover, the very few DNA templates could be amplified because our nested PCR was designed for the detection of one molecule DNA template.

New one cell or one individual direct PCR method: In order to solve the free DNA contamination problem, it was apparently effective to degrade the free DNA in the PCR tube by using DNase I before the cell disruption. In addition, we thought that the cell disruption efficiency has to be improved.DNA templates of the 18S rRNA gene of a rotifer individual are more abundant compared to DNA template from unicellular protozoa. However, did not succeed in the amplification of the target rotifer gene. Hence, it was thought that the incorrect amplification was caused by the low efficiency of the cell disruption. Therefore, we added the microwave treatment and the ultrasonication treatment between the DNase I treatment and the PCR. In addition, we expected to completely denature the DNase I before the PCR by the additional treatments.

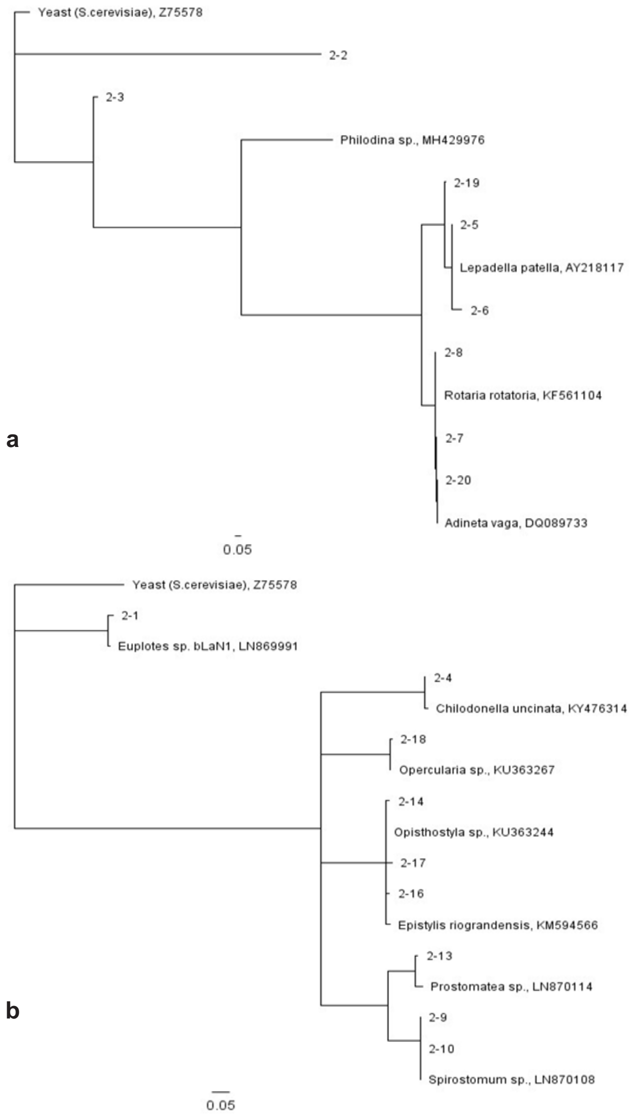

Fig. 2. Phylogenetic tree of 18S rRNA gene sequences of the isolated rotifers (a) andciliates (b) with the sequence of closest species obtained from NCBI

The BLAST search exactly resulted in *Philodina* sp. and *Lepadella* sp. for the sample 2-2 and the sample 2-3, respectively (Table 2). We succeeded to correctly identify unicellular protozoa *Euplotes* sp. by the new one cell direct PCR method. In case of this new method for the activated sludge sample, 83 per cent of the results of the BLAST search showed the same results by morphological identification. However, the three organisms could not be correctly identified yet (Table 2). The result of the BLAST search of the sample 2-11 matched 99.5 per cent consensus with the 18rRNA gene sequence of *Amoebozoa* sp., which is an amoeba, though the morphology apparently showed a ciliate. The sample 2-12 showed 100 per cent match for *Cladosporium* sp., and the sample 2-15 also showed 100 per cent match for *Symmetrosporagracili*. The both organisms were known as fungi. Many 18S rRNA genes of fungi were detected according to a previous study on the diversity of eukaryotic microorganisms in activated sludge, (Matsunaga et al 2014). Therefore, we need to improve our method to obtain a more exact result. Protozoan and rotifers listed in Table 2 were popular species as an indicator (SBI) in the operation of activated sludge facility (Sudo and Inamori 1997). Figure 2 showed the phylogeny trees for protozoan and rotifers in which were correctly identified in Table 2.

One of the goals of this study is to replace the morphological identification of protozoan and metazoan with the identification based on DNA sequence for the diagnosis of a biological wastewater treatment system using SBI, because the total workflow of DNA extraction, PCR and sequencing are easier than the morphological identification. Furthermore, a portable sequencer MinION™ (Oxford Nanopore Technologies, UK) was recently applied for the identification of bacteria by direct PCR amplification product of 16Sr RNA genes (Kai 2019). Shortly, we can apply such portable sequencer device for the diagnosis of practical wastewater treatment system with reasonable cost. At that time, a local database of protozoan and metazoan must be more important. We expect that our new method contributes to building the local DNA database.

CONCLUSION

In this study, examined a new method for one cell or one individual direct PCR of protozoan and metazoan 18Sr RNA gene. The addition of BSA was effective in accelerating the isolation step. DNase I was mixed in the PCR tube before the amplification, in order to remove free DNA (extracellular dissolved DNA). Moreover, sonication and heat treatment by microwave oven was supplemented to improve the cell disruption efficiency. By using our new method, we could correctly identify rotifers and ciliates for 17 samples in a total of 20 samples from ponds samples and activated sludge treatment facilities.

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REFERENCES

Canter HM, Heaney SI and Lund JWG 1989. The ecological significance of grazing on planktonic populations of cyanobacteria by the ciliate *Nassulaaurea*. *New Phytologist* **114**: 247-263.

Foissner W 1991. Basic light and scanning electron microscopic method for taxonomic studies of ciliated protozoa. *European Journal of Protistology* **27**: 313-330.

Foissner W 2016. Protists as bioindicators in activated sludge: Identification, ecology and future needs. *European Journal of Protistology* **55**: 75-94.

Gong Y, Patterson DJ, Li Y, Hu Z, Sommerfeld M, Chen Y and Hu Q 2015. *Vernalophrys algivore* gen. nov., sp. nov. (Rhizaria: Cercozoa: Vampyrellida), a New Algal Predator Isolated from Outdoor Mass Culture of *Scenedesmus dimorphus. Applied and Environmental Microbiology* **81**(12): 3900–3913.

Itayama T, Iwami N, Koike M, Kuwabara T, Whangchai N and Inamori Y 2008. Measuring the effectiveness of a pilot scale bioreactor for removing Microcystis in an outdoor pond system. *Environmental Science and Technology* **42**(22): 8498-8503.

Iwami N, Inamori Y, Sugiura N and Matsumura M 1996. Degradation characteristics of toxic Microcystis viridis by mastigophora, *Monas guttula* using aquatic large-scale microcosm. *Journal of Japan Society on Water Environment* **19**: 140-146. (In Japanese)

Iwami N, Sugiura N, Itayama T, Inamori Y and Matsumura M 2000. Control of cyanobacteria Microcystis using predatory microanimals inhabiting in bioreactor. *Environmental Technology* **21**(5): 591-596.

Jung JH, Park KM, Yang EJ, Joo HM, Jeno M, Kang SH, Choi HG, Park MH, Min GS and Kim S 2015. Patchy-distributed ciliate (Protozoa) diversity of eight polar communities as determined by 454 amplicon pyrosequencing. *Animal Cells and Systems* **19**(5): 339-349.

Kai S, Matsuo Y, Nakagawa S, Kryukov K, Matsukawa S, Tanaka H, Iwai T, Imanishi T and Hirota K 2019. Rapid bacterial identification by direct PCR amplification of 16S rRNA genes using the MinION™ nanopore sequencer. *FEBS Open Biology* **9**(3): 548-557.

Kratz WA and Myers J 1955. Nutrition and growth of several blue-green algae. *American Journal of Botany* **42**(3):282-287.

Kreader, C A 1996. Relief of Amplification Inhibition in PCR with Bovine Serum Albumin or T4 Gene 32 Protein. *Applied and Environmental Microbiology* **62**(3): 1102.

Lampert W 1987. Laboratory studies on zooplankton cyanobacteria interactions. *New Zealand Journal of Marine and Freshwater Research* **21**(3): 483-490.

Lebonah DE, Dileep AK, Chandrasekhar S, Sreedevi SB and Kumari JP 2014. DNA Barcoding on Bacteria: A Review. Advances in Biology **2014**: Article ID 541787, 9.

Machida RJ and Knowlton N 2012. PCR Primers for Metazoan Nuclear 18S and 28S Ribosomal DNA Sequences. *PLoS ONE* **7**(9): e46180 pp.

Madoni P 1994. A sludge biotic index (SBI) for the evaluation of the biological performance of activated sludge plants based on the microfauna analysis. *Water Research* **28**(1): 67-75.

Matsunaga K, Kubota K and Harada H 2014. Molecular diversity of eukaryotes in municipal wastewater treatment processes as revealed by 18S rRNA gene analysis. *Microbes and Environments* **29**(4): 401-407.

Medlin LK, Metfies K, Mehl H, Wiltshire K and Valentin K 2006. Picoeukaryotic plankton diversity at the helgoland time series site as assessed by three molecular methods. *Microbial Ecology* **52**(1): 53-71.

Mizuno T and Takahashi E 2000. *An Illustrated Guide to Freshwater Zooplankton in Japan*, Tokai University Press, Tokyo, Japan, 556 pages. ISBN4-486-0149-0. (In Japanese)

Nagai M, Yoshida A and Sato N 1998. Additive Effects of bovine serum albumin, dithiothreitol and glycerol on PCR. *Biochemistry and Molecular Biology International* **44**(1): 157-163.

Nishibe Y, Kawabata Z and Nakano S 2002. Grazing on *Microcystis aeruginosa* by the heterotrophic flagellate *Collodictyont riciliatum* in a hypertrophic pond. *Aquatic Microbial Ecology* **29**: 173-179.

Patterson DJ, Drawings by Stuart Hedley 1996. *Free-Living Freshwater Protozoa A Colour Guide*, New York: Wiley, London: Manson Pub, Sydney: UNSW Press, Washington DC: ASM Press, 223 pages.

Pringsheim EG 1946. The Biphasic or Soil-Water Culture Method for Growing Algae and Flagellata. *Journal of Ecology* **33**(2):193-204.

Salter I 2018. Seasonal variability in the persistence of dissolved environmental DNA (eDNA) in a marine system: The role of microbial nutrient limitation. *PLoS ONE* **13**(2): e0192409.

Shimano S, Sanbe M and Kasahara Y. 2008. Linkage between light microscopic observations and molecular analysis by single-cell PCR for ciliates. *Microbes and Environments* **23**(4): 359-359.

Stanier RY, Kunisawa R, Mandel M and Cohen-Bazire G 1971. Purification and properties of unicellular blue-green algae (order Chroococcales). *Bacteriological Reviews* **35**(2):171-205.

Sudo R and Inamori Y 1997. *Illustration, Diagnosis of treatment performance from the viewpoint of microfauna*. Sangyo YousuiChyosakai, Tokyo, Japan, 287 pages. ISBN-978-4879120014.

Tanaka M 2002. *Illustrations of the Japanese Freshwater Plankton*. The University of Nagoya Press. Nagoya, Japan, 584 pages. ISBN4-8158-0435-4.

Yamamoto Y 2009. Effect of temperature on recruitment of cyanobacteria from the sediment and bloom formation in a shallow pond. *Plankton and Benthos Research* **4**(3): 95-103.

Zhang X and Watanabe MM 2001. Grazing and growth of the mixotrophic chrysomonad *Poterioochromonas malhamensis* (Chrysophyceae) feeding on algae. *Journal of Phycology* **37**: 738-743.

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Model-Based Clustering Approach for Regional Flood Frequency Analysis

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Abstract: A major challenge in the field of hydrology is to estimate the relationship between the magnitude and frequency of floods which is one of the most dangerous natural hazards that causes huge loss to livelihood of human resulting in number of fatalities. Regional flood frequency analysis using model-based clustering approach has been developed to estimate the flood quantiles for the return periods 2, 5, 10, 20, 25, 50, 100, 200, 500 and 1000 years. The approach has been carried out on the flood frequency attributes of 61 gaging stations in Indiana, United States. The primary objective is to derive the regional quantiles for the ungauged sites where the amount of information available is very little. L-moments are derived for the sites and discordance measure removes the discordant sites from the study. The proposed approach Bayesian Information Criterion (BIC) resulting in 2 clusters are proved to be homogeneous when applied to the Indiana streams. Goodness of fit measures is extensively applied in determining the error statistics for evaluating the performance of the model. Results show that the proposed approach in estimating the flood frequency and magnitudes are very accurate and hence useful for water resources planning and management.

Keywords: Frequency analysis, Clustering, L-moments, Bayesian information Criterion, Return period

The information on past flooding with the estimates of magnitude and frequency are essential for flood control projects and water resources management. The magnitude and frequency of floods must be accurately estimated for the flood plain management, flood damage assessment program and for the effective utilization of the water resources of the nation. Flood frequency analysis develops the relationship between the magnitude and frequency which are essential for the construction of hydraulic structures near the water bodies. Hydrologists face a real challenge in predicting the flood quantiles for the ungauged sites where little or no information is available for study (Gnanaprakkasam and Ganapathy 2019, Srinivas 2009). Various regionalization approaches are developed in order to estimate the quantiles of extreme events by obtaining the information from the neighborhood of the water sheds or from the similar watersheds which are not geographically adjacent to the target sites (Yarrakula et al 2016). Depth functions are used statistically to determine the similarity between the target site and the gauged site (Wazneh and Chebana 2014). Burn applied the region of influence techniques in estimating the flood quantiles for the target site by obtaining the information from the gauged sites using the Euclidean distance measure Burn 1990). Clustering approaches are applied in regionalization by grouping the similar sites under one category and moving the dissimilar sites to the other. Linear clustering techniques such as partitioning based and fuzzy clustering approaches are used in the application of frequency analysis by delineating the watersheds in the estimation of the flood quantiles for the ungauged sites (Srinivas et al 2008). Disorderliness based new regional flood frequency analysis was developed, where the regions with least entropy are selected to form the group (Basu and Srinivas 2016). Canonical correlations analysis method has been extensively applied in regional flood frequency analysis which mainly concentrates on the linear relationship between the variables (Ouarda et al 2001). The primary objective of the present study is to identify the group of homogeneous sites using model-based clustering approach which uses gaussian mixture models using different covariance structures and Bayesian information criterion that results in the number of components to be used in the study. At site and regional quantiles are estimated and the error statistics for various return periods are evaluated to check accuracy.

MATERIAL AND METHODS

Study area and data: The annual max flows for 61 sites from the Indiana watershed in United States has been used for this study (Fig. 1). Minimum 10 years of data are considered and the maximum record length taken here is 107 years. The attributes include drainage area of range 0.18 to 28813 sq.km, main channel slope ranging from 0.55 to 165 feet per kilometer, main channel length varying between 0.48 to 506 km, average basin elevation from 125 to 362 meters, storage

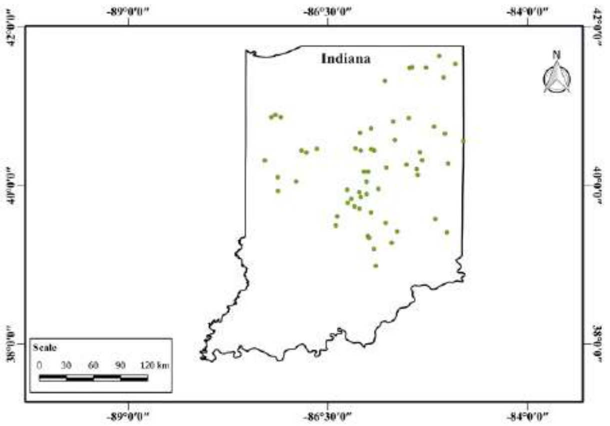

Fig. 1. Study area with the location of 61 sites

area covered by lakes, ponds or wetlands ranges between 0 to 13.3 per cent, forest area between 0 to 88.4 per cent, mean annual precipitation varying from 86 to 116 cm, 24 hours rainfall with a return period of 2 years ranging from 5 to 8.5 cm and soil runoff coefficient from 0.3 to 1. The geographical coordinates area expressed in decimal degrees. Annual max flows were extracted from the database of United States Geological Survey and the attributes were taken from the record of Glatfelter(1984).

The first step is to extract all the attributes to be considered in the study to frame the regionalization approach (Fig. 2). Cluster analysis is carried out in the second step, where the resultant clusters formed are subject to the homogeneity test in the third step. Finally flood quantiles are estimated for various return periods with the appropriate distribution chosen.

Identification of Homogeneous Regions

Cluster analysis: Clustering is a widely used technique to assemble the data points into a set of groups or clusters. The basic principle behind the method is to segregate the data points into a group which holds high degree of similarity among them and the data points which are not similar to the previously formed group falls under the next cluster. The traditional partitioning algorithms such as k means and hierarchical clustering require to provide the number of clusters at the initial stage which are difficult to find and are sensitive to scale and outliers. The traditional models are replaced by the model based clustering where the data is assumed to have generated from a distribution which is a combination of two or more components. (Fraley and Raftery 2002, Chris Fraley et al 2012).

Framework: Consider a data set A which contains the data points {$a_1,,,a_n$ }, z the number of clusters, set B, of z probabilistic clusters, $B_1,..B_z$ with the probability density functions $c_1,,,c_z$, and their probabilities $y_1,,,y_z$. The probability

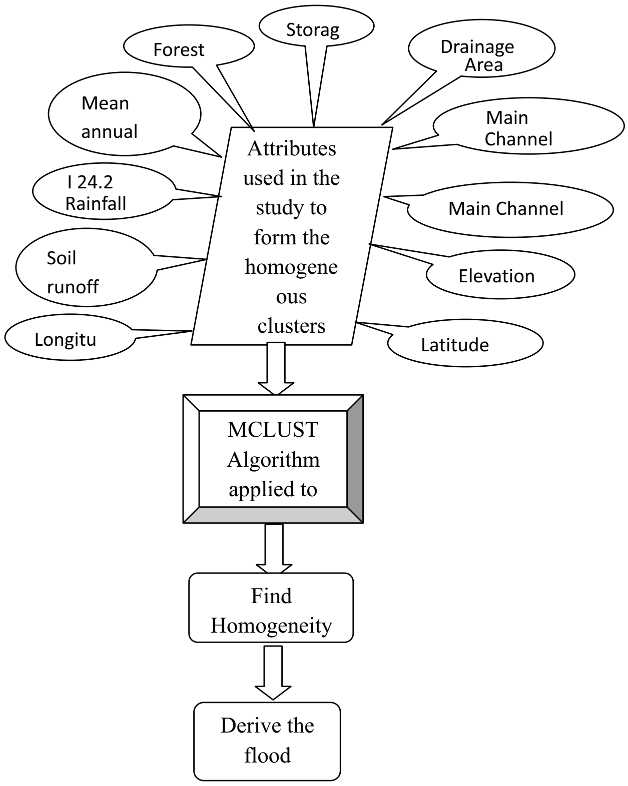

Fig. 2. The methodology of the study

that the data point *a* belongs to the cluster z is given by,

$$P(a|b) = \sum_{v=1}^{s} y_v c_v(a) \quad (1)$$

For the data set A of a objects, we have,

$$P(A|B) = \prod_{u=1}^{j} p(a_i|B) = \prod_{u=1}^{j} \sum_{v=1}^{z} y_v c_v(ai) \quad (2)$$

The probabilistic model-based cluster generates the z probabilistic clusters belonging to the set B of the data set A in such a way that P(A|B) is maximized. The center μ_v and the standard deviation σ_v are the two parameters for every cluster in the distribution.

$$\partial_v = (\mu_v, \sigma_v) and \partial = \{\partial_1 ... \partial_v\}$$

For $a_i \mathcal{E} A$, we have,

$$P(a_i|\partial_v) = \frac{1}{\sqrt{2\pi\sigma_v})} e^{-\frac{(a_v - \mu_v)^2}{2\sigma^2}} \quad (3)$$

The main task of the algorithm is to maximize the equation (3) so that ∂ can be inferred. Every object is assigned to the cluster using the closest center criterion. Similarity among the objects within a cluster should be maximized by adjusting the cluster centers to the closest object. (Yeung et al 2001)

Homogeneity test: Cluster group is recognized to be acceptably homogeneous if H < 1, possibly heterogeneous if

1<=H<2 and definitely heterogeneous if H >2 (Hosking and Wallis 1997). L-moments gives the appropriate shape of the frequency distribution along with the location, scale or dispersion, skewness and kurtosis values. Discordance test is carried out to remove the discordant sites from the clusters. If the D_i value of each and every site is below the critical value 3, then those sites are included in the analysis, otherwise excluded from the group.

Regional flood frequency relationships: Flood frequency estimates are derived for the gauges with little information using the data derived from the neighboring sites or from sites with similar attributes. Regional estimation is carried for deriving the quantiles by considering one site at a time as ungauged for different return periods.

Growth curve for site v is given by $q_v = Q_v/\mu_v$ (4)

Where Q_v = quantile function, μ_v = index flood (mean) for every site v. Regional growth curve is multiplied with the index flood value to get the quantile function. Similar frequency distribution provides similar results within the respective clusters. To estimate regional flood quantile $R_v(T)$ for each site v, with respect to a T year return period, the following equation is used.

$R_v(T) = \Sigma\, gc_v(T)\ scf_v\, p_{vq} / \Sigma\, p_{vq}$ (5)

where $gc_v(T)$ is the regional growth curve for site v, Scf_v is the scaling factor for site v as per the index flood procedure (Dalrymple 1960).

RESULTS AND DISCUSSION

Formation of homogeneous groups: Based on the discordance test, only one site has the Di value 3.77 which is greater than the critical value 3. Hence site number 3339108 alone is removed from the study and the remaining 60 sites are subject to the analysis. The model-based clustering approach classifies the Indiana watershed into two homogeneous clusters for the purpose of estimating the flood quantiles (Table 1). The size represents the total length of the sites in the cluster. H1 represents the heterogeneity measure value and RFD stands for the regional frequency distribution for the respective clusters. Both the clusters fall under the category of "Definitely Homogeneous" upon applying the heterogeneity test. H1 value of cluster 1 is -0.239 and cluster 2 is -0.0085, which shows that both the clusters are homogeneous as they satisfy the condition (H <1). Figure 3 clearly depicts the location of all the homogeneous sites with their respective clusters.

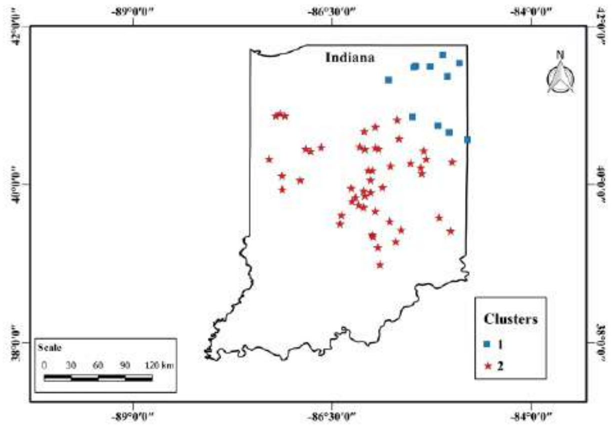

Fig. 3. Clusters formed based on model-based clustering approach

Regional frequency distribution: Goodness of fit measure and L-moment ratio diagrams are used to select the appropriate distribution for the clusters (Table 2). The rank given to the distribution for both the clusters. If the Z_{dist} <= 1.64, then that distribution can be selected favorably. Preference is given to the distributions that are closer to 0. Cluster 1 takes the generalized logistic distribution and cluster 2 fits with the generalized extreme value distribution. The goodness of fit measure chooses the appropriate distribution based on a numerical value; L-moment ratio diagrams gives a more visual presentation of the chosen distribution (Table 3). L-moment ratio diagrams for the cluster 1 and cluster 2 to choose the best distribution is shown in Figure 4.

Table 2. Z Statistics values and rank for all the clusters

Cluster		L-kurtosis	Z value	Rank
1	Gen. logistic	0.1952	0.56 *	1
	Gen. extreme value	0.1565	-1.39 *	2
	Gen. normal	0.1495	-1.74	3
	Pearson type III	0.1337	-2.54	4
	Gen. Pareto	0.0687	-5.82	5
2	Gen. logistic	0.2015	3.07	3
	Gen. extreme value	0.1649	-1.17 *	1
	Gen. normal	0.1556	-2.26	2
	Pearson type III	0.1365	-4.47	4
	Gen. Pareto	0.0795	-11.09	5

Table 1. Features of the clusters formed by MCLUST clustering approach

Clusters	Number of sites	Size	H1 value	H2 value	Homogeneity Status	RFD
1	11	505	-0.23913845	-0.509904	Homogeneous	GLO
2	50	2924	-0.00851074	0.6616398	Homogeneous	GEV

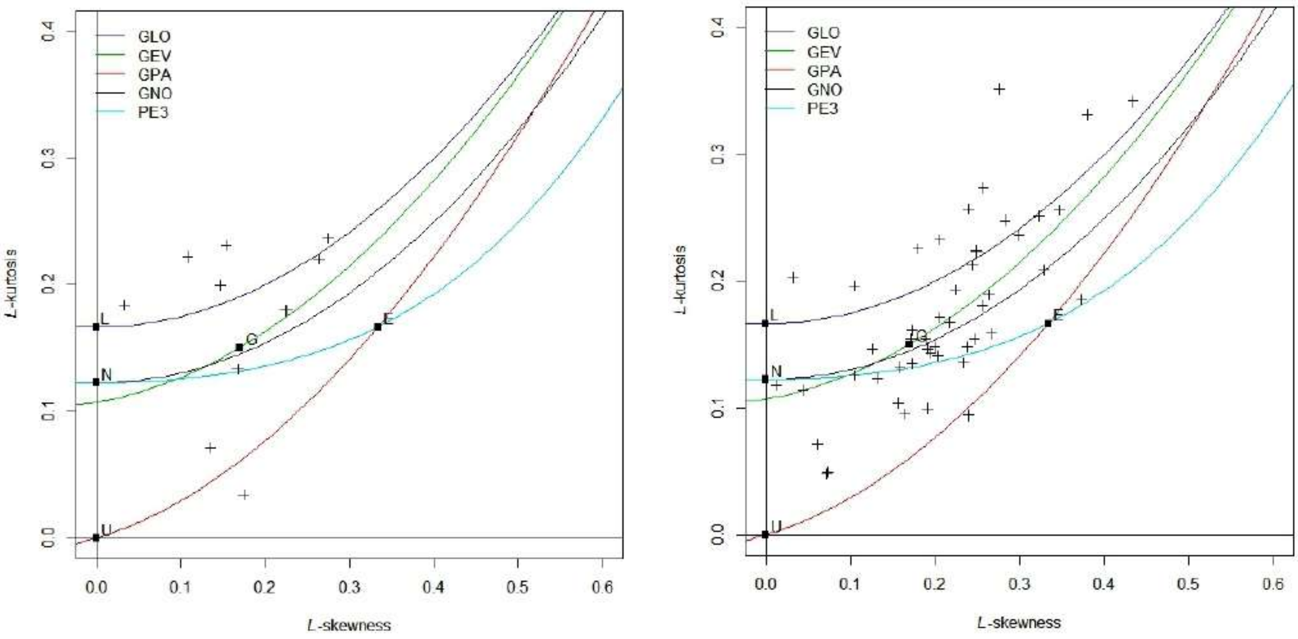

Fig. 4. L-moment ratio diagrams for the clusters 1 and 2

Regional Flood Frequency Relationships

Cluster analysis: Normal mixture models are applied extensively on the dataset to derive the model-based clusters, classifiers and to estimate the density. Covariance parameters and the number of clusters are selected using the Bayesian Information Criterion (BIC) (Schwarz 1978). Figure 5a shows the summary of BIC plot corresponding to all the attributes considered in the study which clearly states that VEV model gives the best output with 2 components. The BIC score is -2266.86 which proves to be the best score. The log likelihood value is -605.6346 and the integrated complete-data likelihood criterion value is -2266.941. The model is ellipsoidal with varying volume, equal shape and varying orientation. The density plots are shown in Figure 5b and based on the estimation results of density diagnostics, the plots of estimated CDF and empirical distribution function and Q-Q plot of sample quantiles vs quantiles from density estimation are obtained which are depicted in Figure 5c and 5d.

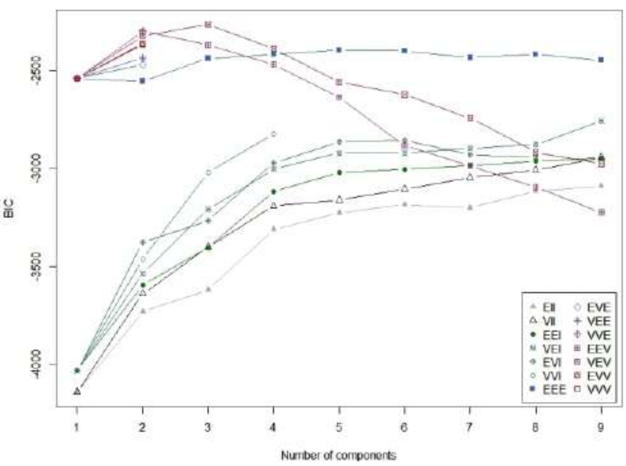

Fig. 5a. BIC score for the gaussian mixture model dataset

Table 3. Parameter estimates for the distributions cluster wise

Cluster		Location xi	scale α	shape k
1	Gen. logistic distribution	0.9317	0.2155	0.185
2	Gen. extreme value	0.7577	0.3831	-0.0532

At site and regional quantiles: The values are closer to the diagonal line, indicating the fact that the model is best fit (Fig. 6). The percentage of time that the stream flow is likely to equal or exceed a specific threshold is represented through flow duration curve plots for both at site and regional quantiles (Fig. 7). A vertical dotted line at 20 per cent indicates that all the values to its left are of high flows and the line at 70 per cent indicates that values to its right are of low flows. Information concerning the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest is extremely useful for the design of structures on a stream. When constructing dams, bridges, culverts on a river, it is very important to prejudice the time when the river flow would be equalled or exceeded a particular threshold. The error statistics used in the performance analysis namely Nash- Sutcliffe Efficiency (NSE) ranges from 0.87 to 0.98 and the other metrics like index of agreement (D) and coefficient of determination (R^2) also have similar values that are closer

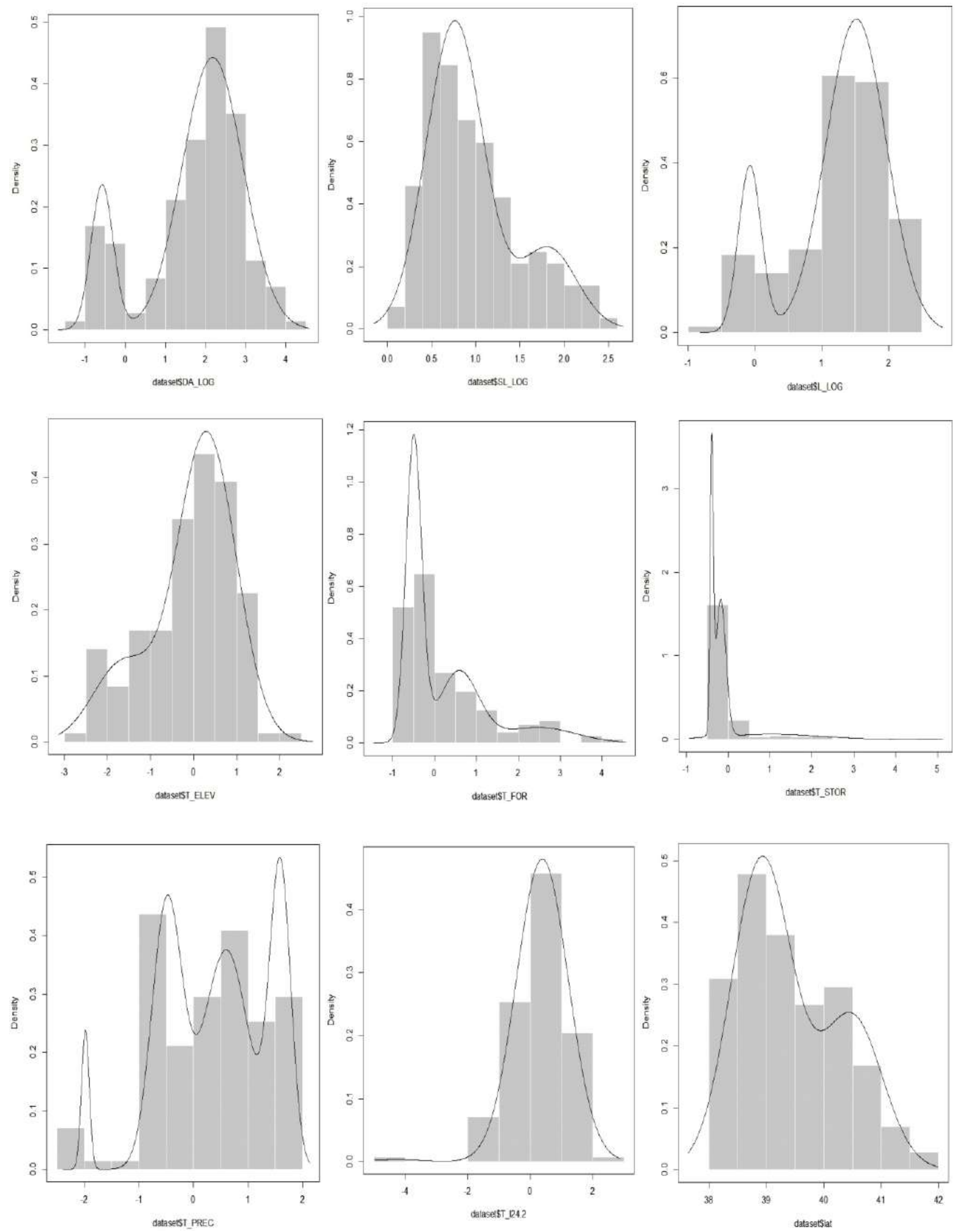

Fig. 5b. Density estimation for the Indiana attributes

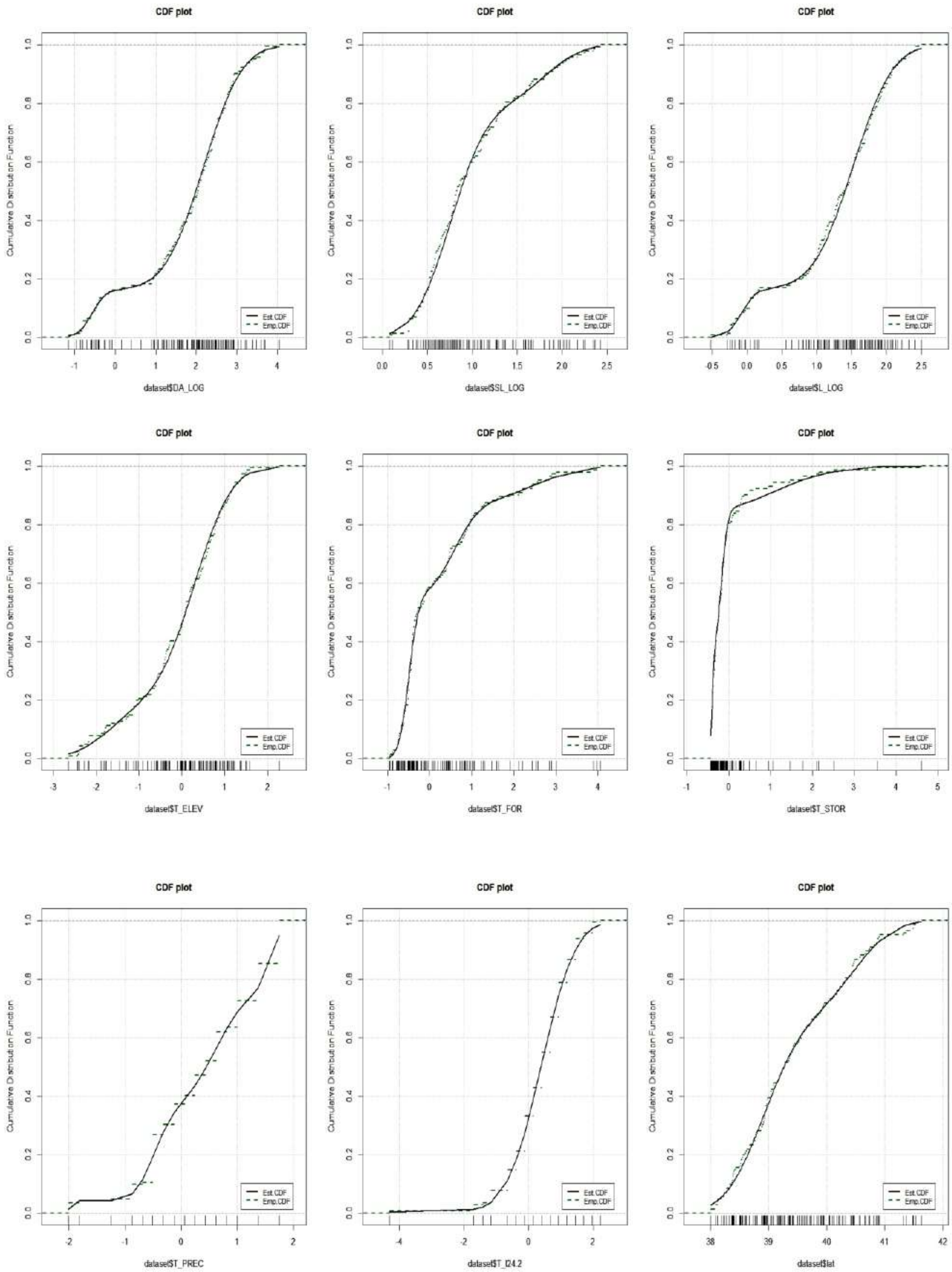

Fig. 5c. Relationship between the Empirical CDF and Estimated CDF

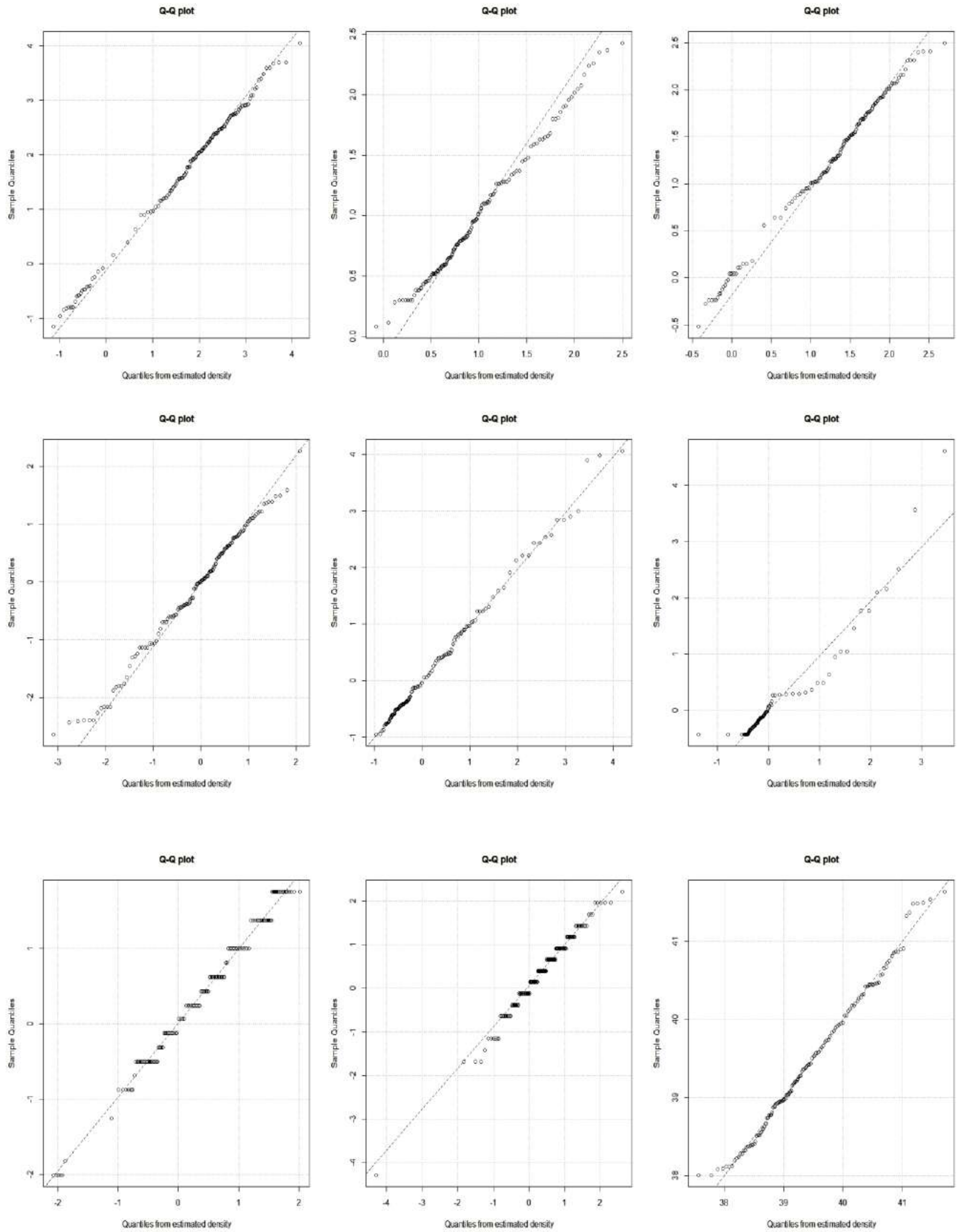

Fig. 5d. Relationship between the sample quantiles and the quantiles from estimated density

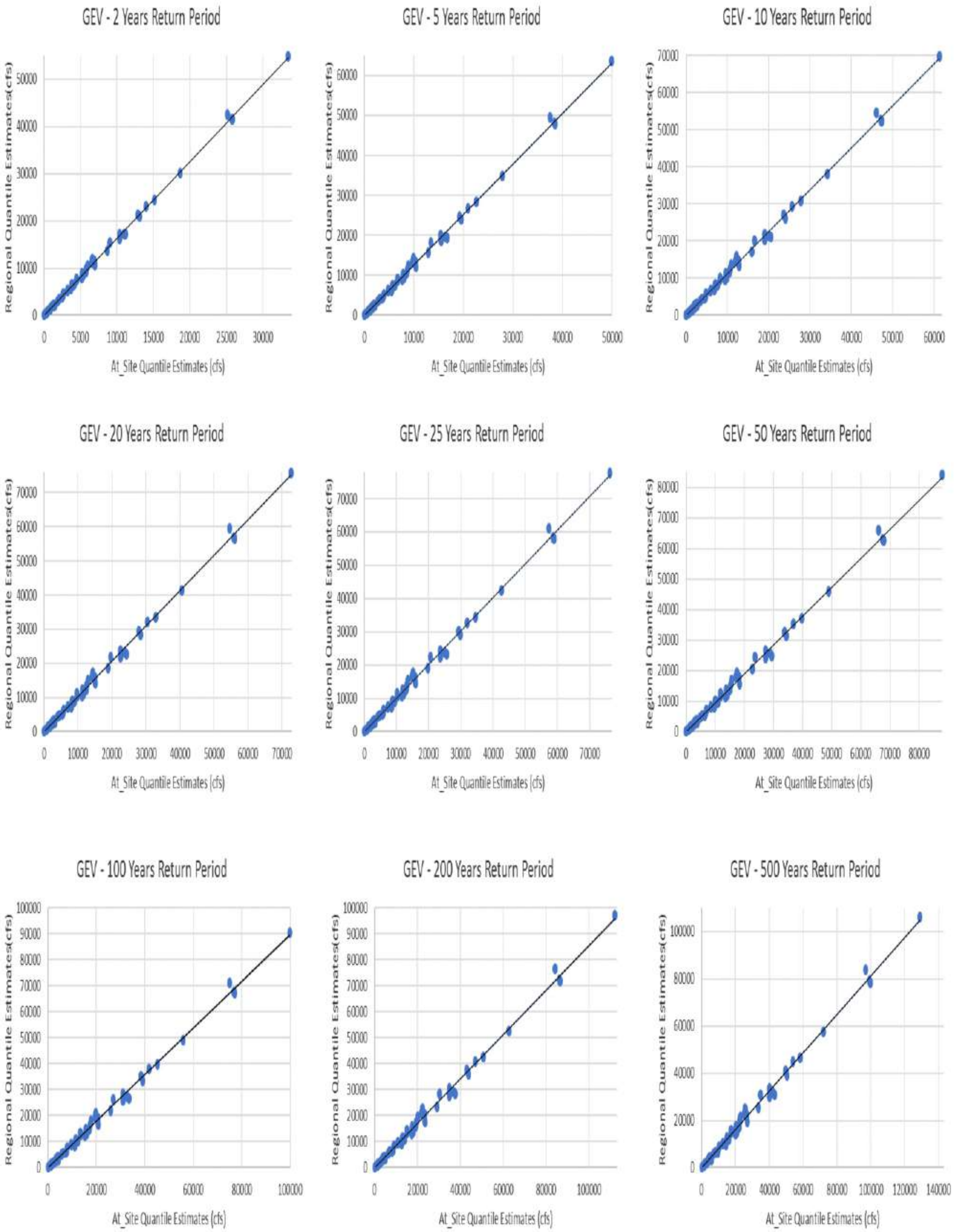

Fig. 6a. Results of the at site and the regional flood quantile estimates for GEV distribution

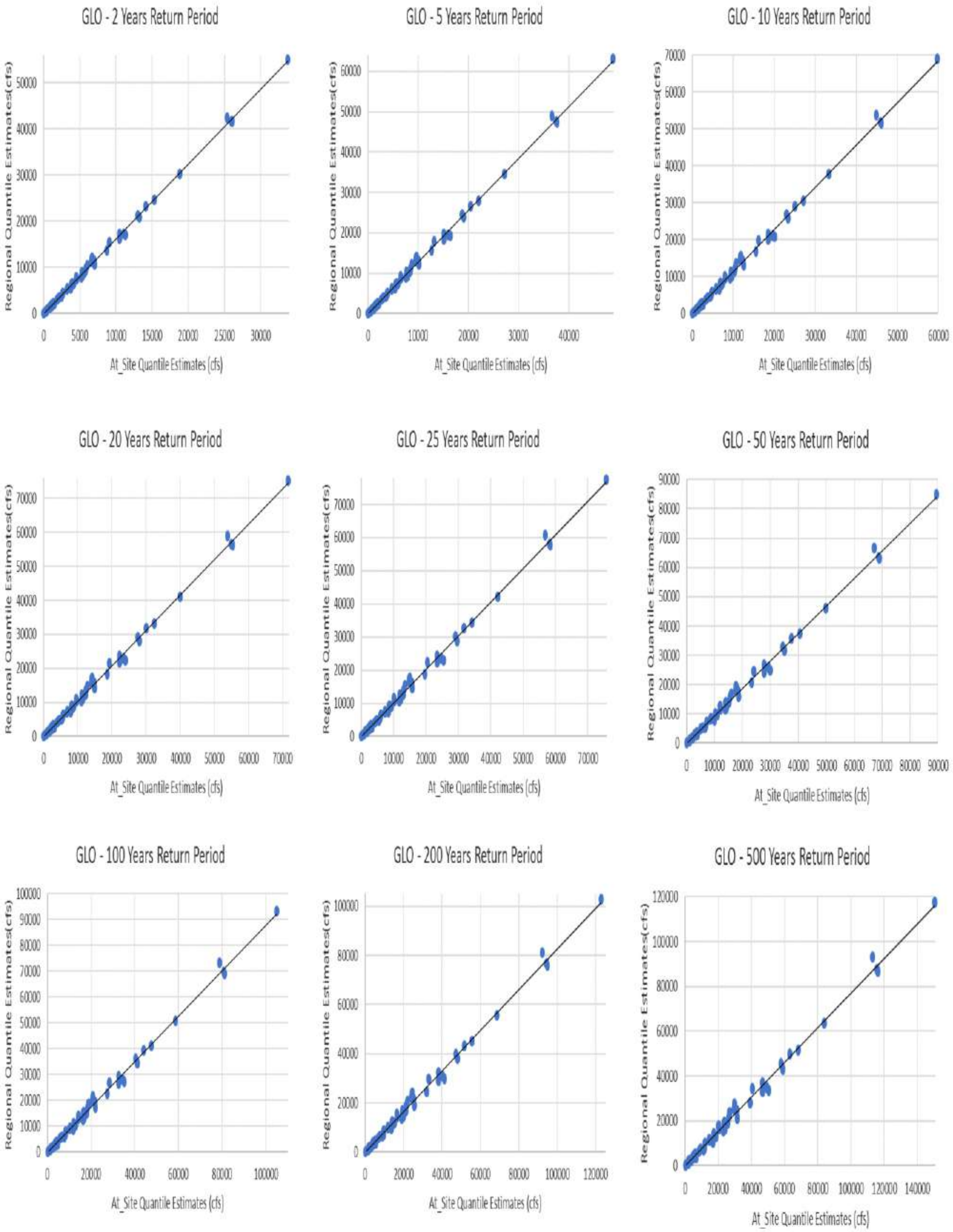

Fig. 6b. Results of the at site and the regional flood quantile estimates - GLO distribution

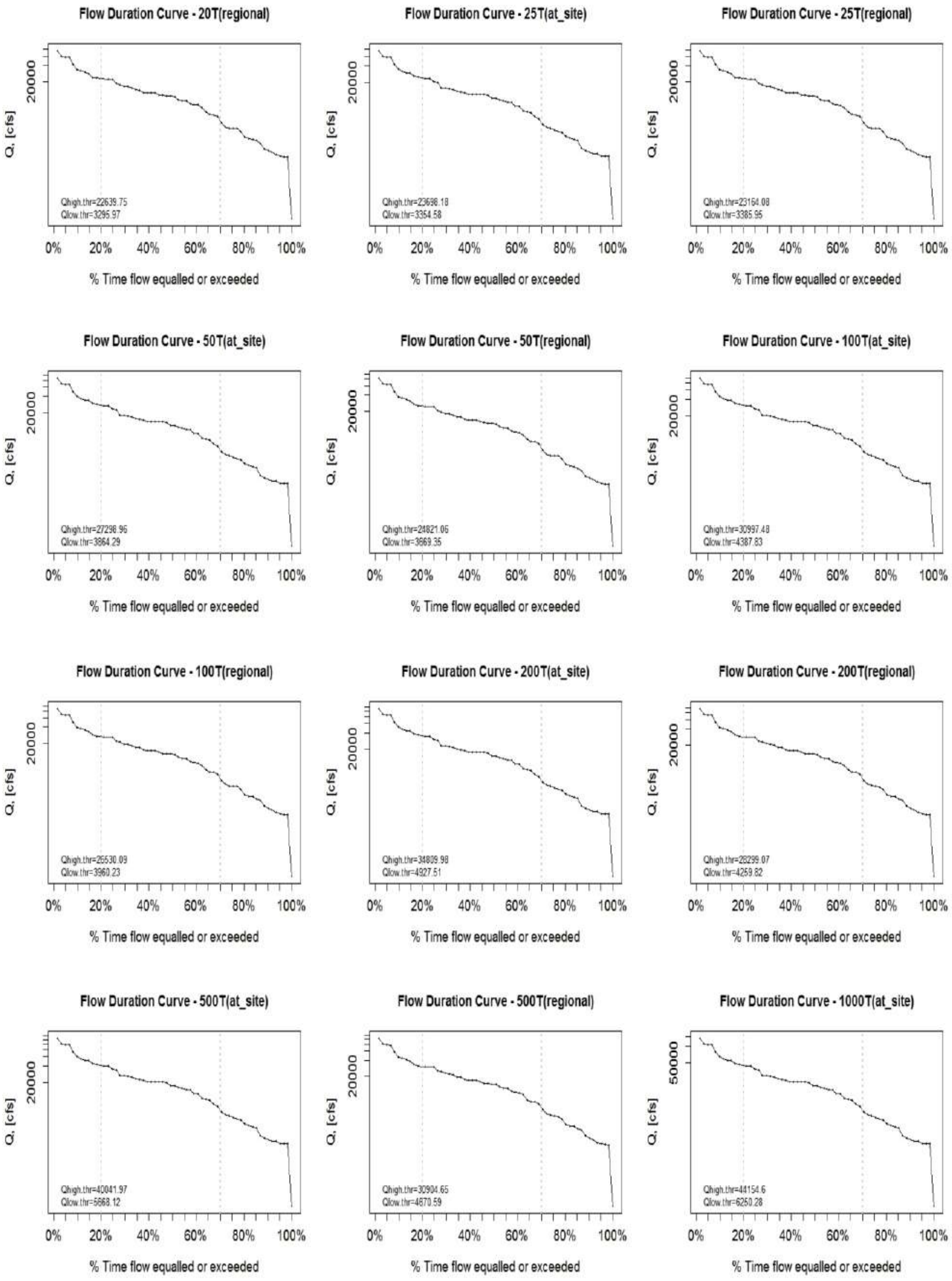

Fig. 7. FDC for at site and the regional flood quantile estimates

Table 4. Performance measures of the model

T Years	5	10	20	25	50	100	200	500	1000
NSE	0.87	0.97	0.9	0.98	0.98	0.98	0.96	0.93	0.91
D	0.97	0.98	0.97	0.98	0.98	0.98	0.98	0.98	0.97
R^2	0.91	0.91	0.93	0.93	0.94	0.96	0.96	0.92	0.92

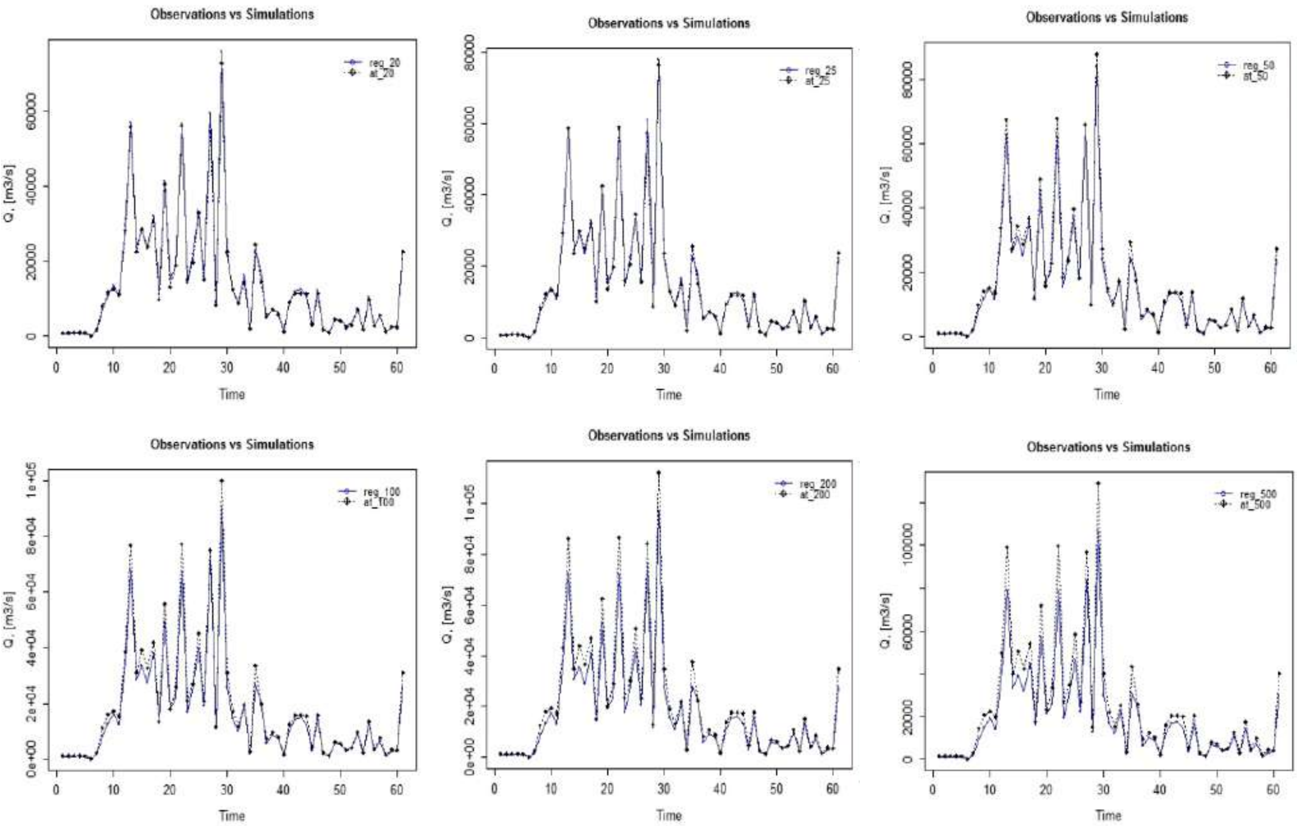

Fig. 8. Error Statistics for at site and the regional flood quantile estimates

to 1, which indicates that the model suits well for the analysis (Fig. 8, Table 4) .

CONCLUSIONS

Model-based clustering approach was extensively applied on 61 sites in Indiana watershed and has been classified into 2 homogeneous clusters. Site 1 was removed as it was discordant from the group. The Homogeneity test had revealed that both the clusters are homogeneous. GLO distribution has been identified as the best distribution for cluster 1 and GEV distribution has been chosen for cluster 2. The model-based clustering approach is more robust than the traditional partitioning and fuzzy clustering methods. Because determining the number of clusters at initial stage is not required and hence it is more general rather than the empirical methods. Larger data sets can be categorized in a less time which is not possible in partitioning methods. If the data set is very small then the model-based clustering approach is computationally expensive. Accurate estimates of at site and regional quantiles were generated whose performance was evaluated by the NSE, index of agreement d and R^2 measures whose values are closer to 1 indicating that the model is the best. Based on the results, model-based clustering approach proves to be the robust method in determining the homogeneous regions and hence can be applied in accurate estimation of flood quantiles, which is essential to prevent the flood-based disasters. Before constructing any structures like bridges, dams in a river, frequency of flood and the magnitude are determined in advance to avoid disasters and hence the results prove that the model-based clustering approach is more potent in categorizing the clusters and in the estimation of flood quantiles.

REFERENCES

Basu B and Srinivas VV 2016. Regional flood frequency analysis using entropy-based clustering approach. *Journal of Hydrologic Engineering* **21**(8): 1–10.

Burn Donald H 1990. An appraisal of the 'Region of Influence' approach to flood frequency analysis. *Hydrological Sciences Journal* **35**(2): 149–165.

Fraley C and A E Raftery 2002. Model-based clustering, discriminant analysis, and density estimation. *Journal of the American Statistical Association* **97**(458): 611–631.

Fraley Chris, Adrian E Raftery, T Brendan Murphy and Luca Scrucca 2012. *Mclust Version 4 for R: Normal Mixture Modeling for Model-Based Clustering, Classification, and Density Estimation.* Technical Report, Department of Statistics, University of Washington **597**: 1–57

Glatfelter DR 1984. *Techniques for Estimating Magnitude and Frequency of Floods on Streams in Indiana*. US Geological Survey, Water Resources Investigations Report: 84–4134

Gnanaprakkasam, Shiyamalagowri and Ganapathy Pattukandan Ganapathy 2019. Evaluation of regional flood quantiles at ungauged sites by employing nonlinearity-based clustering approaches. *Environmental Science and Pollution Research* (In press)

Ouarda Taha BMJ, Claude Girard George S Cavadias, and Bernard Bobée 2001. Regional Flood Frequency Estimation with Canonical Correlation Analysis. *Journal of Hydrology* **254**(1–4): 157–173.

Schwarz, Gideon 1978. Estimating the Dimension of a Model. *The Annals of Statistics* **6**(2): 461–464.

Srinivas VV 2009. Regionalization of watersheds using soft computing techniques. ISH *Journal of Hydraulic Engineering* **15**(sup1): 170–193.

Srinivas VV, Shivam Tripathi, Rao S Govindaraju and A Ramachandra Rao 2008. Regional flood frequency analysis by combining self-organizing feature map and fuzzy clustering. *Journal of Hydrology* **348**: 148–166.

Wazneh H and Chebana FD 2014. Delineation of homogeneous regions for regional frequency analysis using statistical depth function. *Journal of Hydrology* **521**: 232-244.

Yarrakula Kiran, Kumar KS and Samrat G 2016. Hydrodynamic modeling of krishna river for the assessment of flood affected areas using remote sensing and GIS. *Indian Journal of Ecology* **42**(1): 331–337.

Yeung K Y et al 2001. Model-based clustering and data transformations for gene expression data. *Bioinformatics* **17**(10): 977–987.

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Irrigation Water Quality Assessment using Principal Component Analysis of Hydrological Data from Parakai Lake, Tamil Nadu, India

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Abstract: The principal component analysis (PCA) applied in this study to define the parameters like EC, TDS, Na, SSP, SAR, RSC, Boron of shallow water quality data groups were obained from the Parakailake, Tamil Nadu, during north east monsoon and hot weather times. The water quality parameters were taken for two seasons from the four stations. The lake water was polluted by residential discharge and small scale industries located nearby the city and the villages. The PCA produced three significant main components such as correlation matrix generation, find out the correlation coefficient and extracted factors are rotated and also explained 89.37 per cent of the variance in high flow periods and 92.49 per cent of variance in low flow periods; therefore there are major water pollution threats in the lake due to urbanization. To improve the water quality, the PCA technique is used to support assessment changes in detecting the significances like the electrical conductivity had a loading effect of 0.983 is directly correlated to ions in the water and also comprised of inorganic salts.

Keywords: Data treatment, Principal components analysis, Statistical packages, Water quality parameters

The quality of lake water is a very complex problem and it is a great environmental concern worldwide. It is very dangerous for long-term economic development, environmental sustainability and social welfare. In recent years, there has been growth in awareness and alarm about water pollution across the globe. Thus new approaches towards achieving sustainable water resources management have been developed internationally. In view of this, Factor analysis was applied to the hydrochemical data in order to extract the principal factors responsible for the different hydrochemicalfacies. By using Kaiser normalization, the principal factors were extracted from the data. The analysis reveals six sources of solutes which correspond to six possible sources of groundwater pollution (Jozsef Kovacs 2012). During low-flow conditions, agricultural usages are strongly affecting the water quality. On the other hand, the main contamination source changed from agricultural uses to municipal land uses in high-flow periods (Hulya Boyacioglu 2006 and Ajay Kumar et al 2015). The present study focuses on the environmental and health risks associated with the use of sewage mixed waste water produced from Pazhayar system tank, the Parakailake for irrigation. The measured data are used to evaluate the various water suitability parameters for irrigation purposes.

MATERIAL AND METHODS

Study area: The study area is the Parakailake in the Kanyakumari district. The area is about 1,684 km^2 and occupies 1.295 percentage of total area of Tamil Nadu. The Kanyakumari is the district gets the maximum annual rainfall in the monsoons like southwest monsoon and the northeast monsoon. The southwest monsoon is from June to September and the northeast monsoon is from October to December. Its annual rainfall ranges from 14.5 mm to 382.2 mm and the temperature at this region in the period of October 2016 to May 2017 is maximum 33º.1'and minimum 23º.1'. Water quality parameter estimated from the lake and it is of system tank having the holding capacity of 2.351 m^3. The storage depth is 3.20 m and the bound length is 4000m. It has 2 inlets and 10 outlets, among the two inlets the first is from the Pazhayar river and the ten outlets are the point source for the surrounding agricultural fields and the major source of water for the lake is Pazhayar river. In the study area discharges originate from either domestic or industrial contaminators due to increasing rates of pollution originating mainly from human activities.

The water quality parameters are selected from four stations S1, S2, S3 and S4 might provide sufficient information for water quality assessment of surface water of Parakailake, Tamil Nadu (Table1, Fig.1).

Method: The climate of the region is typically Mediterranean divided in south west monsoon, north east monsoon, winter and hot weather. The hydrological conditions of the river during the north east monsoon and hot weather periods are somewhat not the same. Understanding the pollutants present in lake water and their sources different hydrological period must be considered. One is high flow period and another one is low flow period, so consider north east monsoon (high flow) period and hot weather (low flow). The assessment of water quality for high flow period and low flow period separately will help in determining the main concern to improve the water quality in two different hydrological periods. The methods which are used in the study is parameter analysis and principle component analysis.

Table 1. Water quality sampling stations along Parakailake

Sampling station	Geographic coordinate	
	Latitude	Longitude
S1	8° 16.28'	77°.44.99'
S2	8°14.62'	77°45.21'
S3	8°14.04'	77°45.39'
S4	8°14.58'	77°45.69'

Fig. 1. Location of the sampling stations on the Parakai Lake

Physicochemical parameters: The water quality parameters were estimated from four stations to provide sufficient information for water quality assessment of surface water of Parakailake, Tamil Nadu (Table 2).

The characteristics of selected parameters of surface water quality are electrical conductivity (EC),calcium (Ca), magnesium (Mg), sodium (Na), total dissolved solids (TDS),sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP), and boron (B).

Data analysis and Principal components analysis (PCA): The statistical package for the social sciences software-SPSS used for factor analysis of water quality parameters which included

- A correlation matrix is generated for all the variables.
- Founded on the correlation coefficients, variables are extracted from Principal components analysis (PCA)
- The extracted factors are rotated by Oblimin with Kaiser Normalization.

Factor analysis is an exploratory technique applied to a set of observed variables that seeks to find underlying factors from which the observed variables were generated by using Statistical Package for the Social Sciences Software-SPSS 10.0 for Windows. Factor analysis is carried out on the correlation matrix of the observed variables. A factor is a weighted average of the original variable. The factor analyst hopes to find a few factors from which the original correlation matrix may be generated. Usually the goal of factor analysis is to aid data interpretation. The factor analyst hopes to identify each factor as representing a specific theoretical factor. Once the correlation matrix and eigen values are obtained, the correlation between the variables and factors are measured by factor loading. Factor rotation is used to

Table 2. Water standard specifications given by Indian Standards 11624

Parameter	Permissible limits	Analytical method
Total salt concentration (μs cm^{-1})	129-405	Electrometric conductivity meter
Total Dissolved Solids (mg l^{-1})	195-520	Filtration and Gravimetric
Sodium (mg l^{-1})	14-72	Flame Photometer
Sodium soluble percentage (%)	44.1-72.7	By Calculation
Sodium absorption ratio (mg l^{-1})	3.75-17.23	By Calculation
Residual sodium ratio (mg l^{-1})	21.52-149.49	By calculation
Boron (mg l^{-1})	0-1.52	Annex H of IS 13428 4500- BB, APHA 22^{nd} Edition 2012

assist the interpretation by so long as a simpler factor structure.

RESULTS AND DISCUSSION

Assessment of water quality parameters in Low-flow period: By principal component analysis, the correlation matrix of variables was generated, factors extracted and rotated by Oblimin with Kaiser Normalization (Table 3).

The positive loading indicates that the contribution of the variables increases with the increasing loading in dimension and negative loading indicates a decrease. In general, component's loading larger than 0.6 may be taken into consideration in the interpretation, in other words, the most significant variables in the components represented by high loadings have been taken into consideration in evaluation the components (Jane Ndungu et al 2014). Three important component factors which explained 98.250 per cent of the variance in data groups (Table 4).

Factor 1: EC,TDS, Na+, SAR, SSP, RSC, Boron; Factor 2 and 3 : low scores factor EC, TDS, Na+, SSP, SAR, RSC, boron were correlated with factor 1 (F1) explained 92.493 per cent of the variance. Factor 2 (F2) and factor 3 (F3) were not correlated with EC, TDS, Na+, SAR, SSP, RSC, boron. The F1 had loading in EC, TDS, Na+, SAR, SSP, RSC, boron, which were 0.983, 0.973, 0.972, 0.978, 0.972, 0.976 and 0.871. Salts that are commonly found in drainage water include sulphates, chlorides, carbonates, and bicarbonates of calcium, and magnesium. Tail water also may contain these salts, but generally in much lower concentrations than drainage water (Jacobsen and Basinal, 2004). Based on the results of the factor analysis and typical sources of water pollutants, F1 factor with presence of TDS predominantly comprised of inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates), EC is directly correlated to ions in the water, which comes from dissolved salts and inorganic materials. The dissolved salts and inorganic materials are alkalis, chlorides, sulfides and carbonate compounds, which were discharged from residential and small scale industries. The high levels of Na+ in drinking-water may cause ill effects. The residual sodium carbonate (RSC) present in lake water is indicating the alkalinity danger in waste water. The Factor F2 and F3 has low scores of organic pollution factor were distributed in the lake. Negative factor loading (F2) of EC, TDS, Na, SSP and SAR explained the waste water treatment efficiency. Highest

Table 4. Factor loading matrix and total variance (low-flow conditions)

Variable	Component factor		
	1	2	3
EC	0.983	-0.020	-0.074
TDS	0.976	-0.137	0.093
Na^+	0.972	-0.102	-0.180
SSP	0.978	-0.065	0.120
SAR	0.972	-0.188	0.111
RSC	0.976	0.082	-0.129
Boron	0.871	0.482	0.067
Eigenvalue	6.475	0.309	0.094
Per cent total variance	92.49	4.41	1.35
Cumulative per cent	92.49	96.90	98.25

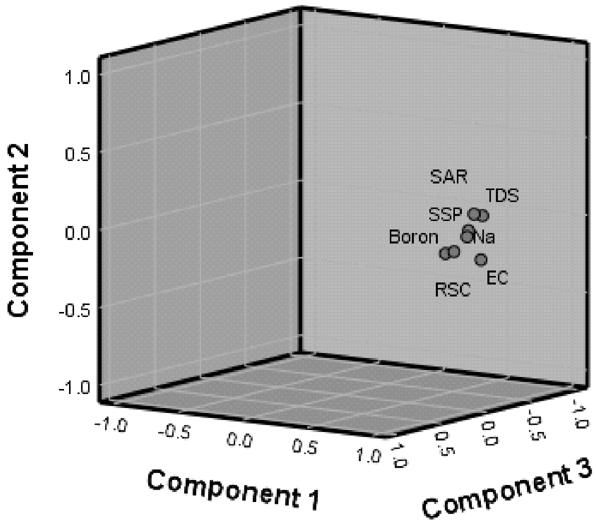

Fig. 2. The loading plot of factor scores in low-flow period

Table 3. Descriptive statistics of irrigation water quality parameters under low-flow conditions (Mean±SD)

Parameters	S1	S2	S3	S4
EC (μScm^{-1})	325.75±142.35	1052.50±235.00	615±93.81,507 -731	612±89.06, 514-725
TDS (mgl^{-1})	605±79.95	1098.25±142.01	815.25±137.84	810.5±156.36
Na (mgl^{-1})	33.25±4.27	100.25±23.02	63±16.41	65±14.69
SSP (mgl^{-1})	50.675±4.46	74.675±3.03	62.675±3.68, 12.36-18.59	62.83±3.85, 59.46-68.33
SAR (mgl^{-1})	9.35±2.07	20.06±3.95	15.087±2.69	15.13±3.21
RSC (mgl^{-1})	32.07±3.23	123.14±15.28	77.44±9.30	73.78±6.55
BORON (mgl^{-1})	0.06±0.04	1.73±0.17	0.89±0.10	0.06±0.04

Table 5. Descriptive statistics of irrigation water quality parameters under high-flow conditions (Mean± SD)

Parameters	S1	S2	S3	S4
EC (μScm^{-1})	168.5±40.38	362.25±114.70	262.25±62.33	256±58.53
TDS (mgl^{-1})	283.75±128.23	425.5±237.128	381±173.073	377±170.26
Na (mgl^{-1})	26.75±8.42 19	59±12.30 42	41.75±7.80 48	40.00±5.29 45
SSP (mgl^{-1})	49.93±3.53	66.475±1.62	58.325±1.66	58.19±2.01
SAR (mgl^{-1})	5.855±1.466	16.28±1.39,14.52	12.28±1.05, 11.26	12.175±1.14
RSC (mgl^{-1})	24.82±3.25	131.42±30.03	43.65±6.92	47.25±8.04
BORON (mgl^{-1})	0.0115±0.012	1.25±0.135,\	0.49±0.163, 0-	0.0115±0.0123

Table 6. Factor loading matrix and total variance explained (high-flow conditions)

Variable	Component factor		
	1	2	3
EC	0.908	0.400	0.127
TDS	0.990	-0.136	-0.033
Na^+	0.476	0.720	0.174
SSP	0.270	0.869	0.172
SAR	0.440	0.775	0.139
RSC	0.233	0.905	-0.355
Boron	0.437	0.799	-0.055
Eigenvalue	2.42	3.511	0.255
Total variance (%)	89.37	9.400	1.088
Cumulative (%)	89.37	98.77	99.86

and lowest values were detected. The region having no treatment plants increased the organic pollution risk. Therefore, during the low flow period water quality of the Parakailake was mainly controlled by the nearby residence, from municipalities and small scale industries. The loading plot of component factor scores is shown in Figure 2.

Assessment of water quality parameters in High-flow period: The high-flow period may have positive effects of *rainfall* events which *may* affect runoff water, increases pollutant concentrations, and thereby decreases quality in rivers *flowing.* Factor analysis was applied to data groups obtained from four monitoring stations between October 2016 to January 2017 to assess the water quality of the Parakai lake under high-flow conditions. Under high flow period descriptive statistics of the data group are presented in Table 5. Factor-loading matrix, eigenvalues and total and cumulative variance values are obtained from factor analysis given in Table 6. Three factors that are indicated below explained 99.86 per cent of total variance.

Considering distribution of factor scores and locations of the monitoring stations, it is concluded that: Factor 1: EC, TDS Factor 2: SSP, RSC Factor 3: Low scores factor

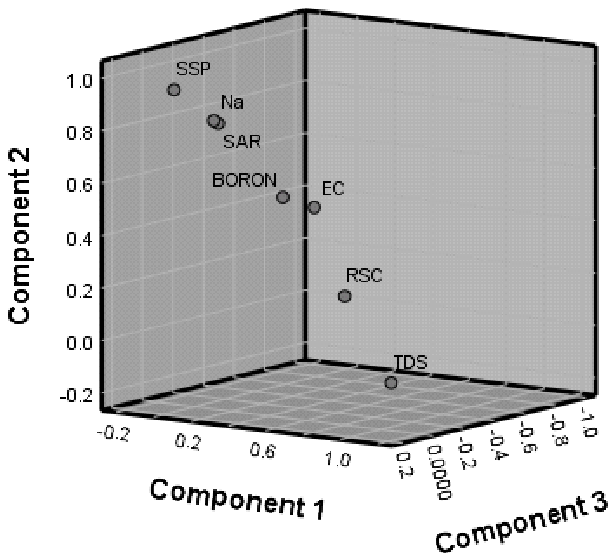

Fig. 3. The loading plot of factor scores in high-flow period

The F1 explains 89.37 per cent of variance in the presence of EC and TDS, assigned as the urban land use factor, which is strongly correlated with EC and TDS Factor loadings were 0.908 and 0.99.F2 is correlated with RSC present in lake water indicates the alkalinity danger in waste water, so F2 represents the 'inorganic pollution' factor. There was no correlated variables in F3 and was not marked. Hence, during the hot weather period discharges from nearby residence and from municipalities, small scale industries are mainly affects the water quality of the Parakai lake. The loading plot of component factor scores is shown in Figure 3.

CONCLUSION

The lake water quality was controlled by residential and small scale industries during the low-flow period and 92.49 per cent of total variance. It was 89.37 per cent of total variance under high flow conditions. The pollutants are mainly originated from residential and small scale industries and urban land use. So, the major pollutant source caused during the hot weather period. Therefore importance should be given to minimization of these sources to improve water quality in the Parakailake.

REFERENCES

Ajay Kumar, Charu Singh and Pragati Saini 2015. Seasonal variation in physico-chemical and microbiological analysis of sewage water in Gwalior city, India. *Indian Journal of Ecology* **42**(1): 279-281.

Aydin Uncumusaoglu A 2018. Statistical assessment of water quality parameters for pollution source identification in Bektaş Pond (Sinop, Turkey). *Global Nest* **20**(1): 151-160.

Dhundhel RS, Neda Davic, Natalija Matic and Dragan Radovic 2013. Assessment of ground water quality and source of contamination by multivariate factor analysis. *International Journal of Water Research* **1**(2): 43-46.

Eva Singovszka and Magdalena Balintova 2012. Application factor analysis for the evaluation surface water and sediment quality. *The Italian Association of Chemical Engineering* **26**: 183-188. DOI: 10.3303/CET1226031.

Hulya Boyacioglu 2006. Surface water quality assessment using factor analysis. *Water SA* **32**(3): 389-393.

Jane Ndungu, Denie CM Augustijn and Suzanne JMH Hulscher 2014. A multivariate analysis of water quality in Lake Naivasha, Kenya. *Marine and Freshwater Research* **66**(2): 177-186.

Joliffe IT and Morgan B 1992. Principal component analysis and exploratory factor analysis. *Statistical Methods in Medical Research* **1**(1): 69-95.

Josephine Njeri Ngure, Kihoro JM and Anthony Watitu 2015. Principal component and principal axis factoring of factors associated with high population in urban areas: A case study of Juja and Thika, Kenya. *American Journal of Theoretical and Applied Statistical* **4**(4): 258-263.

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Jozsef Kovacs, Peter Tanos, Janos Korponai, Ilona Kovacsne Szekely, Karoly Gondar, Katalin Gondar-Soregi and Istvan Gabor Hatvani 2012. Analysis of water quality data for scientists. *Water Quality Monitoring and Management* **3**: 65-94. DOI:10.5772/32173.

Olasehinde P, Amadi AN, Dan-Hassan MA, Jimoh MO and Okunlola I 2015. Statistical assessment of groundwater quality in Ogbomosho, Southwest Nigeria. *American Journal of Mining and Metallurgy* **3**(1): 21-28.

Pradeep T and Ananda Kumar S 2018. Geochemical studies on surface water quality in lower Noyyal sub-basin, Cauvery river, Tamil Nadu, India. *Indian Journal of Ecology* **45**(1): 140-145.

Ridhi Saluja and Garg JK 2015. Surface water quality assessment of Bhindawas lake (Haryana, India) using multivariate statistical techniques. *Journal of Global Ecology and Environment* **2**(1): 34-46.

Shadia AH Fathy, Fatma F Abdel Hamid and Mohamed A Shreadah 2012. Application of principal component analysis for developing water quality index for selected coastal areas of Alexandria Egypt. *Resources and Environment* **2**(6): 297-305.

Suleiman M, Tashtoush, Sameer A and Al-Subh 2015. Interpretation of groundwater quality parameters for springs in Tafileh area in South of Jordan using principal components analysis. *Environmental Sciences* **3**(1): 31-44.

Sangam Shrestha and Somphinith Muangtong 2014. Assessment of surface water quality of Songkhram river (Thailand) using environmetric techniques. *International Journal of River Basin Management* **12**(4): 341-356.

Volkan Yilmaz and Meral Buyukyildiz 2015. Factor analysis of surface water quality parameters for the Rivers of Turkey. *Fresenius Environmental Bulletin* **24**(1): 113-123.

Ying Ouyang 2005. Evaluation of river water quality monitoring stations by principal component analysis. *Water Research* **39**(12): 2621-2635.

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Spatial Variability Modeling of Field Infiltration Capacity

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Abstract: Infiltration from rainfall is a major abstraction loss in the hydrological cycle that influences runoff generation and groundwater recharge processes. Accurate characterizing of infiltration is required to develop improved hydrological models. In this study the infiltration models were compared to estimate the infiltration behavior of IIT Kharagpur campus and their spatial variability presented. Infiltration test was performed at 12 different experimental sites with double ring infiltrometer. The infiltration data were fitted four commonly used infiltration models: Kostiakov (1932), Horton (1940), Philip (1957). The model performances were evaluated using three statistical criteria: coefficient of determination (R^2), root mean square error (RMSE). The spatial variability of infiltration in the study area was analyzed by using the coefficient of variation (CV) of model parameters and steady-state infiltration rates. The Philip's model performs best in estimating the infiltration behavior at study area followed by Kostiakov and Horton. However, Horton model estimates steady-state infiltration rate accurately than other models at maximum number of the experimental sites. The large spatial variability of model parameters and steady-state infiltration rate indicates the soil heterogeneity and non-Darcian flow pattern of water infiltration at IIT Kharagpur campus.

Keywords: Infiltration, Infiltration models, Comparison of infiltration models, Spatial variability

Infiltration refers to the process of water penetration from the ground surface and take downward movement in soils and may be defined for rain or ponded conditions as "the rate at which a soil will absorb water ponded on the surface at a shallow depth when the pounded area is infinitely large or when adequate precautions are taken to minimize the effect of divergent flow at the borders (Islam et al 2017, Sihag et al 2017). The rate at which infiltration occurs in a soil profile is based on the amount of water available and movement within the soil. Soil water and physical properties such as porosity of soil media (macrospores, stones, fissures, cracks and root holes) and fluid media (viscosity and temperature), methods of measurement greatly effects on the infiltration rate (Hegui et al 2019). Determination of infiltration and evaluation of infiltration models is essential for scientists, researchers and engineerspredict infiltration with high precision because it represents the ability of the soil surface to accept continuous heavy rainfall or irrigation. Infiltration equations and models is waidely applied in designing irrigation, drainage and waste water systems, studying runoff characteristics and groundwater recharge, modelling of movement of water and pesticides from agricultural land to irrigation system design, hydrological runoff estimations, and groundwater replenishment (Das et al 2014, Sihag et al 2017, Islam et al 2019). The Green-Ampt, Holtan, Horton and Philip models were evaluated by using large plot field datafound that the Green-Ampt and Philip models predicted infiltration rates that were too low for times greater than the duration of the experimental test and the Holtan and Horton models predicted steady state infiltration rates accurately. The suitability of the Horton, Kostiakov and Philip models for infiltration data collected from a variety of mostly semi-arid rangeland plant communities from both Australia and the USA and the Horton model best fit the infiltrometer data, but only under certain conditions fourteen popular infiltration models were compared by using infiltration data collected from field and laboratory tests conducted in India and the USA on soils ranging from coarse sand to fine clayand all the models generally performed poorly in field tests on Georgia's sandy soils, except the Robertsdale loamy sand (Mishra et al 2003). Prediction of infiltration capacity were done in humid forest in southern Nigeria using ring infiltrometer and fit the infiltration data into the Philip and Kostiakov infiltration models in order to quantify the hydrological behavior of the soil and the ability of these models to predict infiltration into the Inceptisols of a humid forest and found that Philip's model was more suitable than Kostiakov's model (Oku and Aiyelari 2011, Wilson Rachel 2017). The constant infiltration rates of different soils (black cotton, clay and sandy soil) under different soil conditions (compacted, ploughed and harrowed) estimated and compared with Kostiakov, Modified Kostiakov, Horton's and Green-Ampt infiltration models and found that the Horton's model and Green-Ampt model were best fitting with observed field data to estimate infiltration with high degree of correlation coefficient and minimum degree of standard error (Dagadu and Nimbalkar 2012, Mao et al 2016). The above discussion shows that in studies on comparative evaluation different infiltration models have been considered using either laboratory experiments or field experiments and the results obtained have been mixed. Furthermore, it is not clear which model is better and under what conditions. The models perform differently when applied in the laboratory and in the field. The objective of this paper, therefore, was to evaluate three popular infiltration models and compare them for their performance on a different set of infiltration data collected from double ring infiltrometer at 12 different location.

MATERIAL AND METHODS

Experimental site: The infiltration tests were carried out in IIT Kharagpur campus, Kharagpur lies on 22°19'9.52" northern latitude and 87°18'35.85" eastern longitude with an area of 2100 acres. A total of 12 tests were made in different locationsat IIT Kharagpur campus map. The majority of the infiltration tests were made on lawns and grass-covered plots. The climate is humid subtropical with an average annual rainfall of around 1400 mm. About 80% of the total rainfall occur in the month of June to September. Winters are brief but chilly, lasting from December to mid-February (10° to 25°C) and summer (March to June) is hot (25° to 40° C) and sometimes humid in Kharagpur. Relative humidity of the atmosphere varies from 50 to 95 percent.

Field test: Infiltration tests were made by ponding water into a double ring infiltrometer. The inner cylinder, from which the infiltration measurements are taken, had a diameter of 300 mm while the outer cylinder 600 mm in diameter. The cylinders are installed about 10 cm deep in the soil. Care is taken to keep the installation depth of cylinders the same in all experiments. The cylinders are driven into the ground by a hammer striking on an iron plate placed on the top of the cylinder. Water was first added to the outer ring and water level in the inner ring was immediately measured by the field type point gauge attached to a float. The average depth of water maintained in the cylinder is 7 to 12 cm (Farid et al 2019). The water level was read at 1,2,3,5,10,15, 20 and 30 minute intervals until the steady state infiltration rate was reached. The steady state water infiltration rate was assumed to be reached when three consecutive similar water infiltration rates were observed. The time taken to reach steady state infiltration rate at all sites varied between 128 minutes and 228 minutes.

Infiltration models: Several equations have been derived in order to describe ponded infiltration. Three of the best-known expressions for water infiltration rate applied in engineering are those Kostiakov (1932), Horton (1940), Philip (1957). These three sets of infiltration equations were applied to the field-measured infiltration data.

Kostiakov equation: Kostiakov proposed a simple empirical infiltration equation based on curve fitting from field data. It relates cumulative infiltration to time as a power function.

$$F = at^{b}$$

The infiltration capacity could be expressed as:

$$f = (ab)\ t^{(b-1)} \qquad (2)$$

Where, F= Cumulative infiltration [L], f= infiltration capacity [LT^{-1}], t = time after infiltration starts [T], aand b are constants that depend on the soil and initial conditions [a>0 and 0<b<1].

The parameters, a and b must be evaluated from measured infiltration data, since they have no physical interpretation. It was proved mathematically that the Philip's transmissivity term and the Kostiakov's "a" represent similar soil physical properties. The "b" term in Kostiakov's model to be significantly correlated with any measured soil properties and concluded that "a" appears to be less influenced by physical properties than other parameters. The equation describes the measured infiltration curve and given the same soil and same initial water condition, allows prediction of an infiltration curve using the same constants developed for those conditions.

Philip equation: Philip developed an infinite-series solution to solve the non-linear partial differential Richards' equation. For cumulative infiltration the general form of the Philip infiltration model is expressed in powers of the square-root of time, t, as

$$F = St^{\frac{1}{2}} + K1t + K2t^{\frac{3}{2}} + \ldots \qquad (3)$$

Where, F = cumulative infiltration [L], S = sorptivity [$LT^{-1/2}$], Philip defined sorptivity (S) as the measurable physical quantity that expresses the capacity of a porous medium for capillary uptake and release of a liquid. The sorptivity is an integral property of the soil hydraulic diffusivity.

The time derivative of F is the infiltration rate, *f* [LT^{-1}] which is

$$f = \frac{1}{2}St^{\frac{1}{2}} + K1t + \frac{3}{2}K2t^{\frac{1}{2}} + \ldots \qquad (4)$$

For horizontal infiltration (no gravity driven flow), all terms are zero except for the first term on the right side of equations 3 and 4 and the equations apply to all times greater than zero. For vertical infiltration, equation 3 and 4 apply only for a short time when the matric-potential gradient is much greater than the gravity-potential gradient. All terms beyond the first two terms on the right-hand side of equations 3 and 4 are considered to be negligible .

Philip proposed that by truncating his series solution for infiltration from a ponded surface after the first two terms, a concise infiltration rate equation could be obtained which would be useful for small times. The resulting equation is,

$$f = \frac{S}{2} t^{\frac{1}{2}} + K \tag{5}$$

Where, F = infiltration rate [LT^{-1}], S = sorptivity [$LT^{-1/2}$], t = time after start of infiltration [T] and *K*= rate constant [LT^{-1}]. Using the expression for *f* as in Equation 5, plot the observed values of *f* against $t^{-0.5}$ in MS Excel. The best fitting straight line through the plotted points gives K as the intercepts and S/2 as the slope of the line.

Horton equation: Horton recognized that infiltration capacity (*f*) decreased with time until it approached a minimum constant rate (f_c) andattributed this decrease in infiltration primarily to factors operating at the soil surface rather than to flow processes within the soil. The infiltration rate was related to the rate of work performed and the change in infiltration capacity from *f* to f_c as the work remaining to be performed, with β as the proportionality factor. Horton (Bervin, 2004) derived his equation for infiltration, which describes a pattern of exponential decay of infiltration rate from this basic relationship.

$$\frac{-df}{dt} = \beta (f - f_c) \tag{6}$$

He divided both sides of equation 6 by (f-fc) and multiplied both sides by the yield

$$\frac{-df}{f - fc} = \beta\, dt \tag{7}$$

Next the integrated equation 7 to obtain

$$In\ (f\text{-}fc) = -\beta t + constant \tag{8}$$

when, t = 0, *f*= f_o, therefore constant must equal to ln (f_o-f_c). Therefore,

$$\frac{f - f_c}{f_o - f_c} = e^{-\beta t} \tag{9}$$

The final form of the Horton equation is obtained when both sides of equation 9 are multiplied by the denominator on the left hand side followed by addition of f_c to both sides.

$$f = f_c + (f_o - f_c)e^{-\beta t} \tag{10}$$

where, *f* = the infiltration capacity or potential infiltration rate [LT^{-1}], f_c = the final constant infiltration rate; [LT^{-1}], f_o = the infiltration capacity at t = 0 [LT^{-1}], β = soil parameter [T^{-1}] that controls the rate of decrease of infiltration and must depend on initial water content, θi [L^3L^{-3}] and application rate, R [LT^{-1}] and t = time after start of infiltration (T).

Determination of model parameters: Data from double ring infiltrometer experiments were used to generate data sets *f* and F values for various time t values (Table 1).

Evaluation of model performance: The values of the parameters estimated from fitting infiltration models to field observed infiltration data, were then incorporated into the respective models equation and the capability of each model to simulate infiltration rate for each points was evaluated by comparing the models simulated data with field-observed data. In order to evaluate the robustness of the applied models in reproducing the water infiltration process three statistical indicators such as coefficient of determination (R^2), Root Mean Square Error (RMSE) and Nash–Sutcliffe efficiency (NSE) were used.

Coefficient of Determination (R^2): Coefficient of determination (R^2) is the square of the Pearson's correlation coefficient (R) and describes the proportion of the total variance in the observed data that can be explained by the model. For example, a coefficient of determination (R^2) of 0.80 indicates that the model explains 80 per cent of the variability in the observed data. It is expressed as:

$$R^2 = \left[\frac{\sum_{i=1}^{n}[(h_{pi} - \overline{h_p})(h_{oi} - \overline{h_o})]}{\sqrt{\sum_{i=1}^{n}[(h_{pi} - \bar{h}_p)^2 (h_{oi} - \bar{h}_o)^2]}} \right]^2 \tag{11}$$

where, h_{pi} = ith number of model predicted value,

h_p = mean of model predicted value, h_{oi} = ith number of observed value and

h_o = mean of observed value, The values of R^2 range from 0 to 1, with higher values indicating better agreement between observed and predicted/simulated values.

Root Mean Square Error (RMSE): The root mean square error (RMSE) is defined as follows:

$$RMSE = \sqrt{\frac{i}{n}\sum_{i=1}^{n}(h_{oi} - h_{pi})^2} \tag{12}$$

where, *n* = total number of value, h_{oi} = i^{th} number of observed value and h_{pi} = i^{th} number of predicted value.

RMSE indicates the overall discrepancy between the observed values and the calculated (predicted or simulated) values. The lower the value of RMSE, is the more accurate the prediction/simulation. Models having higher R^2 value, lower RMSE and higher NSE were numerically ranked with lower numbers signifying a better performance. The ranks were later summed up to obtained the overall rank and performance for each infiltration model.

Spatial Variation of model parameters andsteady state infiltration rates: Soils are heterogeneous rather than homogeneous, simply because of variability in their formation process due to freezing, thawing, shrinking, swelling, and so on. Because soils are variable, the extent of variability in relation to mean of the specific parameter (model parameters and steady-state infiltration rate) obtained by coefficient of variation (CV):

$$cv = \left(\frac{\sigma}{m}\right) \times 100 \qquad (13)$$

Where, m = mean (average value of the parameter) and σ = standard deviation (range of the parameter).

Mathematically the mean and standard deviation is described as

$$m = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (14)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - m)^2}{(n-1)}} \qquad (15)$$

where, x_i = measured values of the parameter and n = sample number.

Parameters with high variability are likely to log-normally distributed (owing to soil heterogeneity) while those of low variability have a normal distribution (homogeneous soil). As a result most of the spatial variability within the experimental locations described statistically.

RESULTS AND DISCUSSION

The comparison of predicted infiltration rates of Kostiakov, Horton, Philip's infiltration model with observed infiltration rates at 12 experimental sites at IIT Kharagpur campus shows that the Kostiakov model under predict initial infiltration rate at all 12 experimental sites, whereas over predict the steady state infiltration rate at 7 sites and no sites found under predicted steady state infiltration rate. Horton model under predict the initial infiltration rate at all sites, whereas predicted similar steady state infiltration rate as observed in the field at all sites. Philip's model over predict initial infiltration rate at 8 sites, whereas over predict the steady state infiltration rate at 6 sites and under predict at 2 sites. The Phillp's and Kostiakov model estimate overall infiltration better than other models while Horton model gives similar steady-state infiltration rate as observed in field experiment sites and this is quite logical since the Horton equation uses observed steady-state infiltration rate values for prediction.

Horton's equation has advantages over the Kostiakov equation. First, at t equals 0, the infiltration capacity is not infinite but takes on the finite value f_o. Also, as t approaches infinity, the infiltration capacity approaches a nonzero constant minimum value of f_c. Horton's equation has been widely used because it generally provides a good fit to data. Although the Horton equation is empirical in that β, f_c and f_o must be calculated from experimental data, rather than measured in the laboratory, it does reflect the laws and basic equations of soil physics. However, the Horton equation is cumbersome in practice since it contains three constants that must be evaluated experimentally. A further limitation is that it is applicable only when rainfall intensity exceeds f_c. Horton's approach has also been criticized because he neglects the role of capillary potential gradients in the decline of infiltration capacity over time and attributes control almost entirely to surface conditions.

Models having higher R^2 value, lower RMSE and higher NSE were numerically ranked with lower numbers signifying a better performance (Table 3). The ranks were later summed up to obtained the overall rank and performance for each infiltration model (Table 4).

It is evident from the Philip model performed very well for predicting infiltration rate in IIT Kharagpur campus (Table 3). Based on the overall ranking, the models were ranked in the decreasing order of their performance as: Philip's model, Kostiakov model, and Horton model.

For different experimental locations in IIT Kharagpur campus, the values of the Kostiakov model parameter 'a' vary from 2.11 to 17.31(CV=64.87%) and 'b' from 0.40 to 0.69 (CV=15.33%) (Table 5). Horton model parameter 'f_o' vary from 31.34 cm h^{-1} to 7.59 cm h^{-1} (CV=46.79%), 'β' from 1.45 min^{-1} to 3.89 min^{-1} (CV=25.53%) and 'f_c' from 0.3 cm h^{-1} to 6.60 cm h^{-1} (CV=88.23%). The Philip model parameter 'S' varies from 4.47 cm to 13.21 cm (CV=34.11%) and 'A' from -2.93 to

Table 1. Infiltration models studied and parameters associated with each model

Model No.	Name	Parameters to estimate
1	Kostiakov (1932)	a, b
3	Horton (1939, 1940)	β fc , fo
4	Philip (1957)	S, A

Table 2. Estimated values of the model parameters

Sites	Kostiakov		Philip (1957)		Horton (1940)		
	a	b	S	A	β	*fC*	*fO*
R1	6.62	0.50	10.69	-2.62	3.06	2.00	17.83
R2	5.52	0.48	9.85	-2.93	2.80	1.20	16.04
R3	2.81	0.51	4.47	-1.30	3.07	0.60	7.80
R4	3.68	0.51	5.69	-1.19	3.56	0.90	11.55
R5	2.11	0.40	5.01	-2.34	3.85	0.30	7.59
R6	3.09	0.45	6.05	-2.10	3.15	0.48	9.94
R7	6.07	0.60	6.41	0.59	2.01	1.50	14.40
R8	17.32	0.69	13.21	5.27	1.45	6.60	31.34
R9	13.01	0.64	12.10	2.36	2.13	4.80	28.45
R10	3.75	0.48	6.98	-2.37	2.60	1.20	8.74
R24	7.47	0.60	8.41	0.11	2.81	2.40	19.43
R25	9.64	0.57	11.02	0.54	2.40	2.70	22.77

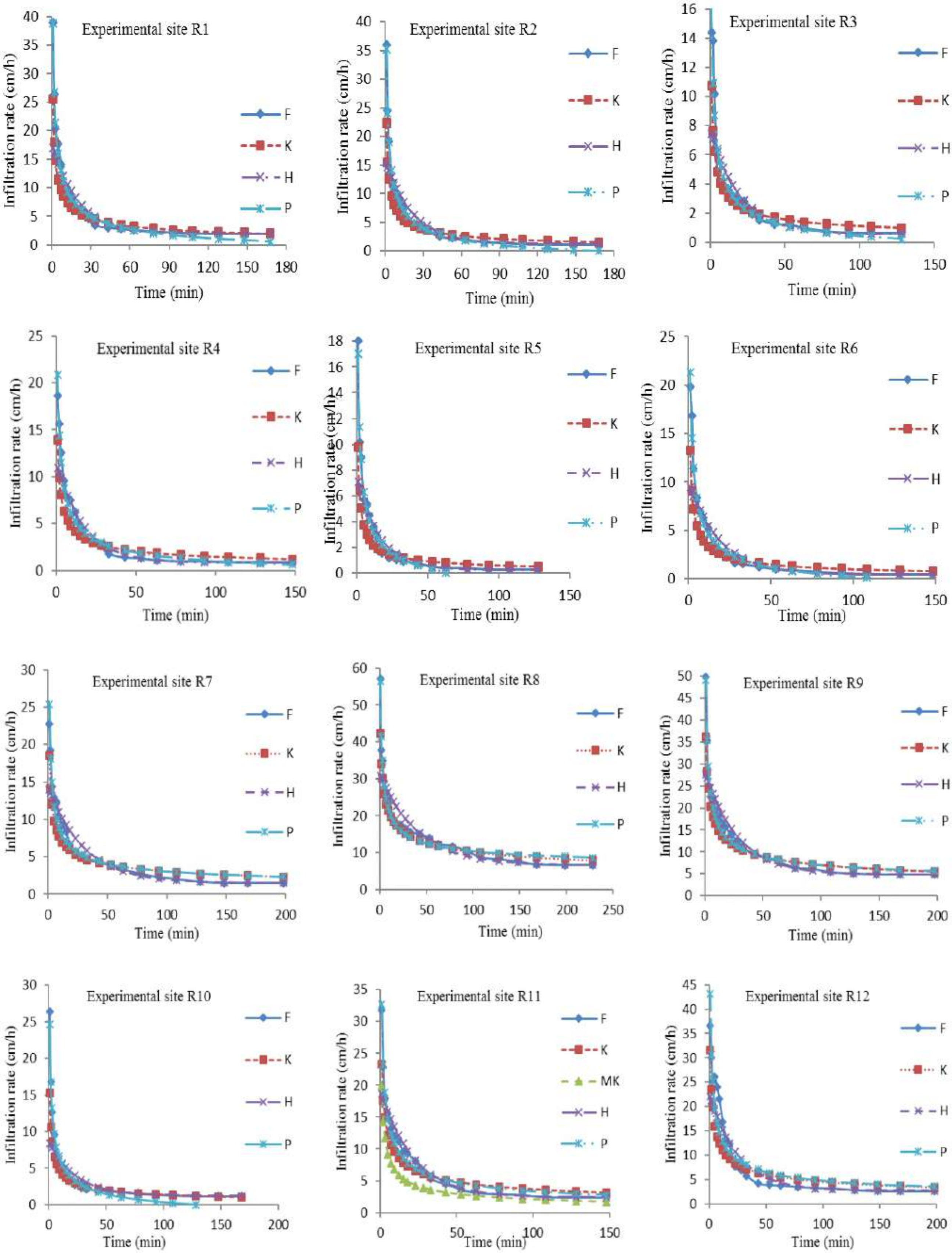

Fig. 1. Comparison of infiltration models at different experimental sites

Table 3. Model performance evaluation

Model Name	Statistical Indicators		
	Mean R^2	Mean RMSE	Mean NSE
Kostiakov	0.9490	3.1044	0.8140
Horton	0.7861	3.9330	0.7127
Philip	0.9712	1.1802	0.9711

Table 4. Ranks of infiltration models using results criteria

Criterion	Kostiakov	Horton	Philip
R^2	3	3	1
RMSE	2	3	1
NSE	2	3	1
Overall rank	2	3	1

Table 5. Statistical properties of model parameters

Model name	Parameter	Minimum	Maximum	Mean	CV (%)
Kostiakov	a	2.11	17.31	6.76	64.87
	b	0.40	0.69	0.54	15.33
Horton	β	1.45	3.85	2.74	23.53
	f_c	0.30	6.60	2.06	88.23
	f_o	7.59	31.34	16.32	46.79
Philip	S	4.47	13.21	8.32	34.11
	A	-2.93	5.27	-0.05	467.49

5.27 (CV=467.49%). Negative values of A were recorded at some experimental sites in Philip's model. This is not uncommon as had reported negative values of A. More so, the small values of a suggest that the second term in Philip's model could be neglected.

CONCLUSION

Five empirical, semi-empirical and approximate physically based infiltration models including Kostiakov (1932), Horton (1940), Philip (1957) were evaluated using three statistical criterion such as coefficient of determination (R2), root mean square error (RMSE) and Nash-Sutcliffe efficiency (NSE) The Philip's model perform best in estimating the infiltration behavior at study area and Kostiakov, Horton ranked 2nd, and 3rd respectively. However, Horton model estimates steady-state infiltration rate accurately than other models at maximum number of experimental sites. The high coefficient of variations of model parameters and steady state infiltration rates indicates spatial variability of infiltration mechanism in the study area due heterogeneity and complexity of soil hydraulics. Non-Darcian infiltration models and scaling of infiltration measurement are necessary to better representation of infiltrations in the study area. However, those limitations do not constraints the use of above infiltration models. Philip's and Kostiakov models can be used for estimation initial abstraction and Horton model for estimation of steady-state infiltrationin hydrologic modeling satisfactorily.

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REFERENCES

Bervin KJ 2004. Robert E. Horton's perceptual model of infiltration processes. *Hydrological Processes* **18**: 3447-3460.

Dagadu JS and Nimbalkar PT 2012. Infiltration studies of different soils under different soil conditions and comparison of infiltration models with field data. *International Journal of Advance Engineering Technology* **3**: 154-157.

Das P, Islam A, Dutta S, Dubey AK and Sarkar R 2014. Estimation of runoff curve numbers using a physically-based approach of preferential flow modelling. **In:** Hydrology in a Changing World: Environmental and Human Dimensions: Proceedings of the *FRIEND-Water 2014*; IAHS Publication: Wallingford, Germany **363**: 443–448.

Farid HU, Mahmood Khan Z, Ahmad I, Shakoor A, Anjum M N and Iqbal MM 2019. Estimation of infiltration models parameters and their comparison to simulate the onsite soil infiltration characteristics. *International Journal of Agriculture and Biology* **12**(3): 84–91.

Hegui H, Nabou M and Gliz M 2019. Spatio-temporal salinity and mapping of irrigated perimeter of Abadla Bechar, SW Algeria. *Indian Journal of Ecology* **46**(1): 7-12

Islam A, Mailapalli DR and Behera A 2017. Evaluation of saturated hydraulic conductivity methods for different land uses. *Indian Journal of Ecology* **44**(3): 456-466.

Islam A, Mailapalli DR and Behera A 2019. Comparison of Saturated Hydraulic Conductivity Methods for Sandy Loam Soil with Different Land Uses. **In:** Rathinasamy M., Chandramouli S, Phanindra K and Mahesh U (eds) *Water Resources and Environmental Engineering* 99-117.Springer, Singapore

Mao L, Lia Y, Hao W, Zhou X, Xu C and Lei T 2016. A new method to estimate soil water infiltration based on a modified Green–Ampt model. *Soil and Tillage Research* **161**: 31–37.

Mishra SK, Tyagi JV and Singh VP 2003. Comparison of infiltration models. *Hydrological Processes* **17**: 2629-2652.

Oku E and Aiyelari A 2011. Predictability of Philip and Kostiakov Models under Inceptisols in the Humid Forest Zone, Nigeria. *Kasetsart Journal (Natural Science)* **45**: 594-602.

Sihag P, Tiwari NK and Subodh R 2017. Estimation and inter-comparison of infiltration models. *Water Science* **31**: 34–43.

Wilson Rachel L 2017. *Comparing Infiltration Models to Estimate Infiltration Potential at Henry V Events.* Undergraduate Honors Thesis. Portland State University. 1825 SW Broadway, Portland, OR 97201, USA.

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Assessing Human Dependency on the Provisioning Ecosystem Services of *Chatla* Floodplain Wetland of Barak Valley, Assam, Northeast India

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Abstract: The present study was conducted in *Chatla*- a typical floodplain wetland of Barak valley, Assam, northeast India to investigate the various provisioning ecosystem services (PES) provided by the wetland from 2013 to 2015. The riparian communities were inevitably dependent on the different PES of the wetland viz., the supply of fish, paddy, soil, surface water, and NTFPs (thatch grass, fuelwood, fodder, and cane & common donax), availability of which varied across seasons. In spite of substantially less monthly income of the riparian communities, their survival has been possible because of the supplemental role played by the wetland through the generation of various PES. The study revealed the intrinsic value of *Chatla* for survival and sustainable livelihood of its riparian communities. For e.g., the primary PES of the wetland during the dry season comprises of provision to agriculture and culture fishery, and NTFPs like fuel wood, fodder, cane & common donax; whereas, during the wet season, the dominant PES of the wetland is the capture of fishery resources and NTFPs like fodder and thatch grass. Therefore, considering the intricate relationship of the wetland with the riparian communities, there is an urgent need for consideration of scientific and sustainable management strategies for *Chatla* and similar wetlands for ensuring continuous delivery of various PES.

Keywords: Floodplain wetland, Human dependency, Ecosystem services, Northeast India, Sustainable management

Globally wetlands are considered as the most productive natural ecosystems on the earth (Ghermandi et al 2008) and have long been recognized as providing a suite of benefits known as ecosystem services to the society (ten Brink et al 2012). Wetlands support millions of people, both living in their periphery (riparian communities) and residing far away, through its various goods (e.g., fishery products) and services (e.g., maintenance of habitats for diverse aquatic and terrestrial communities of human use). The Millennium Ecosystem Assessment (MEA 2005) has identified four broad categories of ecosystem services namely provisioning services (harvestable products or goods obtained from ecosystems), regulating services (benefits obtained from regulation of ecosystem processes), cultural services (non-material benefits derived from ecosystems) and supporting services (services necessary for the production of all other ecosystem services). However, unfortunately, wetlands globally have become the most sensitive ecosystems and are under serious threat due to increased anthropogenic pressures viz., urbanization, land use changes, conversion for agricultural use, infrastructure development, pollution from industrial effluent and agricultural runoff and climate change (Bassi et al 2014). Such threats have immediate negative socio-economic and severe ecological impacts viz., extinction of local biodiversity, reduction in food supply, and a decline in ecosystem's potential for continuous delivery of ecosystem services (Vuki et al 2000, Decleer et al 2016, IPBES 2018). According to MEA (2005), loss of wetland ecosystem services damages the health and well-being of individuals and local communities and diminishes their development prospect. Studies suggest that wetlands around the world, especially in developing countries have been lost or degraded due to elevated anthropogenic pressures, and weak- policy and management strategies without considering long-term conservation strategies (Bassi et al 2014, Lamsal et al 2015). The problem of grave concern is that significant portion of the human population (e.g., the rural and ethnic communities) is highly dependent on the wetland resources for maintaining their daily livelihood. Consequently, the loss of wetlands severely affects the well-being of the dependent communities (MEA 2005). Therefore, for sustainable livelihood of the resident communities maintenance of healthy wetlands is essential. During the last century, India has lost an estimated 50 per cent of its wetlands (Climate Himalaya 2011) which highlight the need for implementation of wetland conservation and management measures at the earliest.

The present study was conducted in *Chatla*, a floodplain wetland of Assam in northeast India. *Chatla* plays a significant role in sustaining the livelihood of the resident communities by providing various provisioning ecosystem services (PES). However, recently it has become a fast-degraded landscape due to its unsustainable utilization like the conversion for human settlement and agriculture, land grabbing for setting up brick kiln industry without adopting necessary measures for its conservation and restoration (Gupta 2009). Hence, for sustainable management of *Chatla* and similar wetlands, there is an urgent need for mass awareness on the role of such wetlands in maintaining the livelihood of the riparian communities through the delivery of various PES. Findings of the study would help enlighten the stakeholders and policymakers about the specific PES of such wetlands to adopt scientific and sustainable management strategies for these wetlands. This would enhance the resiliency of wetland ecosystems for perpetual delivery of various PES, and thus creating a 'win-win' situation.

MATERIAL AND METHODS

Study area: *Chatla* is a seasonal floodplain wetland located in Barak Valley of Cachar, Assam, in North-East India and is the catchment of Ghagra river, a tributary of River Barak. The total area of *Chatla* wetland is ca. 1750 ha covering around 52 villages. *Chatla* retains water for approximately six months and is almost dry during the winter.

Selection of villages for household survey and determination of sample size: The present study was conducted during the years 2013 to 2015 in 26 randomly selected riparian villages covering 50 per cent of the total villages of *Chatla* (Table 1). The sample size for the household survey was determined at a confidence interval of 95 per cent with a standard error of 5 per cent and sample fraction of 60 per cent using the equation as follows (adapted from Cochran 1977):

$$n = \frac{Z^2 \times \prod(1-\prod)}{[\text{S.E.(p)}]^2}$$

Where, n is the required sample size,

Z (i.e., 1.96) is the coefficient of 95 per cent confidence interval, $\prod$ is the proportion of the population, S.E (p) is the standard error of a proportion

To obtain the sample size of 368 households (as estimated through the above equation), 10-30 per cent of the total households were selected from each of the selected villages using the systematic random sampling method.

Information on the utilization of wetland PES: Literature surveys and extensive field visits were carried out initially to get an idea about the settlement patterns around *Chatla*. Data on socio-economic status and resource utilization patterns by the resident communities were gathered through a semi-structured questionnaire survey comprised of both fixed-response and open-ended questions, key informant interview, and direct observation methods (Haines-Young and Potschin 2009, Springate-Baginski et al 2009). Each questionnaire was divided into two parts: (1) General information on social conditions, i.e., community composition; household characteristics (gender, age and occupation); educational status of the household members (illiterate, primary school, middle school, high-, higher secondary, graduate, or post-graduate) and, (2) information on utilization of PES of *Chatla* in terms of both cultivated and harvested goods. For the interaction during household surveys, household heads were interviewed.

Assessment of the socio-economic status of the riparian people: The socio-economic status of the riparian communities settled in the surveyed villages in *Chatla* was assessed based on education of the respondents, his/her occupation and family income per month following Kuppuswamy's Socio-Economic Status Scale, 2014 (Gururaj 2014).

Assessing the extent of human dependency on the various PES of the wetland: To evaluate the degree of dependence on different PES of the wetland by the resident communities in an individual riparian village the following equation was used:

$$\text{Resource use frequency of an individual village (\%)} = \frac{\text{Number of households using a resource}}{\text{Total households surveyed in that village}}$$

RESULTS AND DISCUSSION

Socio-economic profile: The riparian villages of *Chatla* were inhabited by communities like *Kaivarta, Patni, Namasudra, Meitei, Adivasi, Deshwali* and other miscellaneous communities (Fig. 1A), amongst which *Kaivarta* was the dominant community followed by *Deshwali* (Fig. 1A). The primary occupations of the riparian communities comprised of paddy cultivation and fishing (culture and/or capture fisheries within the wetland) and wage labor (within as well as outside the wetland) (Fig. 1B) besides, a few were engaged in government jobs, pottery, craft making, and other small-scale business. The 49 per cent of the total population was educated up to primary level and 20% was illiterate or without any formal education (Fig. 1C). The 55 per cent of the resident households of *Chatla* belonged to 'upper lower class' followed by 'lower middle class' (35%) and 'upper middle class' (10%) (Figure 1D).

Dependency on the various PES of *Chatla*: The riparian communities of *Chatla* were dependent on the different PES of *Chatla* viz., the supply of fish, paddy, soil, surface water and NTFPs (thatch grass, fuelwood, fodder, and cane & common donax) (Fig. 2). Among these, provision of paddy cultivation and culture fishery during the dry season (December-April), and capture fishery during the wet season

(May-October) serve as the primary source of income generation for a significant section of the riparian population viz., the *Kaivartas*. Both paddy and fish were used for their consumption, and the surpluses were sold to the local market. Intervention by the riparian communities on the wetland for production of paddy and fish was mainly due to the terrain condition of the wetland which makes agriculture and fishing more congenial for their livelihood sustenance. Agriculture, particularly cultivation of *Boro* paddy (summer rice) was practiced in the low-lying areas of the wetland which remains saturated with nutrient-rich flood water during monsoon. These low-lying areas in the due course of time dry up and consequently increase the fertility of the wetland soil naturally and thus require no or minimum external input of nutrients for agricultural production (Das et al 2014). Besides, the practice of capture (during the wet season) and culture (during dry season) fishery in the wetland can be attributed to the fact that the wetland serves as a natural breeding ground for a diverse variety of fish during the flood which enter into the wetland through its inlet streams. The riparian people take advantage of this phenomenon by digging ponds and building dikes over small areas where fish along with the water get accumulated for a long time even after the recession of flood. Besides, flooding also rejuvenates the culture fishery system within the wetland by flushing in with oxygenated and nutrient-rich flood water into such a system. As a result, the metabolic residuals of stocked fish in such a system are washed out facilitating enhanced productivity of the culture fishery system naturally (Parven et al 2018).

The riparian communities utilize NTFPs and soil for their daily livelihoods sustenance. Various products viz., fishing gears, handicraft items, and different housing materials are prepared from NTFPs, which are generally used for their household needs, and sometimes the surpluses are sold to the local market for additional income generation. Thus, the products prepared from different wetland resources help the resident communities in maintaining their livelihood and socio-economic status. Besides, the riparian communities use the wetland soil for various purposes viz., housing material, making earthen stoves, and pottery items; whereas, mining of sand from the wetland is done for house construction and also for selling. The communities which are mostly involved in pottery making belong to *Deshwali* community, the second most dominant community of *Chatla*. The primary source of various NTFPs and soil within *Chatla* is

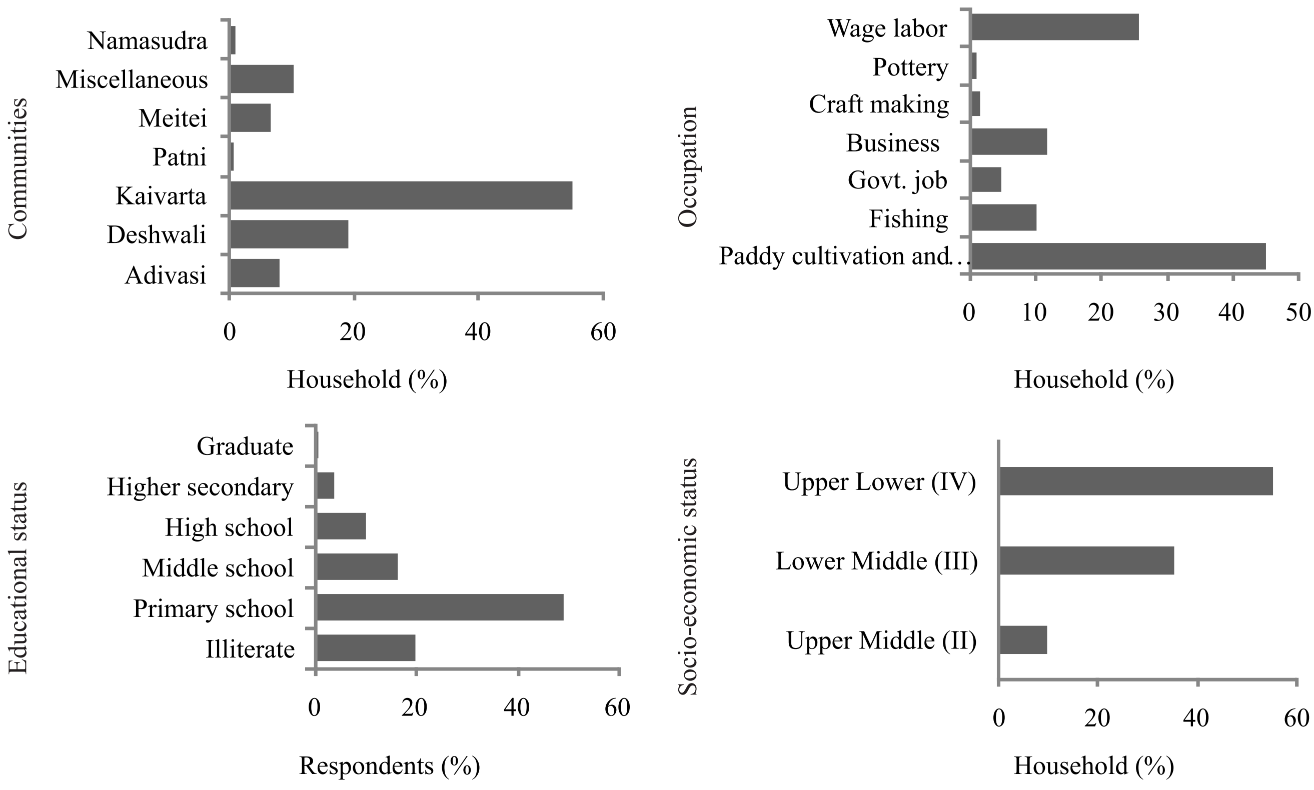

Fig. 1. Community composition (A), occupation (B), educational status (C), and socio-economic status (D) of riparian people settled in different villages of *Chatla*

Table 1. GPS locations of the surveyed villages on *Chatla*

Village name	Latitude	Longitude
Andharighat	24.7277	92.77368
Amtilla	24.72537	92.76163
Baghmara	24.7139	92.74418
Bairagitilla	24.72468	92.75328
Bangalitilla	24.71093	92.7595
Barsangon	24.73013	92.72172
Bariknagar	24.74923	92.7921
Bazartilla	24.69618	92.70852
Bowalmara	24.73558	92.76285
Choudhuripara	24.68003	92.73599
Dargakona	24.6992	92.75562
Harinagar	24.69975	92.73755
Harrintilla	24.72302	92.74747
Haltia	24.73822	92.72137
Kathaltilla	24.7032	92.71827
Madarintilla	24.69598	92.72029
Madhutilla	24.7564	92.77578
Mithapani	24.7069	92.7642
Puran Iringmara	24.69698	92.73492
Ratanpur	24.70857	92.72242
Rajpur	24.74913	92.74268
Roskandy	24.69309	92.71567
Sanyasitilla	24.73743	92.74293
Shantitilla	24.71138	92.76145
Shyampur	24.75422	92.7466
7 number, Silcoori camp	24.7206	92.7176

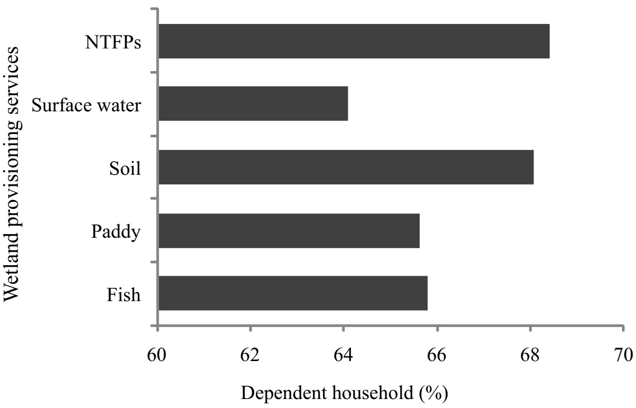

Fig. 2. Dependency (%) of riparian people settled in different villages of *Chatla* on its various provisioning ecosystem services

because of the distinct changes in the LULC of *Chatla* due to its seasonal inundation and subsequent drying. The annual flooding effect in the wetland is responsible for deposition of sand and silt in the wetland every year. Seasonal flooding also affected the availability of NTFPs, e.g., few fodder species and thatch grass are available during the wet season, while few fodder species, fuelwood, cane & common donax are available during the dry season.

Though the surface water of the wetland is being used for bathing, washing, fishery, and irrigation, its use as the potable water source is absent in all the riparian villages. For drinking purpose, the local communities are mostly depended on government (Department of Public Health Engineering, Government of Assam) sources/community wells/private wells, or sometimes small dug-wells near the wetland. Like any other wetlands, the groundwater source of the *Chatla* is being recharged naturally during every flood due to percolation of its surface water to the underground aquifer (MEA 2005) which becomes the source of potable water for the riparian communities. During every flood, the villages located on the small hillocks within the wetland become like small islands and during this season the villagers commute by country-peddled boats as well as motored boats (either personal or on the paid scheme). During monsoon, the waterways act as a source of economy for some of the residents when the wetland remained uncultivable due to flood.

Evaluation of the economic condition of the riparian communities during the study period revealed their average per capita monthly income to be INR 1,784 (ranged between INR 818-2,863) (Fig. 3), which is much below the monthly per capita net national income at market price during the sampling period {INR 6074, 7774 and 8 584 during 2014-15, 2015-16 and INR during 2016-17, source- http://pib.nic.in}. This reveals that in spite of substantially less monthly income survival of the riparian communities has been possible

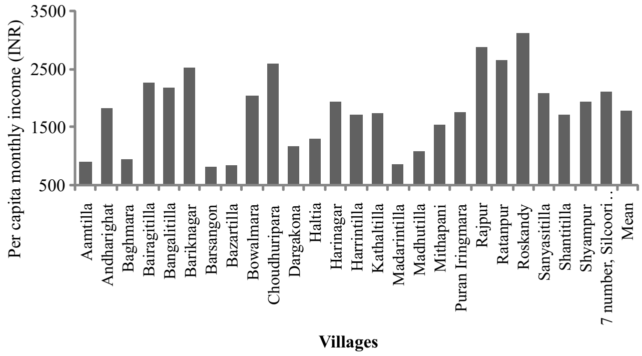

Fig. 3. Per capita monthly income of riparian people settled in different villages of *Chatla*

because of the supplemental role played by the wetland in terms of generation of various PES 'free of cost' or at minimal investments, by the resident communities.

CONCLUSION

The riparian communities are heavily dependent on the various PES of the wetland for maintaining their livelihood. During the dry season, the primary PES of the wetland comprises of the provision to agriculture and culture fishery, and NTFPs like fuel wood, fodder, cane & common donax. During the wet sesason, the dominant PES of the wetland is the capture of fishery resources and NTFPs like fodder and thatch grass. Therefore, looking into this intricate relationship of wetland with the riparian communities, we recommend that policymakers must consider the intrinsic values of wetlands while adopting sustainable management strategies for the perpetual flow of its various PES.

REFERENCES

Bassi N, Kumar MD, Sharma A and Pardha-Saradhi P 2014. Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. *Journal of Hydrology: Regional Studies* **2**(11): 1-19, doi:10.1016/j.ejrh.2014.07.001.

Climate Himalaya 2011. Wetlands at a loss in India.Available at http://chimalaya.org/2011/11/04/wetlands-at-a-loss-in-india/; assessed on 06/06/2019.

Cochran WG 1977. *Sampling techniques (3rd ed.).* John Wiley & Sons, New York.

Das T, Sarkar P and Prasad N 2014. Exploring the potential for concurrent rice-fish culture in wetlands of Assam, North East India. *International Research Journal of Biological Sciences* **3**:60-69.

Decleer K, Wouters J, Jacobs S, Staes J, Spanhove T, Meire P and van Diggelen R 2016. Mapping wetland loss and restoration potential in Flanders (Belgium) an ecosystem service perspective. *Ecology and Society* **21**(4): 46. https://doi.org/10.5751/ES-08964-210446.

Ghermandi A, van den Bergh JCJM, Brander LM and Nunes PALD 2008. The Economic Value of Wetland Conservation and Creation: A Meta-Analysis. [Working Paper 79]. Fondazione Eni Enrico Mattei, Milan, Italy. Available at: http://hdl.handle.net/10419/53239.

Gupta A 2009. Water availability, poverty and socio-economic crisis in the floodplains of Barak Valley, Assam, North East India. In, Eaux, Pauvreteet Crises Sociales Water, Poverty and Social Crisis (H. Ayeb, T. Ruf, Eds.) IRD Editions, Institut De Recherche Pour Le Development, Collection Colloqueset Seminaires, Marseille, France. pp. 221-230.

Gururaj M 2014. Kuppuswamy's socio-economic status scale – A revision of income parameter for 2014. *International Journal of Recent Trends in Science and Technology* **11**(1): 01-02.

Haines-Young RH and Potschin MB 2009. Methodologies for defining and assessing ecosystem services.Final Report, JNCC, Project Code C08-0170-0062, 69 pp.

IPBES 2018. Nature's Contributions to People. IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) consultation and capacity building workshop Bonn, Germany, 4-6 June 2018. Available at *https://www.ipbes.net, on, Accessed on 09.03.2019.*

Lamsal P, Pant KP, Kumar L and Atreya K 2015. Sustainable livelihoods through conservation of wetland resources: a case of economic benefits from Ghodaghodi Lake, western Nepal. *Ecology and Society* **20**(1): 10. doi: http://dx.doi.org/10.5751/ES-07172-200110.

Millennium Ecosystem Assessment [MEA] 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DC 155pp. Retrieved from https://www.millenniumassessment.org/documents/document.356.aspx.pdf.

Parven S, Sarkar P and Das T 2018. Do floodplain wetlands enhance the potential of fish ponds? Assessing supporting ecosystem service of Chatla wetland of Barak Valley, Assam, India. *Current Science* **114**: 2434-2436.

Springate-Baginski O, Allen D and Darwall W 2009. An Integrated Wetland Assessment Toolkit: A guide to good practice. Gland, Switzerland: IUCN and Cambridge, UK: IUCN Species Programme. xv+144p.

ten Brink P, Badura T, Farmer A and Russi D 2012. The Economics of Ecosystem and Biodiversity for Water and Wetlands: A Briefing Note. Institute for European Environmental Policy, London.

Vuki VC, ZannL P, Naqasima M and Vuki M 2000. The Fiji Islands. In: Sheppard, C. (Ed.), Seas at the Millennium: An environmental Evaluation. vol. II. Regional Chapters: The Indian Ocean to the Pacific. Elsevier, Amsterdam, pp. 751–764.

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Application of Synthetic Aperture Radar Imagery for Spatio-temporal Assessment of Flood in Nagavali River

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Abstract: In recent years, the frequency and magnitude of the flood extremely increased due to the effect of climate change. Nagavali River is one of the major flood contributing regions in Andhra Pradesh, India. Synthetic Aperture Radar (SAR) data from Sentinel-1 satellite has been used to perform the flood assessment in Nagavali River. SAR data has the capability to provide accurate, cost-effective, and rapid flood mapping. The preparation of the flood inundation map from SAR imagery involves two major processes such as image pre-processing and image classification. The image pre-processing includes radiometric calibration, speckle filtering, and geometric correction. The pre-processing carried out for raw data obtained from the Sentinel-1 satellite. The unsupervised image classification technique has been used to classify the inundated regions from SAR images. In the present research work, image analysis performed for before, after, and during the flood for the year 2018. Flooded regions have been estimated from the difference of permanent water body extent available from the open street map (OSM) with classified flood inundated region generated from the SAR image. The estimated inundated areas for before, during, and after flood are 89.5, 130.6, and 87.1 km^2, respectively.

***Keywords*:** Nagavali river, Flood inundation mapping, Unsupervised classification, SAR data, Open street map

Floods are one of the most recurring and frequent world natural disasters (Borah et al 2018). According to the CWC (Central Water Commission), one-fifth of deaths related to the flood take place in India (Sangomla 2018). Major socio-economic consequences associated with flood happening across the world (Schumann and Moller 2015). The floods in the year 2018 at Nagavali River caused severe damage to agricultural crops, power supply, and road network of Odisha and Andhra Pradesh (The Hans India 2018). The geospatial technology provides an integrated environment for analyzing remote sensing imagery and other datasets which supports effective monitoring, identification, and assessment of the flood disaster (Haq et al 2012). The presence of cloud cover during the monsoon season is the major constraint for the utilization of optical remote sensing image. The microwave satellite equipped with Synthetic Aperture Radar (SAR) provides a major platform for flood assessment because it has the advantage of penetrating through the cloud (Rahman and Thakur 2018, Sundaram and Yarrakula 2017). The flooded regions from the SAR data can be extracted either by using visual interpretation or by digital image processing technique. The digital image processing algorithm is capable of classifying the larger portion of the surface with minimum time duration. SAR data can be classified based on either unsupervised or supervised techniques. The suitability of the classification techniques depends on the availability of in situ data. The supervised classification produces higher classification accuracy than the unsupervised algorithm but it requires more ground truth information. In the absence of ground truth data, the unsupervised method more suitable for classifying the SAR data (Ince 2010). The present study focuses on flood assessment of the Nagavali River for the year 2018 with the application of SAR data using unsupervised classification approach.

MATERIAL AND METHODS

Description of the study area: The study area located northern part of Andhra Pradesh in the Indian peninsula. The area of the study covers 5,127 km^{2}and is situated between 18.32° N to 18.90° N latitudes and 83.14° E to 83.90° E longitudes. This covers10 taluks (Parvathipuram, Salur, Gajapathinagaram, Bobbili, Chipurupalle, Srikakulam, Palakonda, Pathapatnam, ParalakHemundi, and Koraput). The location of the study is sensitive to flood because of the influence of Nagavali River. Madduvalasa and Thotapalli are two major reservoirs constructed in the Nagavali River (Fig. 1).

Data description: The geospatial data used in this research are Sentinel-1 satellite image, SRTM data, and Open Street Map (OSM). Sentinel-1 satellite carries synthetic aperture radar, designed to provide C-Band imagery which mid frequency of 5.405 GHz. The satellite sensor of Sentinel-1 operated in dual polarization (HH+HV, VV+VH) (European

Space Agency). In the present study, VV and VH polarization data are used (Table 1). United State Geological Survey (USGS) provides SRTM elevation data of 30 m resolution, used for correcting the geometric distortion of the SAR image. Open Street Map (OSM) is the freely available map of the whole world. OSM represents physical features of the land surface and it helps to extract permanent water bodies of the study area (Fig. 2). Hydrologic information needed for the better understanding of flood event such as catchment precipitation, river discharge, and water level. The hydrological model is performed for the Nagavali Basin. The developed model calibrated for the year 2006 and calibrated model validated with the measured stream flow data of the years 2010 and 2013. Due to the unavailability of stage and discharge data for the year 2018, water level and stream flow data simulated from HEC-HMS based calibrated hydrological model using TRMM 3B42 RT satellite derived daily precipitation product (Azmat et al 2017). Figure 5 shows the simulated model for the year 2018 at srikakulam gauging station.

Data processing: The methodology of the present study involves data processing stages such as radiometric calibration, geometric correction, speckle filtering, and unsupervised image classification. Sentinel-1 data are not radiometric calibrated data by default. The radiometric calibration process converts radar reflectivity to backscatter. The calibration process reduces the complexity of SAR image comparison for different acquisition date (Miranda and Meodows 2015). Speckle noise is a regular phenomenon in all SAR imagery. The coherent returns from the numerous surface scatterers are the source of speckle noise in microwave data. Most commonly used speckle filters are the Lee, Median, Kuan, Frost, and Gamma filters. The Lee filter removes additive and multiplicative noise based on the use of local variance and local mean. In the present study, Lee filter is applied to enhance the experimental data. The presence of geometric distortion in the SAR image caused due to side looking nature of the antenna in the microwave sensors. The geometric distortion of the SAR data corrected using Range Doppler Terrain Correction (RDTC) method. RDTC performed the conversion of slant to the ground range with the support of SRTM elevation data (Bayanudin and Jatmiko 2016). Finally, at the end of data pre-processing, image classification is performed for rectified microwave data. Due to insufficient ground truth information in the site during the flood, K-mean clustering algorithm based unsupervised image classification technique used for this study. Clustering is a technique to split a set of data into a specific number of groups. K-mean clustering is one of the most desirable methods (Dhanachandra et al 2015). The pre-processing and classification techniques applied to the SAR images i.e., during the flood, pre-flood, and post-flood events. To estimate the areal extent of the flood, the classified inundation feature validated with permanent water bodies extent from the Open Street Map. Figure 3 shows the flow chart for the preparation of flood inundation map.

RESULTS AND DISCUSSION

Figure 4 shows the calibrated hydrograph of the hydrological model for the year 2010. The calibrated stream flow data validated with measured stream flow data using

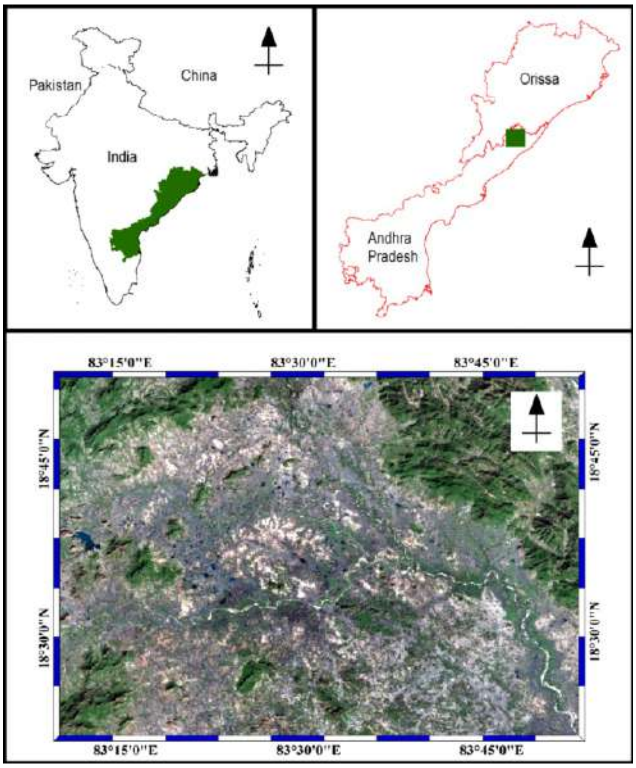

Fig. 1. Geographical setting of the study area

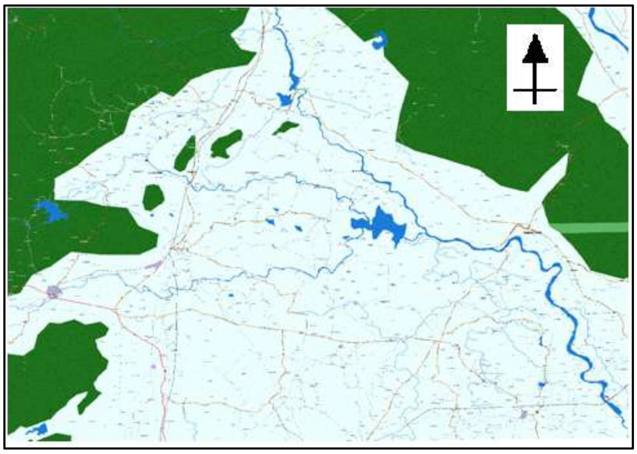

Fig. 2. Open street map of the study area

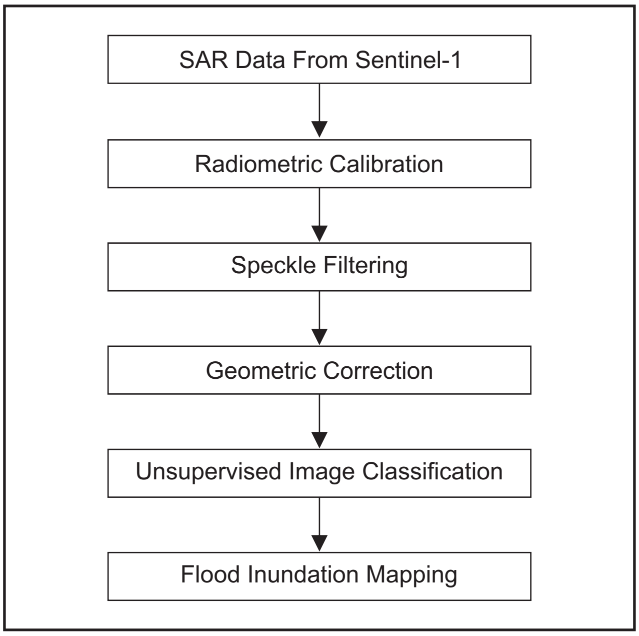

Fig. 3. Methodology for the preparation of flood inundation map

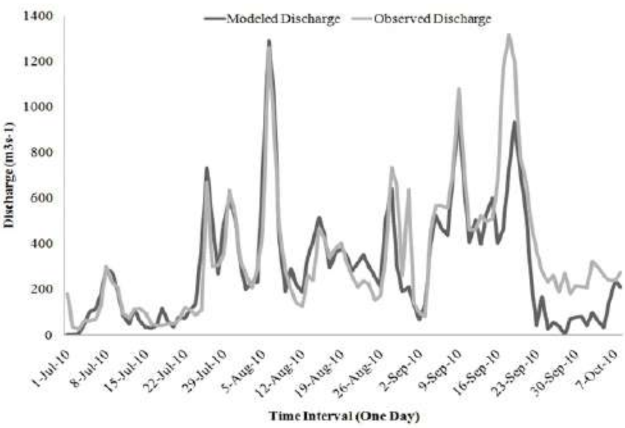

Fig. 4. Flood hydrograph computed from the hydrological model for the year 2010 at Srikakulam

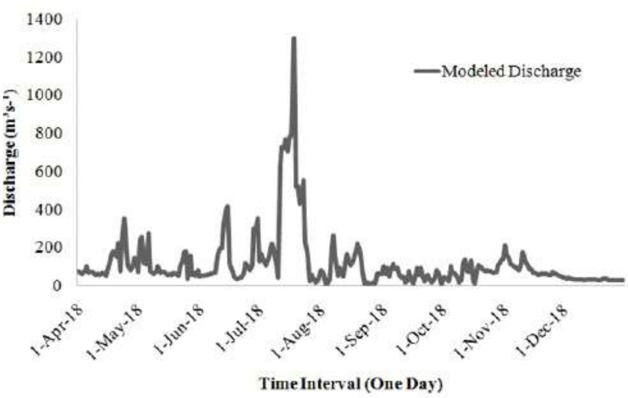

Fig. 5. Simulated discharge data for the year 2018 at Srikakulam

statistical indices. Nash Sutcliffe coefficient of efficiency and coefficient of determination for the calibrated model are 0.78 and 0.85. The statistical indices shows modelled and measured stream flow data has strong correlation and the coefficient of efficiency shows model has good predictive power. Figure 5 shows the simulated discharge data for the year 2018. In the year 2018 flood hydrograph, peak flow discharge happened on 18th July 2018 and the maximum mean precipitation of the catchment (14.54 mm) in the year 2018 also happened on same day. Hydro meteorological data for 2018 flood event estimated and simulated from the satellite precipitation data and hydrological model shown in Table 2.

Spatio-temporal flood assessment of the study area for the year 2018 performed using Sentinel-l satellite image with the image processing technique. The assessment performed for pre-flood (13th April 2018 and 25th April 2018), during the flood (18th July 2018), and post-flood (10th October2018 and 15th November2018). The inundation map extracted from the SAR image over the period of time (Fig. 6). The area of the flood-affected region is estimated by the difference of resultant inundation map and area of the permanent water bodies measured from the OSM data. The estimated area of the flood-affected region is shown in Figure 7. The inundated area of pre-flood is varies from 89.51 to 97.21 km^2, during the flood is 130.55 km^{2}and post-flood inundation is ranging from 87.10 to 97.59 km^2.

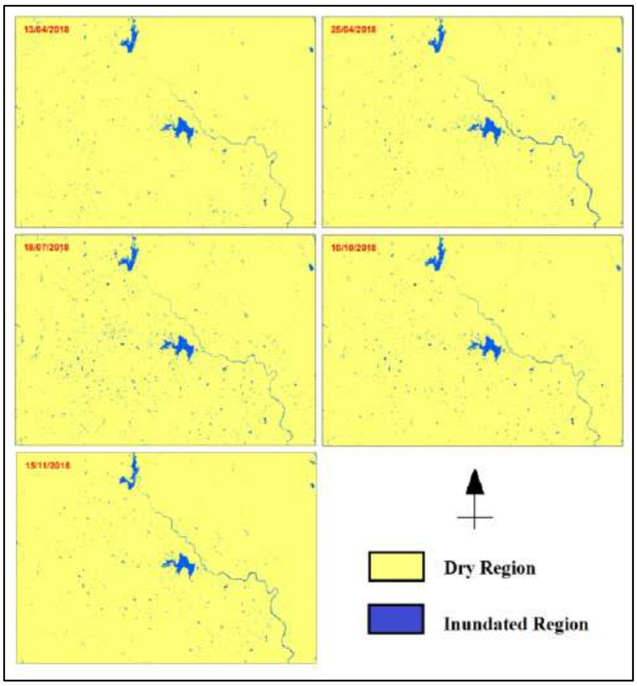

Fig. 6. Prepared flood inundation map from Sentinel-1 data

Table 1. Description of the Sentinel-1 data

Sensor	Band	Frequency (GHz)	Revisit period	Resolution (m)
Sentinel-1	C-Band	5.405	12 days	10

Table 2. Hydrological information for the corresponding inundation

Date	Mean catchment rainfall (mm)	Discharge (m^3/s)	Water level (m)	Inundated area (m^2)
13-04-2018	1.25	69	1.359	89.51
25-04-2018	4.99	355	2.261	97.21
18-07-2018	14.54	1298	3.975	130.55
10-10-2018	3.34	121	1.547	97.59
15-11-2018	1.407	31	1.215	87.10

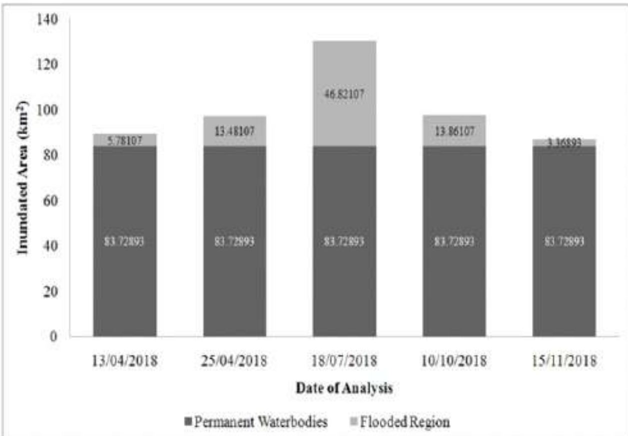

Fig. 7. Flood affected area of different time periods

CONCLUSION

The present study has discussed about the method for extracting the flood affected area using synthetic aperture radar image. In contrast to the classic optical remote sensor, active microwave sensor is capable of providing cloud free data during monsoon season and it also supports day and night operation. SAR data has some limitation for the applicability of the flood assessment. Sentinel 1A satellite can only provide SAR data for 12 days time interval period, sometimes it may not cover the peak discharge date of the flood events. Due to similarity of the backscattering values in road surfaces and water surfaces, classification miss match may happen.

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REFERENCES

Bayanudin AA and Jatmiko RH 2016. Orthorectification of Sentinel-1 SAR (Synthetic Aperture Radar) data in some parts of South-eastern Sulawesi using Sentinel-1 toolbox. *IOP Conference Series Earth and Environmental Science* **47:** 012007.

Borah SB, Sivasankar T, Ramya MNS and Raju PLN 2018. Flood inundation mapping and monitoring in Kaziranga National Park, Assam using Sentinel-1 SAR data. *Environmental Monitoringand Assessment* **190**: 520.

Dhanachandra N, Manglem K and Chanu YJ 2015. Image segmentation using K-means clustering algorithm and subtractive clustering algorithm. *Procedia Computer Science* **54**: 764-771.

European Space Agency. Sentinel Online [WWW Document]. URL https://sentinel.esa.int/web/sentinel/missions/sentinel-1/instrument-payload (accessed 12.14.18).

Gagnon L and Jouan A 1997. Speckle filtering of SAR images - A comparative study between complex-wavelet-based and standard filters, pp. 80–91. **In:** Aldroubi A, Laine AF and Unser MA (eds), *Wavelet Applications in Signal and Image Processing V*.

Haq M, Akhtar M, Muhammad S, Para S and Rahmatullah J 2012. Techniques of remote sensing and GIS for flood monitoring and damage assessment: A case study of Sindh province, Pakistan. *Egyptian Journal of Remote Sensing and Space Science* **15**: 135–141.

Ince T 2010. Unsupervised classification of polarimetric SAR image with dynamic clustering: An image processing approach. *Advances in Engineering Software* **41**: 636–646.

Lee JS 1981. Refined filtering of image noise using local statistics. *Computer Graphics Image Processing* **15**: 380–389.

Miranda N and Meodows PJ 2015. Radiometric Calibration of S-1 Level-1 Product Generated by the S-1 IPF. European Space Agency.

Rahman MR and Thakur PK 2018. Detecting, mapping and analysing of flood water propagation using synthetic aperture radar (SAR) satellite data and GIS: A case study from the Kendrapara District of Orissa State of India. *Egyptian Journal of Remote Sensing and Space Science***21**: S37–S41.

Sangomla A 2018. Floods Kill 511 People, Damage 55,000 Houses Across India [WWW Document]. Weather Co. URL https://weather.com/en-IN/india/monsoon/news/2018-07-17-floods-casualties-monsoon (accessed 12.12.18).

Schumann GJP and MollerDK 2015. Microwave remote sensing of flood inundation. *Physics and Chemistry of the Earth, Parts A/B/C* **83–84**: 84–95.

The Hans India 2018. Floods Damage Paddy Nurseries [WWW Document]. Hans India. URL https://www.thehansindia.com/posts/index/Andhra-Pradesh/2018-07-25/Floods-damage-paddy-nurseries/400776 (accessed 1.7.19).

Azmat M, Qamar MU, Ahmed S, Hussain E and Umair M 2017. Application of HEC-HMS for the event and continuous simulation in high-altitude scarcely-gauged catchment under changing climate. *European Water* **57**:77-84.

Sundaram S and Yarrakula K 2017. Multi-temporal analysis of Sentinel-1 SAR data for urban flood inundation mapping - Case study of Chennai Metropolitan City. *Indian Journal of Ecology* **44**: 564-568.

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Design, Development and Evaluation of Power Operated Drip Lateral Winder

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Abstract: The design, development and performance evaluation of the drip lateral winder was developed and tested. Raw materials like L-angular, flat channels, square pipe, solid rod, bush bearings, pulley and power source of suitable size were selected. The average actual capacity of the drip lateral winder was 148.96 m min^{-1} and the average actual time taken to win the lateral a length of 175 m was 1.17 min. The time taken by the motor operated drip lateral winder to wind a 12mm lateral of length 175 m in varied from 1.14 to 1.19 min, with average of 1.17 min. The time taken by the motor operated drip lateral winder to wind a 12 mm lateral of length 175 m varied from 1.46 to 1.52 min with average time of 1.49 min. The actual capacity of the machine varied from 115.4 to117.58 m/min. The time taken to win the lateral increases, the capacity of the machine decreases eventually. The actual capacity of the power operated drip lateral winder was 148.96 m min^{-1} while that of hand operated drip lateral winder was 117.58 m min^{-1}. The capacity of power operated drip lateral winder was higher than the hand operated drip lateral winder. As the rotational speed of power operated drip lateral winder is higher than the rotational speed of hand operated drip lateral winder.

Keywords: Drip lateral, Winder, Shelf life, Easy operation, Reduction in operation time, Winding

The drip irrigation technology was developed by Symcha Blass; an Israel Engineer early 1940's and later on it is spread to different parts of the world as the most efficient irrigation method especially in water scarcity areas for most of the field, plantation, orchard, vegetable and green house crops and in India, it was introduced in the early seventies. Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. The total area under drip irrigation in India is 64.7 million hectares and in Andhra Pradesh is 66.21 per cent. As the laterals are made up of P.V.C. pipes (16 mm) it is prone to damage, if not handled carefully, damages due to folding or twisting of tube during handling and to make the bundle suitable for proper storage. Farmers have been using manual type of lateral winder, which has various limitations like damage of pipes, timing consuming process, laborious and tedious process. Besides these constraints, the efficiency of manual coiling and de-coiling is very poor and improper coiling and de-coiling increased the damage to the laterals and reduces the life of the laterals. Therefore, the present study was carried out to developed and evaluates the performance of motor operated installer and retriever of the drip line.

MATERIAL AND METHODS

Theoretical considerations: Theoretical considerations such as available engine torque; design of shaft, selection of pulley and selection of beltare considered. The tests were conducted, following are theoretical considerations for design and the performance evaluation of drip lateral winder.

Selection of prime mover

Available engine torque

$$\text{Engine torque} = \frac{60 \times P}{2 \times \pi \times n} \quad .... (1)$$

(Khurmi and Gupta 2005)

Where, P= Power, Watt n =rotational speed of active element, rpm

Design of shaft: Shaft is designed on the basis of strength, rigidity and stiffness. Design of shaft on the basis of load carried which causes bending. When shaft subjected to twisting moment only, following is the equation for determining the shaft diameter.

$$T = \frac{\pi}{16} \tau d^3 \quad .... (2)$$

Where, T= torque, N-mm, τ = allowable shear stress, N/mm^2, d= diameter of shaft, mm

Shaft subjected to bending moment or torque only, the diameter of the shaft obtained by using following equation.

For uniformly distributed load

$$\text{Bending moment} = \frac{wl}{8} \quad .... (3)$$

$$M = \frac{\pi}{32} \times \sigma_{max} \times d^3 \quad .... (4)$$

Where, M = bending moment, N-mmσmax = bending stress induced due to bending moment, N/mm^2, d= diameter of shaft, mm

Shaft subjected to combined twisting moment and bending moment, the diameter of the shaft obtained by using following equations

Equivalent twisting moment

$$T_6 = \sqrt{M^2 + T^2}$$

$$\frac{\pi}{16}\tau d^3 = \sqrt{M^2 + T^2} \quad .... (5)$$

Where, T = torque N-m M = bending moment N-m

Equivalent Bending moment

$$M_6 = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\frac{\pi}{32} \times \sigma_{max} \times d^3 = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] \quad .... (6)$$

Where, T = torque N-m M = bending moment N-m

From equivalent twisting moment and equivalent bending moment, it should take larger value for shaft to withstand so the required diameter is found out...

Selection of pulley: Calculated the diameter of larger pulley by using velocity ratio

$$\text{Velocity ratio} = \frac{N_1}{N_2} = \frac{D_2}{D_1} \quad .... (7)$$

(Khurmi and Gupta 2005)

Where,N_1= speed of rotation of pulley on motor, rpm D_1= Diameter of motor pulley

N_2= required rotation of main pulley, rpm D_2= Diameter of main pulley

Selection of V-belt: V-belt was selected for transmitting motion and power from motor to pulley. Selection of V-belt is usually done on the basis of length of the belt. Length of V-belt can be calculated by using the following formula

$$= \pi\,(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \quad ...... \text{(In terms of pulley radii)}$$

$$= \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \quad \text{(In terms of pulley diameter)}$$

Where, r_1 = radius of smaller pulley ,r_2 = radius of larger pulley, d_1 = diameters of the smaller pulleyd_2 = diameters of the larger pulley, x = Distance between centres of smaller and larger pulley.

Actual capacity of winder (manual or power operated)

Actual capacity (m min^{-1}) = length of the lateral (m)/ time taken to wind (min).

The main functional parts of winder are motor, pulley and a frame. The motor is mounted on the frame at the bottom which is run by electric current. Pulley is used to reduce the rotational speed of the motor and it is attached to the main shaft placed behind the pulley. Bearings are used to support the load on front and rear side of the winder. A special arrangement is made to remove the bundle from the machine. Power is transmitted from motor to pulley and pulley rotates the main shaft which winds the lateral. A measuring tape of 30 m length having least count of 1 cm was used for measuring and marking the field. A digital stopwatch was used to take the time of operation of pushed type rotary tiller. Mechanical type tachometer was used for the measurement of engine speed rpm (Table1).

Description of different components of drip lateral winder

Frame: It is used for connecting all parts at alignment. Boxed frames were made by welding two matching L-angular together. Bearings are fitted at the end of the L-angular to support the main shaft.

Main pulley: A main pulley which is made of cast iron was used to reduce the rotational speed of the motor to the desired extent. The pulley has a diameter of 32 inches which

Table 1. Details of material used for development of winder

Particulars	Specification	Size
L- angular	2.54 cm x 3.81cm	27 feet
Square pipe	1.27 cm	10 feet
Round pipe	1.27 cm	8 feet
Machine shaft	2.54 cm	3 feet
Flat	2.54 cm	15 feet
MS sheet	14 gauge	4 feet X 15 inches
Bearings	2.54 cm	2 no's
Pulley	81.28 cm	1 no
Motor pulley	5.04 cm	1 no
V- belt	A 114	1 no
Electric motor	0.373 kW	1 no

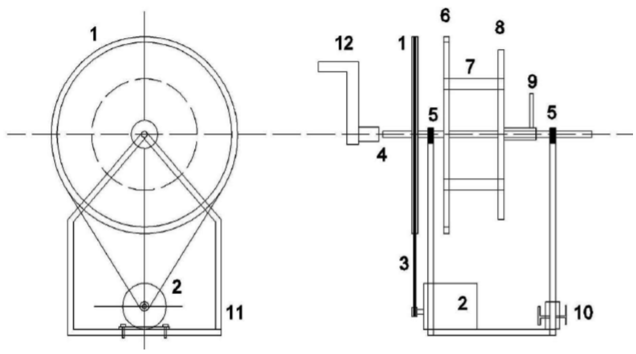

Fig. 1. Schematic diagram of drip lateral winder

consists a hole at the centre of 1inch diameter to fit the main shaft. Thickness of the pulley is 1 inch. There is slot throughout its thickness along its periphery to support a v-belt which transmits the power from motor to the pulley.

Motor pulley: A motor pulley which is made of cast iron is used to transmit the motion from the motor to the main shaft through a pulley fitted on it. The pulley has a diameter of 1.5 inches consisting of a hole of which consists a hole at the centre of 1inch diameter to fit the motor shaft. It consists of a double guard which holds the V-belt for transmission.

Shaft: Machine shaft with 25 mm diameter was used for connecting the pulley with the winding element. It is a mechanical component for transmitting torque and rotation. They are subject to torsion and shear stress, equivalent to the difference between the input torque and the load.

Electric motor: Electric motor of 0.5 hpis used for operating the winder. Motor is fitted on the frame at the bottom in front for convenience. Main purpose of motor is to provide the rotation to the main pulley through v-belt to rotate the main winding element which winds the laterals. The specifications of electric motor were shown in Table 2.

Bearings: Bearing were used to provide a constrained relative motion between two or more parts, typically rotation or linear movement. Bush type bearings were used for connecting the main pulley to the shaft at the frame. Size of bearings used was 1 inch.

Transmission system: Power is transmitted from motor to the main shaft and is reduced at the main pulley. Main pulley is connected to the shaft which rotates the winding element. Transmission system is shown below Figure.

Table 2. Specification of electric motor

Power	0.373kW (0.5 hp)
Speed	1440 rpm
Nature	Low speed

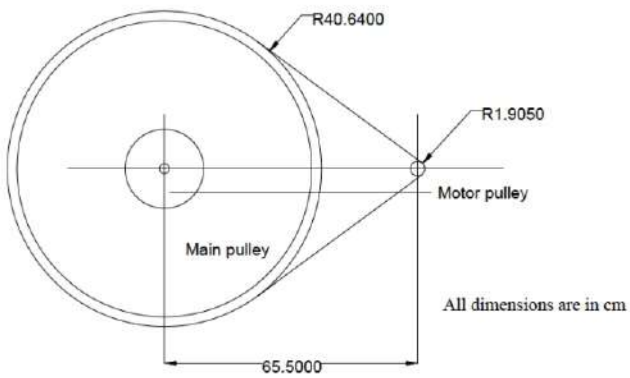

Fig. 2. Transmission system

Method for evaluation: Electric motor located at the bottom portion of the machine is connected to an AC power source. A lateral of length 175m was used and a Stop watch was used for calculating the time required for winding.

RESULTS AND DISCUSSION

Available engine torque: Engine torque was 2.474 Nm. This torque is not enough to operate the pushed type rotary tiller so, for increasing the torque we restricted the speed from 1440 to 90 rpm by using counter shaft (Gear ratio1:16). Then the sufficient torque of 39.6 N-m was obtained.

Design of shaft: Shafts subjected to twisting moment only, the diameter of the shaft obtained from equation (2),(τ, for cast iron =120 Mpa) (Factor of safety for cast iron =5) was 20.33 mm, taken 25 mm for safety. . For uniformly distributed load, bending moment was 192.652 Nm. For the given applied conditions the factor of safety for cast iron was 5 and shafts subjected to combined twisting moment and bending moment.

Shafts subjected to combined twisting moment and bending moment, the diameter of the shaft obtained by calculating, Equivalent twisting moment from equation (5) was obtained as 196.68 N-m. The diameter of the shaft = 34.7 mm (Approximately 35mm) Equivalent bending moment from equation (6) was obtained as 118.14 N-m. The diameter of the shaft was 30mm. but the diameter of the shaft was taken 40 mm.

Selection of main pulley: Speed of the motor is 1440 rpm to reduce it to the desired speed a pulley of larger diameter is selected. The desired speed of the winder is taken as 90 rpm was selected for sake of convenience. The diameter of the main pulley was 0.812 m.

Selection of belt: Selected engine power and speed was 0.373 kW and 1440 rpm respectively. The length of the belt was calculated by equation (8) as 2.88 m.

Fig. 3. Fabricated Drip Winder

Table 3. Performance evaluation of power operated drip lateral winder

S. No.	Time taken (min)	Actual capacity (m/min)
Trail I	1.18	147.55
Trail II	1.14	153.81
Trail III	1.19	147.31
Trail IV	1.19	146.71
Trail V	1.17	149.47
Average	1.17	148.968

Table 4. Performance evaluation of manual operated drip lateral winder

S. No.	Time taken (min)	Actual capacity (m/min)
Trail I	1.49	117.34
Trail II	1.46	119.99
Trail III	1.52	115.40
Average	1.49	117.58

Performance evaluation of power operated drip lateral winder: The average actual capacity of the drip lateral winder was 148.96 m min^{-1} and the average actual time taken to win the lateral a length of 175 m was 1.17 min (Table 3). The time taken by the motor operated drip lateral winder to wind a 12 mm lateral of length 175 m in varied from 1.14 to 1.19 min, with average of 1.17 min.

Performance evaluation of manual operated drip lateral winder: The average actual capacity of the drip lateral winder was 117.58 m min^{-1} and the average actual time taken to wind a lateral of length 175m was 1.49 min (Table 4).

The time taken by the motor operated drip lateral winder to wind a 12 mm lateral of length 175 m varied from 1.46 to 1.52 min with average time of 1.49 min. The actual capacity of the machine varied from 115.4 to117.58 m min^{-1} the time taken to wind the lateral increases, the capacity of the machine decreases. The actual capacity of the power operated drip lateral winder was 148.96 m min^{-1} while that of hand operated drip lateral winder was 117.58 m/min. The capacity of power operated drip lateral winder was higher than the hand operated drip lateral winder. As the rotational speed of power operated drip lateral winder is higher than the rotational speed of hand operated drip lateral winder.

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CONCLUSIONS

Drip Lateral Winder mainly consists of motor, pulley and a frame. Main shaft and the main pulley derive their rotational power from the prime mover which is 0.5 hp electric motor. The actual capacity of the motor and manual operated drip lateral winder was 148.968 and117.58 m min^{-1}.

REFERENCES

Andrady AL, Hamid SH, Hu X and Torikai A 1998. Effects of increased solar ultraviolet radiation on materials. *Journal of Photochemistry and Photobiology B: Biology* **46**(1): 96-103.

Gupta CP and Visvanathan R 1993. Power requirement of a rotary tiller in saturated soil. *American Society of Agricultural Engineers* **36**(4): 1009-1012.

Harby M and Hans-Heinrich T 2013. On-farm evaluation of low-pressure drip irrigation system for smallholders. *Soil and Water Resources* **8**(2): 87–95.

Khurmi RS and Gupta JK 2012. Theory of machines, *S. Chand publishers New Delhi* 325-381.

Khope PB and Modak JP 2013. Design of experimentation for establishing empirical relationship of chaff cutting phenomenon energized by human powered flywheel motor (HPFM). *Journal of Agricultural Advances* **2**(5): 158-164.

Michel AM 2008. *Irrigation Theory and Practice. Vikas Publishing Pvt Ltd, New Delhi* 611-660.

Mohamed T, David L and Hani M 2012. Effects of drip irrigation circuit design and lateral line lengths: I On pressure and friction loss. *Journal of Agricultural Sciences* **3**(3): 392-399.

Najat JS and Zanaib YS 2009. A study the effect of UV Light on pigmented and unpigmented LDPE. *Engenning and Technology Journal* **27**(24):1-7.

Roy PK, Surekha P, Rajagopal C and Choudhary V 2007. Thermal degradation studies of LDPE containing cobalt stearate as pro-oxidant. *Express Polymer Letters* **1**(4): 208-216.

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Changes in Physical Properties and Content of Total Organic Carbon in Postagrogenic Soils

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Abstract: A field trial was carried out concerning the transfer of arable land of the botanic garden of the Southern Federal University (Rostov-on-Don, Russia) into the category of fallow lands with comparative study of soil quality using biological diagnostics method. During the first year of fallow period, the fast growing high grasses such as *Ambrosia artemisiifolia, Artemisia vulgaris, Cyclachaena xanthiifolia, Chenopodium album* were dominant. Total phytomass in the fallow land was 0.76 kg m^{-2}. It was found that physical properties of postagrogenic soils changed due to the emergence and development of grassland vegetation in the first years of fallow period. During the first year, density, temperature and moisture of arable layer changed. In the second year of fallow period, a reliable change in hardness was recorded. In the third year of fallow period, trophic activity of soil mesofauna increased by 17 per cent and CO_2 emissions increased by 18 per cent as compared with arable area. It is noted that there is a straight-line correlation between trophic activity and CO_2 emissions and the time of the study, i.e. biological parameters slowdown in times of drought. In the very first year of fallow period, a reliable difference was determined between total organic carbon in postagrogenic and arable land. During three years of the study, the content of total organic carbon in fallow land did not change significantly. The behavior of increase in the content of active carbon was studied in the third year of fallow period. In the period of active vegetation, the level of this indicator in the areas under study was 4.5–5 times higher than in times of drought. In the arable layer of young fallow land, the content of active carbon was 2.5 times higher than in arable land; however, it was 1.5 times lower as compared with 72-year-old fallow land. Thus, physical and biological properties of postagrogenic chernozems tend to positive change due to the discontinuation of regular cultivation of soil and plants growth already in the first years of fallow period.

Keywords: Organic carbon, Active carbon, Soil quality, Successions, Soil density, Fallow soils, Biological activity

As a result of intense anthropogenic activities, large territories of steppe regions have been changed, thus leading to the destruction of unique vegetation, decline of fauna and changes in topsoil. More than 34 per cent of arable lands in the world are subject to degradation to a greater or lesser extent (Kudeyarov 2019). The total area of unused agricultural land in Russia is 97.2 m ha (44% of all agricultural lands of the country). Maintaining chernozem in black fallow condition leads to significant loss of organic matter and degradation of physical properties of soils (Kogut et al 2019). Physical properties of soil under anthropogenic load are important factors, which determine soil fertility (Marcotullio et al 2008, Gorbov et al 2016). In today's world, the issues related to the recovery of biological properties of chernozem and fertility of fallow soils in various stages of successions are of great relevance. In this regard, it becomes necessary to study the characteristics of postagrogenic soils in the early years of fallow period.

Land fallowed leads to the regeneration of arable soils. Under grassland vegetation, transformation of the former arable layers is based on the sod-forming process (Rusanov et al 2019), density decreases and water permeability increases (Gorbov et al 2016), increase of organic matter content and enzyme activity (Rao et al 2014, Xiao et al 2018, Kogut et al 2019), number of microorganisms increases. Land reclamation is followed by the increase in the content of organic matter (Shchur et al 2016, Kogut et al 2019) resulting in the increased production of enzymes by microorganisms (Acosta-Martinez et al 2000). Labile organic matter is involved in nutrient cycle and determines effective soil fertility (Culman et al 2012, Myasnikova et al 2014), since it carries the major stock of nitrogen and phosphorus necessary for plants nutrition. Compounds of this group of soil organic matter are also referred to as mobile, easily decomposable, active, oxidizable organic matter being indicative of its various properties and functions. Mobile organic matter has high reactivity; it is exposed to plants and microorganisms and is very sensitive to oxidation and decomposition (Wang 2015). The hydrothermal process of soil is an important factor of its fertility, which determines the development of various processes. Soil temperature along with moisture affects extensively the major soil-forming processes, accumulation of biomass and biological productivity (Khan et al 1980, Myasnikova et al 2014).

The problem of soil degradation is still relevant and quite common in terrestrial ecosystems subject to anthropogenic load. The objective of the studies was to study the changes in physical properties and content of total organic carbon in postagrogenic soils Rostov region. The importance of this study is to study of arable ordinary chernozems in the first years of postagrogenic conditions in the steppe region in the south of Russia. The changes density, temperature and moisture of arable layer and trophic activity of soil mesofauna were determined.

MATERIAL AND METHODS

The territory under study has a favorable moderate continental climate. Average annual precipitation is 424 mm, primarily on the atmospheric fronts of cyclones. Average temperature in January is -7°C in July + 23°C. To observe the changes in biological properties of postagrogenic chernozem, a test site located in the Botanic Garden of the Southern Federal University was chosen. The botanic garden is located in the center of Rostov-on-Don in the south-west of the Russian Federation (47°14′13″ N 39°39′12″ E). In 2016, the test site was an arable land being in black fallow condition. In spring, before the first plowing, the land was divided into two parts. One part was transferred into fallow land category for the recovery of biological properties, and the second part was continued to be plowed. Later, the data from the latter was used as negative check. For comparison, two fallow areas located in the Botanic Garden of the Southern Federal University (27 and 72 years) and a virgin steppe area of the natural monument “Persianovskaya Reserved Steppe” were used as positive checks. Soil in all the areas is a carbonaceous medium depth heavy loam ordinary chernozem (Haplic Chernozems). The observations were during three years from 2016 to 2018. Soil samples were taken three times every year in May (maximum active vegetation), the end of July (drought period) and September (beginning of autumn flood). The samples were taken from the upper layer using envelope method while making sure that each sample represents a part of soil typical for soil layers and key areas under study. To avoid erroneous interpreted data, the soil samples were stored in the conditions that change the biological state as little as possible. The studies of biological activity of postagrogenic soils were conducted with 3-9 times frequency on the day following the sampling. The soil samples were prepared for the biological studies immediately on the day of analysis.

Moisture in the areas under study was measured under field conditions by moisture meter with sensor DATAPROBE with 10 times frequency. Temperature of soil surface was measured using digital thermometer HANNA CHECTEMP. Surface density in the test areas was determined through the volume-weight method with 3 times frequency. Soil hardness was determined under field conditions with the help of penetrometer Eijkelkamp for a depth of 50 cm at 5 cm interval with 10 times frequency. Trophic activity and CO_2 emissions were studied in the third year of fallow period (2018). Trophic activity was determined using biat-lamina test (Törne 1990). Carbon dioxide emissions were determined using soda lime (Keith et al 2006). The content of total organic carbon was determined by dichromatic oxidation in acidic medium (Walkley and Black 1934). Active carbon was determined using Blair's method modified by Weil (Blairet al 1995, Culman et al 2012). The principle of this method is based on the oxidation of soil organic carbon in potassium permanganate solution. In contrast to the value of total organic carbon, the content of active organic carbon was stated in fractions of active carbon in a certain amount of soil (mgC kg^{-1} of soil). Statistical data processing was carried out using correlation and dispersion analysis. In the discussion, the statistically valid differences at $p<0.05$ were considered.

RESULTS AND DISCUSSION

During the first year of fallow period, the annual fast growing weeds of *Asteraceae* family, which enrich large biomass, were dominant. In the first year of fallow period, flora of the area under study included 9 weed: *Ambrosia artemisiifolia, Artemisia vulgaris, Artemisia absinthium, Cyclachaena xanthiifolia, Carduus crispus, Cirsium vulgare, Chenopodium album, Rorippa, Oenothera biennis.* Total phytomass in the area under study was 0.76 kg/m^2. In the second year, this value decreased by 10 per cent. In the third year of the study, the value of phytomass decreased by 26 per cent as compared with the first year, which was indicative of the reduction in dominance of high grass weeds. The reverse correlation relationship between phytomass in the area under study (r = -0.97) and the time of fallow period and number of particular kinds of plants (r = -0.98) was observed.

With the emergence of vegetation in postagrogenic area, soil moisture increased by 8 per cent as compared with arable land. Over the fallow period and with the development of soil litter, the moisture level in the area under study grew; in 2018, moisture difference was 17 per cent (Table 1). With the increase of moisture and development of vegetation, the soil surface temperature in fallow land decreased by 5 per cent. The trend of increasing moisture and decreasing temperature of soil surface in postagrogenic area was noted within the whole period of study (r=-0.76). This is associated with vegetation development in fallow land that leads to soil shading. In addition, termination of continuous soil turbation due to cultivation that causes drying of surface layer results in

Table 1. Parameters of the test areas

Parameters	Soil density (kg/m^2)	Soil surface temperature (^0C)	Moisture (%)
2016			
Arable land	1,32	22,2	18,7
Young fallow land	1,17	21,1	20,2
Steppe area	0,95	19,7	32,1
2017			
Arable land	1,29	23,9	14,1
Young fallow land	1,16	20,8	16,1
Steppe area	0,86	20,3	26,2
2018			
Arable land	1,3	33,7	11,7
Young fallow land	1,2	31,8	13,7
Steppe area	0,94	29,7	15,1

the recovery of soil structure and improvement of air and water regime (Gorbov et al 2016). Soil density is affected by the relationship between organic and mineral parts (Myasnikova et al 2014, Kudeyearov 2019), structural aggregates, amount of roots and soil cultivation degree. In the first year of the study, development of plants root system led to the decrease in soil density in postagrogenic area by 11 per cent. Over the fallow period, soil density did not change significantly.

Soil hardness measured by penetrometer shows the resistance of plant root system during its growth. Penetrometers exceeding 5 MPa are indicative of compact soil, which prevents root growth, thus affecting the productivity of vegetation (Myasnikova et al 2014). In arable area, a minimum hardness was observed during the whole period of the studies. In the first year of fallow period, no significant difference between postagrogenic area and arable area was recorded. With the development of root system, soil structure also changes. A significant difference in the hardness of arable layer 0-20 cm between the arable area and young fallow land was noted in the second year of the study, the difference was 33 per cent. Over the fallow period, this difference grew; in the third year, it was 42 per cent.

Weeds development stage of progressive succession led to a significant increase in organic carbon amount in soil and on its surface. Positive increase in organic carbon in postagrogenic area was recorded in the 9^{th} month of the study (September 2016). A significant difference in the content of organic carbon between postagrogenic area and arable land was 26 per cent and difference between steppe area and fallow land was 27 per cent (Fig. 1).

Over the fallow period, no significant increase in organic carbon in postagrogenic area was recorded. The content of organic carbon in the areas under study had changed depending on the time of soil sampling. In the period of intense vegetation (May 2017), the content of organic carbon was higher as compared with the time of drought (July 2017) by 11 per cent; in autumn (September 2017), with the onset of the rainy season, decrease of daily mean temperature and activation of biological processes, there was a regular growth of this indicator by 15 per cent. In the second year of fallow period, the content of organic carbon in arable layer of young fallow area was 2.5 per cent of soil weight of 0.1 g that exceeds the value in arable area by 24 per cent. No significant difference from the 27-year-old fallow land was recorded in this period. Maximum difference in the content of organic carbon between postagrogenic area and arable land was in the 33^{rd} month of demutation period. The difference between these areas was 44per cent. For comparison, in this period, difference between young fallow area and 72-year-old fallow land was 17per cent, which is indicative of insufficient amount of organic matter in the surface soil layer.

Trophic activity, CO_2 emissions and change in the content of active carbon in young fallow area were studied in the third year of postagrogenic period. The areas under study were presented by arable land, young fallow land, 27-year-old and 72-year-old fallow lands. During the experiment, a regular relationship between all indicators being studied and the time of the study was observed. Increase of biological activity was observed in May and September. Dry season in the territory of Rostov Oblast in July, slowed all the biological processes (Fig. 2). There was a reverse relationship between trophic activity and soil surface temperature (r = -0.78) in all the areas under study. Maximum trophic activity was observed in 73-year fallow area. The difference with young fallow area in the period of maximum activity was 7 per cent. The difference between arable area and young fallow area in this period was 22 per cent.

There is a direct correlation relationship between trophic activity and CO_2 emissions (r=0.67), as well as the content of organic carbon (r=0.77). The largest emission of carbon dioxide from the surface of areas under study was observed in spring and autumn. In drought period, there is a decrease in soil moisture, slowing down of microbiological processes, negative relationship between CO_2 emissions and soil surface temperature (r=-0.78).

The content of active carbon in top soil had increased in the following order: arable land, 27-year-old fallow land, 72-year-old fallow land, stepper area. On the other hand, there was a high rate of change in the content of active carbon during vegetation period, i.e. the determined values of active carbon varied widely depending on the time of soil sampling. In the period of active vegetation (May 2018), the content of

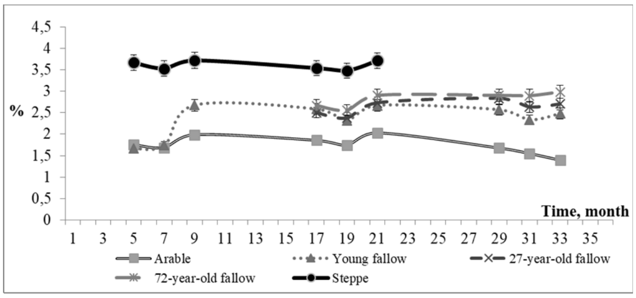
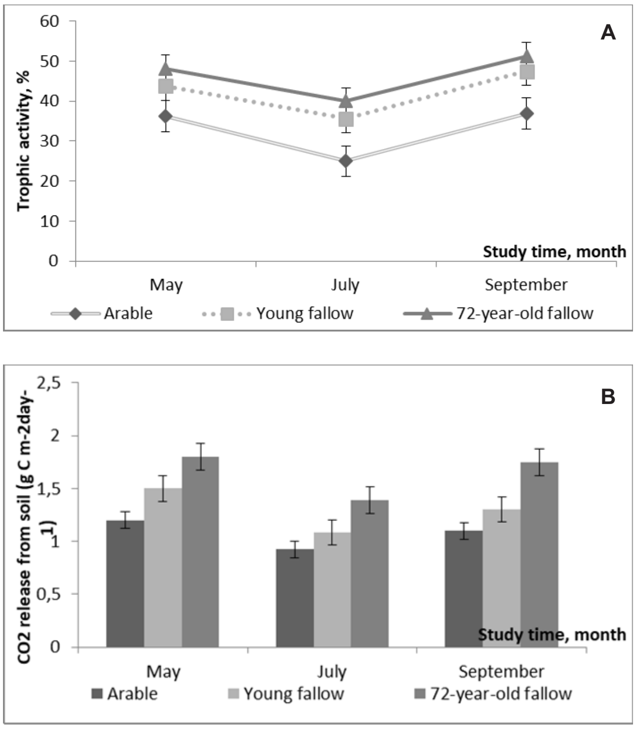


Fig. 1. Total organic carbon of postagrogenic chernozem during thirty six months of research



Note: Significant difference p <0.05

Fig. 2. Changes in biological processes in the third year of research: (A) – trophic activity, %; (B) – CO_2 emissions, gC m^{-2} day^{-1}

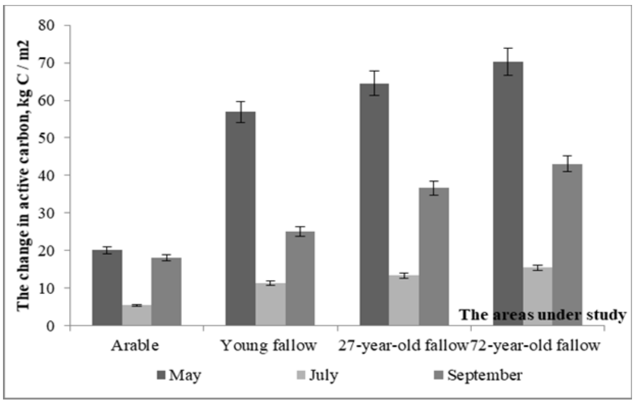


Fig. 3. Active carbon of postagrogenic chernozem in the third year of research

active carbon in all the areas under study was 4.5–5 times higher than in the period of soil drying out and slowing of biological processes (July 2018). In the dried soil, vegetation almost stopped, biological activity notably decreased (Fig. 3). In autumn, the content of active carbon in young fallow area increased by 55 per cent as compared with drought period.

In May 2018, the content of active carbon in 3-year-old fallow area was 2.5 times higher than in arable area, however, this value was also 12% lower than in 27-year-old area. In drought period, a trend of increasing values of active carbon as compared with check areas was similar to May observations. The content of the indicator under study in 3-year-old fallow area was 53% higher than in arable area and 15% lower than in 27-year-old fallow land. A reliable straight-line correlation was defined for the content of organic carbon and active carbon (r=0.93).

CONCLUSIONS

Recovery of biological processes begins from the first years of fallow period. Physical properties of fallow land change due to the emergence and development of grassland vegetation. The following properties change in the first year: density, temperature and moisture of arable layer. A reliable change in soil hardness was recorded in the second year of fallow period. After three years of fallow period, trophic activity of soil mesofauna increased by 17 per cent and CO_2 emissions increased by 18 per cent as compared with arable area. A straight-line correlation was noted between trophic activity and CO_2 emissions and the time of the study. The content of organic matter in the upper layer of chernozem that was continuously subject to anthropogenic impact during plowing increases already in the first year of fallow period. The content of total organic carbon in young fallow area increases by 26 per cent as compared with arable area. In the three years of progressive succession, the content of active carbon in young fallow area increased significantly. The difference between arable area and young fallow area was 65% in the third year. There was a relationship between the content of organic carbon and active carbon and the time of soil sampling. A reliable positive correlation was defined for the content of total carbon and active carbon.

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REFERENCES

Acosta-Martinez V and Tabatabai MA 2000. Enzyme activities in a limed agricultural soil. *Biology and Fertility of Soils* **31**(1): 85-91.

Blair GJ, Lefroy RD and Lise L 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. *Australian Journal Agriculture Research* **46**: 1459-1466.

Culman SW, Snapp SS, Freeman MA, Schipanski ME, Beniston J, Lal R, Franzluebbers AJ, Glover DJ, Grandy AS, Lee J, Six J, Maul JE, Mirsky SB, Spargo JT and Wander MM 2012. Permanganate oxidizable carbon reflects a processed soil fraction that is sensitive to management. *Soil Science Society of America Journal* **76**: 494-504.

Gorbov SN, Bezuglova OS, Abrosimov KN, Skvortsova EB, Tagiverdiev SS, Morozov IV 2016. Physical properties of soils in Rostov Agglomeration. *Eurasian Soil Science* **49**(8): 898-907.

Keith H and Wong SC 2006. Measurement of soil CO_2 efflux using soda lime absorption: both quantitative and reliable. *Soil Biology and Biochemistry* **38**: 1121-1131.

Khan BM, Ahmad S and Ashraf I 1980. Rain moisture conservation for crop production in Pothowar area of Pakistan. *Soil and Water Research Report* **1**. Dir. S&I, PARC, Islamabad.

Kudeyearov VN 2019. Soil-biogeochemical aspects of arable farming in the Russian Federation. *Eurasian Soil Science* **52**(1): 94-104.

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Myasnikova MA, Chernikova MP, Kazeev KS, Yermolaeva OY, Kolesnikov SI, Kozun YS, Akimenko YV and Yarovaya EV 2014. Biological features of the black soil deposits in the botanical garden of SFU. *Scientific journal KubGAU* **104**(10): 615-626 (in Russian).

Rao MA, Scelza R, Acevedo F, Diez MC and Gianfreda L 2014. Enzymes as useful tools for environmental purposes. *Chemosphere* **107**: 145-162.

Rusanov AM and Anilova LV 2009. The humus formation and humus in forest-steppe and steppe chernozems of the southern Cisural region. *Eurasian Soil Science* **10**: 1184-1191.

Shchur AV, Vinogradov DV and Valckho VP 2016. Effect of different levels agroecological loads on biochemical characteristics of soil. *South of Russia: ecology, development* **11**(4): 139-148 (in Russian).

Törne E 1990. Assessing feeding activities of soil-living animals. I. Bait-lamina-tests. *Pedobiologia* **34**: 9-101.

Walkley A and Black IA 1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Xiao W, Chen X, Jing X and Zhu B 2018. A meta-analysis of soil extracellular enzyme activities in response to global change. *Soil Biology and Biochemistry* **123**: 21-32.

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Soil and Climatic Bonitation of Agricultural Lands of the Steppe Zone of Ukraine

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Abstract: Spatial modeling was performed by using methods of geostatistics and algebra of maps of ArcGIS 10.1. software product. As a result of geomodeling, raster models were created and spatial patterns of distribution of the four components of the zonal soils bonitation were established: the total value of soil properties, humidity index, coefficient of climate continentality, average annual amount of active temperatures greater than 10°C. It was determined that in the territory of the studied steppe region, the agricultural lands of average quality prevail. Depending on the type of crops growing, their area varies from 32.0 to 72.2 per cent, with low quality from 1 to 13 per cent, with high and high-end quality from 15.5 to 67.2 per cent. Bonitation points are established on the basis of a unified scale of assessment of land quality, which allows to objectively calculate the bioproductive potential of the territory, to determine the area of agricultural lands in terms of their qualitative characteristics, to clarify the normative monetary assessment and to determine the optimal level of agricultural land tax, to adjust irrigation rates in order to reduce the volume of water intake from natural water sources, to justify measures and terms for the reclamation of degraded lands.

***Keywords*:** Soils, Climate, Bonitation, Agricultural lands, Crops, Steppe zone of Ukraine, Geomodeling, GIS-technologies

Anthropogenic impact on the natural environment has exceeded the potential of its sustainable development, which resulted in a global environmental crisis. In order to overcome it, it is necessary to introduce a differential-territorial environmental management, which, in turn, consists of a comprehensive assessment of the territory of different localization and a plan of actions aimed at restoring the natural balance. Particular attention should be given to the issues of rational and efficient use of agricultural lands, specialization and concentration of agricultural production with due account for the natural or soil and climatic conditions of individual territories, which include climatic conditions, quality of soil and relief. An important role in the organizational works on the rational use of agricultural lands is bonitation of zonal soils, which is a cross-functional assessment of their fertility when comparing agroclimatic conditions, determination of the intensity of agriculture to ensure effective environmentally safe production with optimal use of soil potential. It also characterizes zonal features of soils as a medium for plant life, expressed in quantitative fertility indices – points (from 0 to 100 points) calculated according to soil properties and climatic conditions, the main of which are the content of humus, thickness of the humus horizon, granulometric composition, content of macronutrients, water availability, amount of active temperatures, etc. It is necessary to take into account all causal relationships, in particular the topographic effect, as a general integral function which determines the process of redistribution of heat and moisture in the soil and largely determines the agricultural crops yields. In relation to soil science A. Gerrard called this approach "the integration of geomorphology and soil science" (Gerrard 1984). Significant spatial differentiation of the relief and natural and climatic conditions largely determines agro-industrial groups of soils and the level of extensive agricultural development of territories in different physical and geographical zones (Lisetskii et al 2016, Zelenskaya et al 2018, Pichura et al 2017, 2019). Medvedev (2006) noted that bonitation should be considered as a uniform system "soil-climate-field". Within the terms of the proposed concept, not only the soil is evaluated, but also the components inextricably connected therewith. At least, it includes climate and field, which makes the assessment of soils more objective and extends its application aspects. The researcher also noted that in calculation of bonitation it is necessary to consider the characteristics of relief, since the slope is an important characteristic of the field and could be used directly in the calculations of bonitation without the use of correction coefficients. The author regards the slope exposition as an important factor of fertility and yield, but, unfortunately, the systematic surveys over the soil regimes and crops yield on the slope of different exposition are not enough.

Soil boniting is the final assessment of the determination of the genetic relations of agrogenesis processes at different hierarchical levels of the spatial and temporal organization of the soil system under conditions of long and variable intensity of agriculture. Lisetskii (2015) noted that the temporary abandonment of the intensive exploitation of soil resources in traditional agricultural practices, the regular launching of natural processes of soil fertility reproduction and the increasing of their qualitative characteristics were suggested to be considered as correctly distributed in time small resonance impacts aimed at implementing the soil system self-organization mechanism. In the California bonitation method, developed by Storie (1978) and used in the United States for more than 50 years, particular attention is paid specifically to the relief as a control factor for the possibility of using land and determining its productivity. The advantage of this method is that on the basis of the slope of the relief, possible development of slope erosion is considered. Thus, possibility of obtaining excessive results of bonitation is excluded, and the influence of each factor is objectively factored into the overall point of bonitation. In order to determine the soil and climatic potential of the territory of the steppe regions of Ukraine, Karmanov's (1980, 2012, 2013) method of zonal soils bonitation was used. The scientist considered bonitation as a quantitative assessment of the fertility of land for the cultivation of certain crops. Assessment criterions are factors, divided into three main groups: natural, economic and scientific-organizational. Karmanov's method is adapted in practice for the creation of a uniform comparative scales of soil fertility assessment for different physical and geographical conditions. The advantages of this method are noted in scientific works Pichura (2017) and Beznitska (2017).

Bonitation of soils is a logical continuation of integrated land surveys and the state cadastral valuation of agricultural lands, which in the field of land relations is the basis for establishing land tax, mortgage rates and rent amounts, starting prices for tenders and auctions, and is also used in other fields, related to management of land resources. Cadastral valuation should be directed to maximally accurate account of all conditions that affect the value characteristics of soils (Potravka 2007, Tanklevska et al 2015). Therefore, the actual task is to specify points of soils bonitation within the limits of separate land use in conditions of terrain heterogeneity. Such an assessment is necessary to ensure sustainable land use, which mainly depends on correctly selected territories, indicating the ecological status of soil suitability for cultivating various crops, determining the specialization of farms, and developing comprehensive measures to improve or regulate soil fertility. The current level of development of geoinformation systems, their ability to analyze and solve applied tasks, fully allows this task to be realized.

MATERIAL AND METHODS

In order to create spatial models of soil bonitation in the territory of the steppe regions of Ukraine (Dnipropetrovsk, Zaporizhzhia, Kirovohrad, Mykolaiv, Odesa, Kherson regions) in accordance with a uniform comparative scale of soil fertility assessment, the method of zonal soil bonitation by Karmanov (1980, 2012, 2013) was adapted and tested. In the foundation thereof, in addition to the soils properties, the bonitation of the climate with due account for the principal climatic indicators that correlate with yield – the amount of active temperatures, humidity index and climate continentality, is laid. The method reflects the general patterns of spatial distribution of yields by natural physical and geographical zones and allows calculating soils bonitation points for each crop separately (Table 1). Having the data on the relief, it is possible to extrapolate the climatic characteristics of each local element of the landscape, which will make it possible to specify the conditions of the microclimate and, accordingly, establish the soil bonitation point. Calculation of soil and climatic potential of soils and obtaining of raster models of its distribution should be carried out under the formulas for calculating zonal soils bonitation point in the Raster Calculator of ArcGIS working module. The magnitude of the coefficient of climate continentality (CC) was calculated as:

$$CC = \frac{360(t^o_{\max} - t^o_{\min})}{\varphi + 10} \qquad (1)$$

where $t°_{max}$ – the average monthly temperature of the warmest month; $t°_{min}$ – the average monthly temperature of the coldest month; φ – the latitude of the terrain.

Humidity factor (HF) is determined by formula:

$$HF = P/E \qquad (2)$$

where P – average annual amount of precipitation, mm; E – average annual evaporation, g cm^{-2}. The total value of soil properties is established in accordance with the coefficients of the total value (V) of soil properties from 0.5 to 0.98.

For the detailed local assessment of soils within a separate administrative-territorial units and land users, correction coefficients under environmental and agrochemical indices of soil condition are additionally used. In addition, the ratio and exposure of slope are taken into account. For irrigation conditions, additional irrigation moisture and adverse environmental and soil reclamation properties (groundwater level, salinity type and salinization) should be included in soil bonitation. Based on the results of spatial geostatistical modeling and the algebra maps of ArcGIS program, cartograms, reflecting points of the soil differences bonitation in the territory of the studied steppe regions of Ukraine, are created. On the basis of the soil bonitation point a group and land-use capability according to the scale of their qualitative assessment (Table 2) was determined.

The spatial models of the amount of active temperatures, humidity factor and climate continentality were determined based on the extrapolation of the decompositions of the publicly available data CliW are (http://cliware.meteo.ru/meteo), additional data of the individual weather stations and the national atlas. In order to determine the value of the total value of soil properties, vectorization of a soil map of Ukraine at scale 1:2500000 was carried out. The ArcGIS zone statistics method calculates the average values of the soil bonitation components for each administrative unit.

Table 2. Scale of qualitative soil assessment

Bonitation class	Bonitation point	Group of lands
I	91-100	Soils of high-end quality
II	81-90	
III	71-80	Soils of high quality
IV	61-70	
V	51-60	Soils of average quality
VI	41-50	
VII	31-40	Soils of low quality
VIII	21-30	
IX	11-20	Soils of bottom quality
X	1-10	Unusable soils

RESULTS AND DISCUSSION

The soil cover of the steppe regions of Ukraine is characterized by low-humic soils with a content of humus in a layer of soil of 0 ... 20 cm from 0.30 per cent to 4.75 per cent (Fig. 1). The spatial heterogeneity of the humus content is determined by the complexity of soil cover structure, which is primarily due to zonal factors of soil formation and heterogeneity of hydrothermal conditions, and secondly, to the development of gluten processes in the soil waters due to their waterlogging with melted and rain waters, and thirdly, to an intense manifestation of salination and salinization at shallow groundwater deposits.

The main types of soils in the regions of the Steppe zone of Ukraine (Fig. 2) are chernozems, which occupy 83.2 per cent of the total agricultural lands area, chestnut and dark chestnut soils – 7.7 per cent. The total area of steppe region was 167.4 thousand km^2, including agricultural lands of 133.5 thousand km^2 (79.7% of the studied area: Dnipropetrovsk region – 15.0%, Zaporizhzhia region – 13.4%, Kirovohrad region – 12.1%, Mykolaiv region – 12.0%, Odesa region – 15.4% %, Kherson region – 11.8%), including arables land of 113.5 thousand km^2 (85.0% of the agricultural lands area: Dnipropetrovsk region – 15.9%, Zaporizhzhia region –14.3%, Kirovohrad region – 13.2%, Mykolaiv region – 12.7%, Odesa region – 15.6%, Kherson region – 13.3%), of which the irrigated lands area is 6.3 thousand km^2 with the

Table 1. Calculation bonitation points for different crops by using soil and climatic formulas

Crop	Calculation formula	Note
Cereals	$B = 8{,}2V \dfrac{\sum t^o \geq 10^o \cdot \text{HF}}{\text{CC} + 70}$	HF more than 0.9 is taken equal to 0.9
Sunflower	$B = 6{,}8V \dfrac{\sum t^o \geq 10^o (\text{HF} + 0{,}2)}{\text{CC} + 50}$	HF more than 0.7 is taken equal to 0.7
Sugar beet	$B = 4{,}3V' \dfrac{(\sum t^o \geq 10^o + 2000)(\text{HF - } 0{,}2)}{\text{CC}}$	HF more than 0.9 is taken equal to 0.9; $V' = \dfrac{4V - 1}{3}$
Perennial grasses	$B = 5{,}9V'' \dfrac{(\sum t^o \geq 10^o + 2000)(\text{HF- } 0{,}1)}{\text{CC+100}}$	HF more than 1 is taken equal to 1; $V'' \dfrac{V + 1}{2}$
Annual grasses	$B = 6{,}8V'' \dfrac{(\sum t^o \geq 10^o + 1000)\text{HF}}{\text{CC+100}}$	

where *B* – bonitation point; *V* – total value of soil properties; $\sum t^o \geq 10^o$ – average annual amount of air temperature above 10°C; *HF* – humidity factor by Ivanov; *CC* – continentality coefficient proper functioning of the irrigation systems infrastructure ensured (5.6% of the arable land area: Dnipropetrovsk region – 1.8% , Zaporizhzhia region – 0.4%, Kirovohrad region – 0%, Mykolaiv region – 0.3%, Odesa region – 0.4%, Kherson region –2.7%).

Depending on the type of soils, the spatial differentiation of the value of the total value (V) of the properties of zonal soils, which depends on their agricultural value for the studied steppe region, is from 0.5 for soddy-sand and chestnut- solonetzic soils, which are in the southern part of Kherson region, to 0.98 for typical chernozems, which are more likely to be in Odesa and Kirovohrad regions (Fig. 3).

The humidity factor (HF), calculated. Ivanov's method (1949) is determined by the ratio of the annual amount of precipitation to the annual value of evaporation for the corresponding landscape, it is an indicator of the ratio of heat and moisture, with which the zones of provision of biocenosis with moisture are distinguished. In the territory of the studied steppe region, the value of HF decreases from the northwest to the southeast from 0.72 to 0.30 (Fig. 4). It was established that 33.5 per cent of the territory of agricultural lands is in the territory with very dry (HF 0.33-0.44), dry (HF 0.44-0.55) – 43.3 per cent, semi-dry (HF 0.55-0.77) – 23.2 per cent conditions.

The reverse process is characterized by the climate continentality (CC) index, which at high values characterizes the high amplitude of air temperature, a small amount of precipitation and light winds. In the territory of the studied steppe region, the value of the CC varies within 143.8-167.9 (Fig. 5).

The bioclimatic potential of agricultural production is considerably related to solar radiation, biochemical accumulation and migration of substances in the soil, which are especially manifested in a frostless season at an air temperature above 10°C. The average annual amount of active temperatures above 10°C increases from the northwest to the southeast of the studied territory from 2793°C to 3382°C (Fig. 6).

As a result of GIS modeling by using soil and climatic models and the Raster Calculator of ArcGIS 10.1, the calculation of the zonal soils bonitation point for growing grain crops, sunflower, annual and perennial grasses has been calculated within the individual areas of the studied steppe region (Fig. 7) and its individual administrative-territorial units (Fig. 8). Under the existing soil and climatic conditions of the studied steppe region, the most favorable conditions for farming are attributable to the administrative-territorial units of the northwest steppe region, located in Odessa and Kirovohrad regions (Table 3). The maximum value of a bonitation point for different crops intended for sowing ranges from 67 to 85 points.

In the territory of the Steppe zone of Ukraine, lands of average quality with a bonitation point within the range of 41-60 points, which include ordinary and southern medium- and low-humic chernozems, prevail. There are also some typical chernozems. The area of agricultural land with an average quality of land for growing individual crops varies from 32.0 per cent for sunflower to 72.2 per cent for annual grasses. The territories of agricultural lands with the lowest soil and climatic potential are located in the southern and

Table 3. Distribution of agricultural lands according to the soil and climatic potential of growing crops

Group of lands	Bonitation class	Bonitation point	Area, km^2	% to the total area
Growing of cereals				
Low quality	VIII	21-30	1,50	1,12
	VII	31-40	16,33	12,23
Average quality	VI	41-50	47,83	35,83
	V	51-60	47,19	35,35
High quality	IV	61-70	20,48	15,34
	III	71-80	0,16	0,12
High-end quality	II	81-90	–	–
Growing of sunflower				
Low quality	VIII	21-30	–	–
	VII	31-40	1,24	0,93
Average quality	VI	41-50	7,32	5,48
	V	51-60	35,27	26,42
High quality	IV	61-70	49,85	37,34
	III	71-80	38,09	28,53
High-end quality	II	81-90	1,72	1,29
Growing of annual grasses				
Low quality	VIII	21-30	–	–
	VII	31-40	15,61	11,69
Average quality	VI	41-50	48,37	36,23
	V	51-60	48,05	35,99
High quality	IV	61-70	21,05	15,77
	III	71-80	0,43	0,32
High-end quality	II	81-90	–	–
Growing of perennial grasses				
Low quality	VIII	21-30	–	–
	VII	31-40	2,91	2,18
Average quality	VI	41-50	45,36	33,98
	V	51-60	47,07	35,26
High quality	IV	61-70	31,35	23,48
	III	71-80	6,81	5,10
High-end quality	II	81-90	–	–
		Total	133,50	100

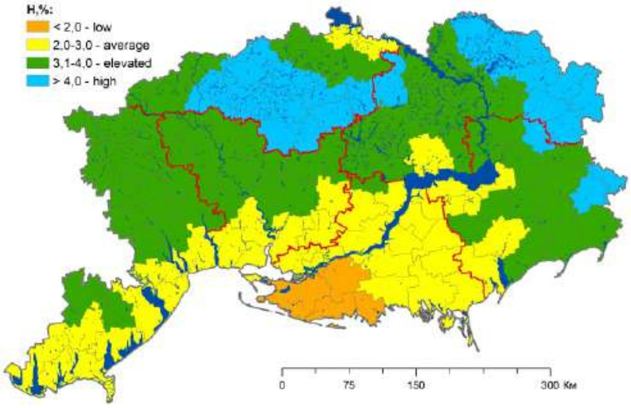


Fig. 1. Spatial differentiation of humus (H, %) content in soils of agricultural lands in the Steppe zone of Ukraine

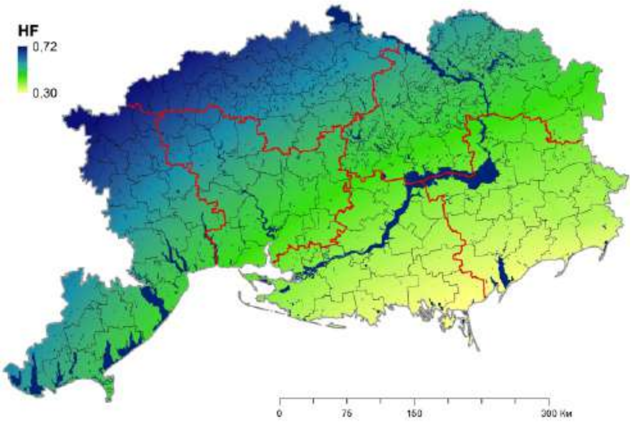


Fig. 4. Rasters of spatial differentiation of the values of the humidity factor (HF) in the territory of the Steppe zone of Ukraine

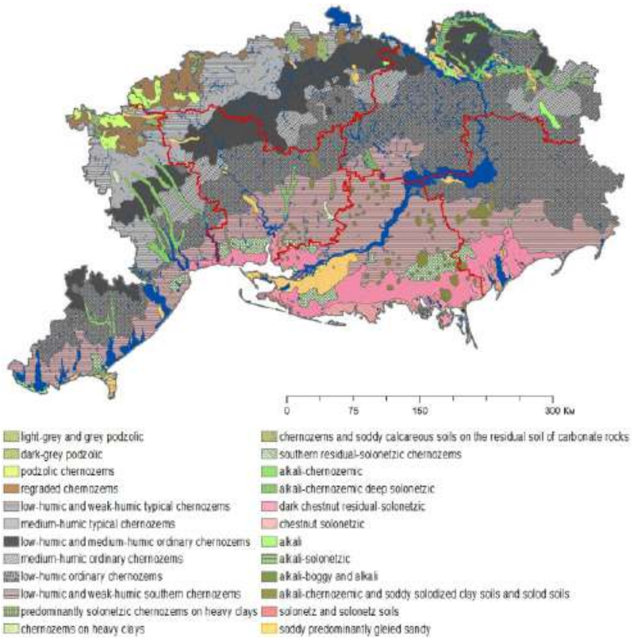


Fig. 2. Types of soils in the studied steppe regions

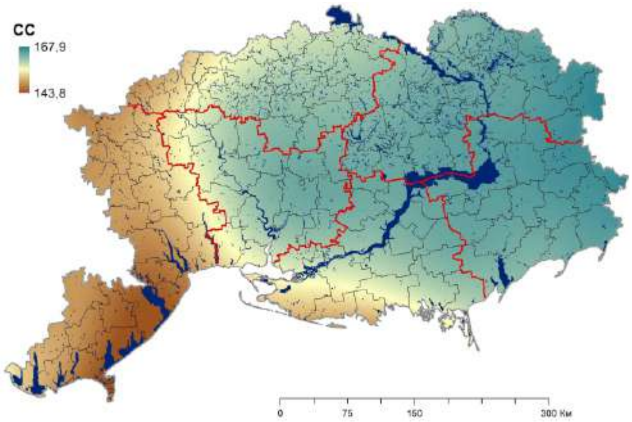


Fig. 5. Rasters of spatial differentiation of the values of the climate continentality (CC) index in the territory of the Steppe zone of Ukraine

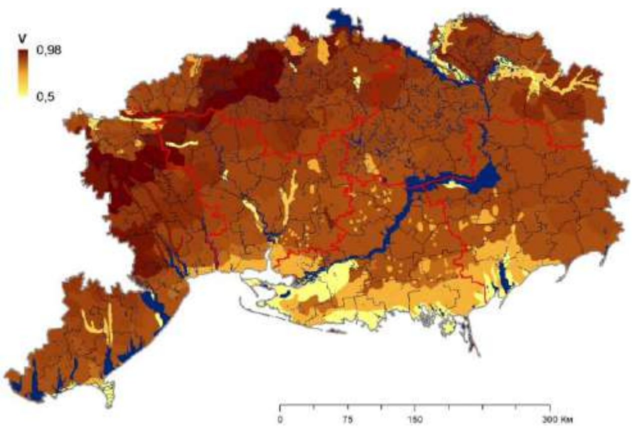


Fig. 3. Rasters of spatial differentiation of the total value (V) of the properties of zonal soils in the territory of the Steppe zone of Ukraine

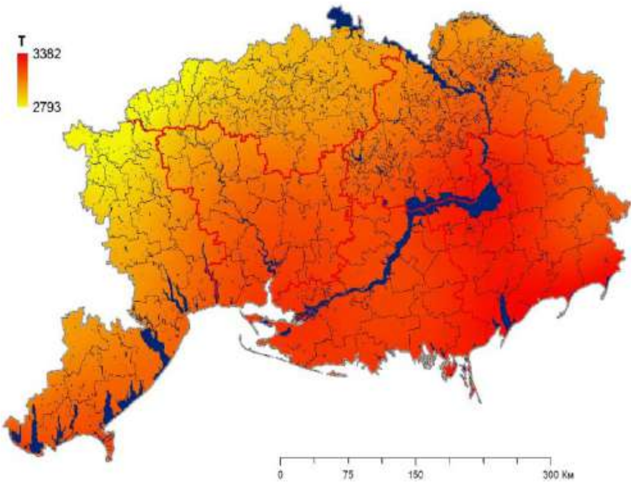


Fig. 6. Rasters of spatial differentiation of values of the average annual amount of active temperatures (*T*) above 10°C in the territory of the Steppe zone of Ukraine

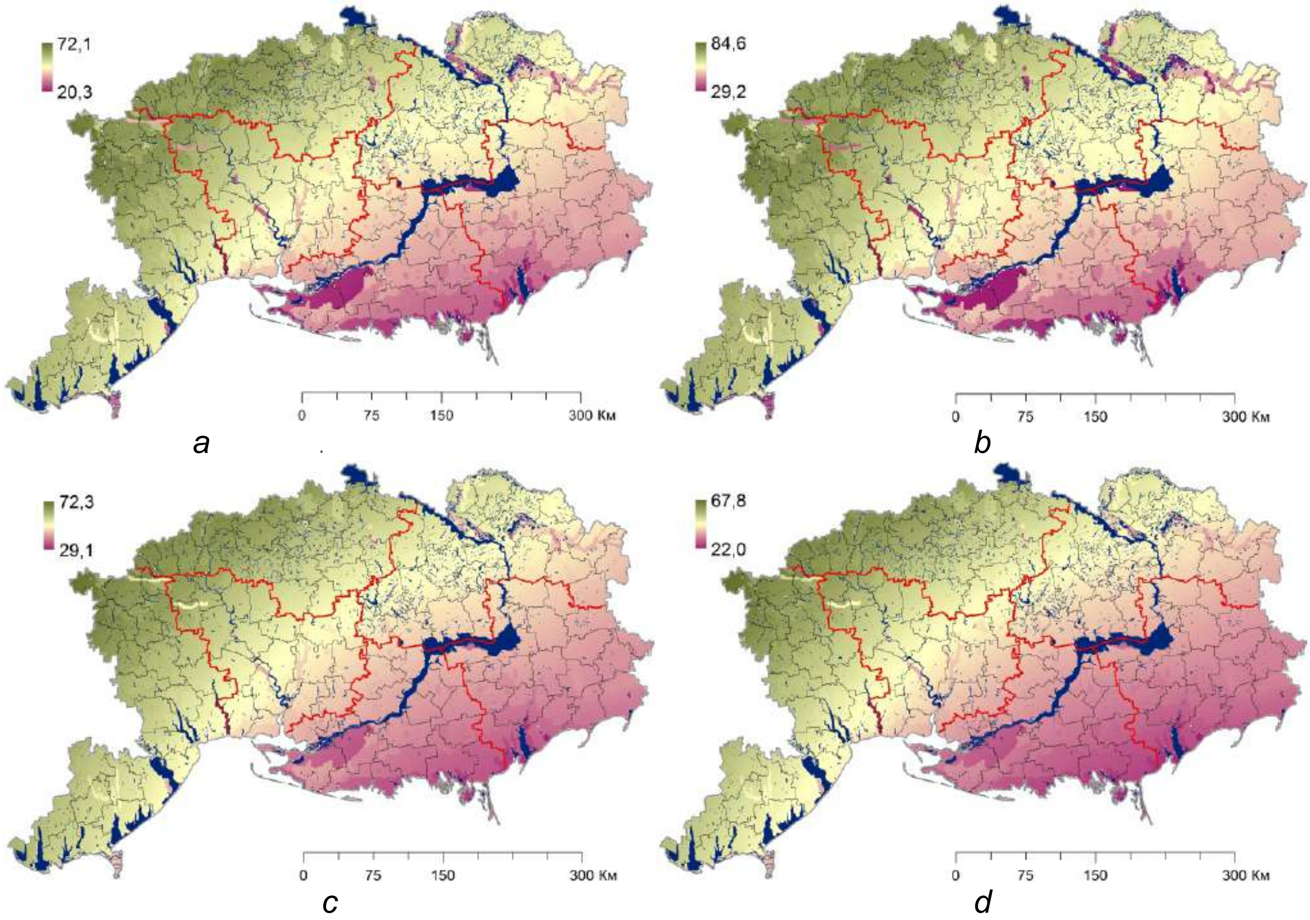
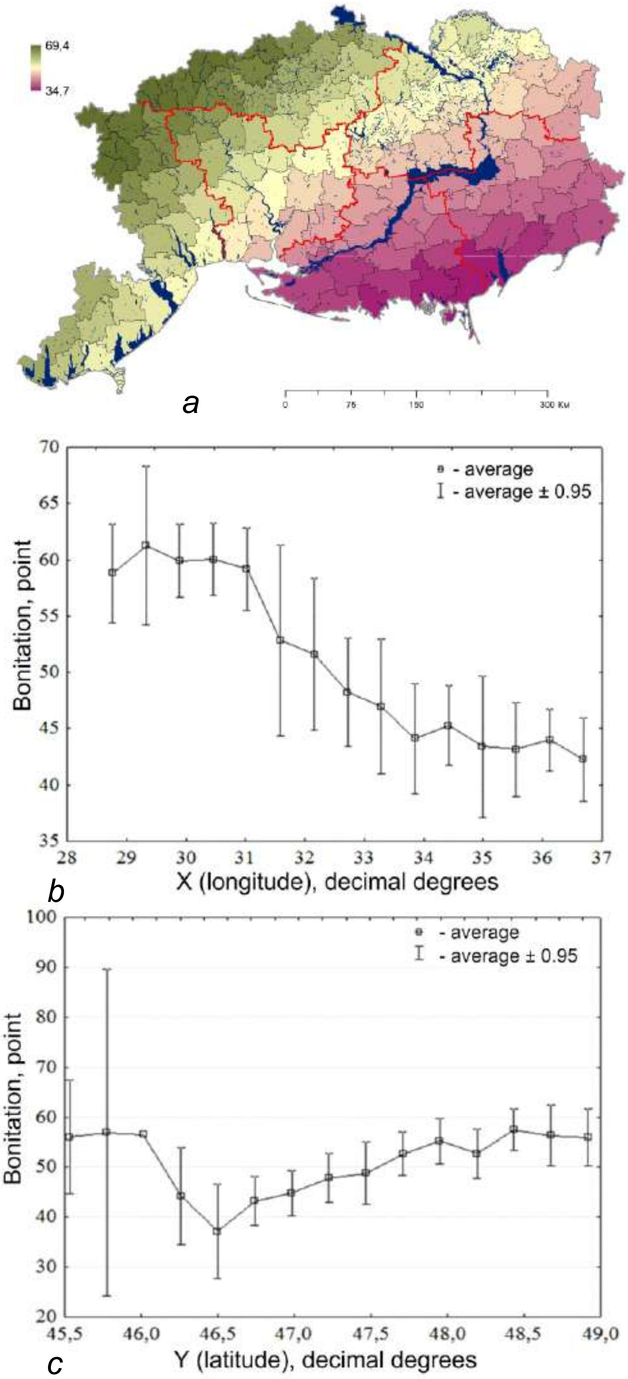


Fig. 7. Zonal soils bonitation (points) within the territory of the Steppe zone of Ukraine: *a* – growing of grain crops; *b* – growing of sunflower; *c* – growing of annual grasses; *d* – growing of perennial grasses

southeastern parts of the studied steppe region (40 points or less – lands of low quality) in the southern medium-humic, dark chestnut, chestnut solonetzic soils of Kherson and Zaporizhzhia regions. The area of arable lands with low quality land for growing individual crops varies from 1 per cent for sunflower to 13 per cent for cereals. The lands with high and high-end quality (more than 60 points) are located in the northwestern part of the studied area on the regaraded, typical and ordinary medium- and low-humic chernozems with the area of agricultural lands from 15.5 per cent for grain crops to 67.2 per cent for sunflower.

CONCLUSIONS

Approbation of zonal soils bonitation method and the results obtained for the Steppe zone of Ukraine provided a clarification of the spatial differentiation of agricultural lands bonitation, taking into account the soil type and changes in climatic conditions. Raster models were created and spatial patterns of distribution of the four components of the zonal soils bonitation were established: the total value of soil properties, humidity index, coefficient of climate continentality, average annual amount of active temperatures greater than 10°C. It was determined that in the territory of the studied steppe region, the agricultural lands of average quality prevail. Depending on the type of crops growing, their area varies from 32.0 per cent to 72.2 per cent, with low quality from 1 per cent to 13 per cent, with high and high-end quality from 15.5 per cent to 67.2 per cent. Bonitation points are established on the basis of a unified scale of assessment of land quality, which allows to objectively calculate the bioproductive potential of the territory, to determine the area of agricultural lands in terms of their qualitative characteristics, to clarify the normative monetary assessment and to determine the optimal level of agricultural land tax, to adjust irrigation rates in order to reduce the volume of water intake from natural water sources, to justify measures and terms for the reclamation of degraded lands.



Spatial distribution function of bonitation (B)point values:

-47,18X 0,53X 26,61 0,26 0,19 66,52 r^2 = 0,78

where, X - longitude, decimal degrees, Y - latitude, decimal degrees

d

Fig. 8. Spatial distribution of the average value of the zonal soils bonitation (points) within the administrative-territorial units of the Steppe zone of Ukraine: *a* – cartogram of spatial distribution of bonitation; *b* – heterogeneity of distribution from west to east; *c* – heterogeneity of distribution from south to north; *d* – model of spatial distribution

REFERENCES

Gerrard AJ Soils and landforms. Nedra, 1984: 208.

Karmanov II 1980. Soil fertility of the USSR. Moscow: Kolos: 224.

Lisetskii F and Pichura V 2016. Steppe ecosystem functioning of east european plain under age-long climatic change influence. *Indian Journal of Science and Technology* **9**(18): 1-9.

Medvedev VV and Plisko IV 2006. *Bonitation and qualitative assessment of arable land in Ukraine. Kharkov*: 13 printing house: 386.

Pichura VI 2017. Soil, climatic and ecological potential of the area of the transboundary Dnieper basin. *Scientific reports NUBiP Ukraine* **4**(68): http://journals.nubip.edu.ua/index.php/Dopovidi/article/view/9101. (in Ukrainian).

Pichura VI, Potravka LA, Dudiak NV, Skrypchuk PM and Stratichuk NV 2019. Retrospective and forecast of heterochronal climatic fluctuations within territory of dnieper basin. *Indian Journal of Ecology* **46**(2): 402-407

Pichura VI, Domaratsky YA, Yaremko YuI, Volochnyuk YG and Rybak VV 2017. Strategic ecological assessment of the state of the transboundary catchment basin of the Dnieper river under extensive agricultural. *Indian Journal of Ecology* **44**(3): 442-450.

Potravka LO 2007. Improvement of the subsystem level of the infrastructure of the agrarian market of the Southern region. *Bulletin of the Agrarian Science of the Black Sea Region* **39**(1): 109-114.

Storie RE 1978. Storie index soil rating. *Division of agricultural sciences* **3203**: 1-4.

Tanklevska NS and Potravka LO 2015. Systematic Approach to the Solution of Transformation Research Problem of National Economy of Ukraine. *Oblik i Finansi* **68**: 145-149. (in Ukrainian).

Zelenskaya E, Pichura V and Domaratsky Y 2018. Priorities of agroecological monitoring of the composition of soil trace elements taking into account the peculiarities of its formation over time. *Journal of Engineering and Applied Sciences* **13**: 5807-5813

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Response of Soil Properties to Different Tillage Methods and Wood-Ash Application on Productivity of Castor (*Ricinus cumunis* L.)

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Abstract: A field experiment was conducted in 2016 and 2017 cropping seasons to evaluate the effect of different tillage practices amended with wood ash on soil properties, growth and yield of castor oil plant in a Typic Haplustult in South eastern Nigeria. The treatments were mound + 4 t ha^{-1} wood-ash, flat + 4 t ha^{-1} wood-ash, ridge + 4 t ha^{-1} wood-ash, flat, mound and ridge. The highest seed emergence was observed in wood-ash amended tillage practices compared to those without any amendment. Significantly lower bulk densities and higher volumetric moisture content values of soil were observed in tillage practices while higher values of pH, Ca, Mg, Na and Kin wood ash amended tillage practices. Plant height was significantly higher in tillage practices amended with wood-ash compared to tillage practices receiving amendment. At harvest higher castor seed yield was obtained in wood-ash amended tillage practices compared to tillage practices receiving on amendment. These results suggests that tillage practices amended with wood-ash provide a better soil and superior edaphic environment for castor performances than tillage practices receiving no amendment .

***Keywords*:** Liming material, Crop yield, Healthy growth, Soil quality, Acidic soil

Castor (*Ricinus cuminis*) belongs to the family Euphorbiacea that thrive under a wide range of conditions and perform well in a well-drained soil with pH range of 6 – 7.3 while pH of <6.0 is unsuitable for its healthy growth and good yield (Greenepro 2009). In South-eastern Nigeria soil acidity hinders optimum agricultural production because most of the crops grown are vulnerable to soil acidity. The liming of this acid soil is a common agricultural practice. According to Mbah et al *(*2017) liming makes it possible to grow a greater number of crops, reduce aluminium / manganese toxicity, improves nitrogen (N) and phosphorus (P) availability, effective cation exchange capacity, soil structure and promotes N fixation. Anderson et al (2013) reported that the most commonly used liming materials in the tropics are the oxides, carbonates and silicates of calcium and magnesium. These agricultural limes are unavailable and expensive resulting in research into low cost, affordable and adoptable organic and inorganic materials like wood-ash, shells and industrial slag. Scanty information is available on the use of shells, industrial slag and wood-ash as lime in the study area. The liming value and phosphate fertilizer effectiveness of these materials are poorly documented. The tillage is performed to create conditions suitable for germination of seeds, seedling emergence, root growth and reduce weed competition. Selection of tillage to suit crop type, soil and climatic condition is very important to ensure optimum crop productivity and is beneficial by helping to breakdown clods, incorporate organic matter into the soil and create a favourable seedbed which permits or allows better drainage, aeration and root penetration for increased crop productivity (Anikwe et al 2007, Wasaya et al 2011, Khan 2011). Castor (*Ricinus cumunis* L.) is an ecologically unique crop, which is able to grow in ecological conditions which other crops may find difficult or adverse. Though castor is highly used in the study area because of its numerous benefits, many of the farmers are not involved in its production**.** This could be as a result of non-existence of data on the effect of tillage and organic manures especially wood-ash on its production. The present study aimed to effectively tackle and possibly solve the constraints in castor production. The objective of this study is to examine the effect of tillage techniques and wood-ash on soil properties and yield of *Ricinus cumunis* L in a degraded Ultisol.

MATERIAL AND METHODS

Site description: The experiment was carried out in two consecutive cropping seasons (2016 and 2017) at Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki, Nigeria. The area lies between latitude $05^{0}25^{1}$N and longitude $07^{0}15^{1}$ E and has a mean elevation of 450m above sea level. It has an annual rainfall of 1700-1800mm. The rainfall pattern is bimodal between April and October while the dry season is between November and March, with a break in August. The soil is lateritic, derived from sedimentary rocks from successive marine deposits of the cretaceous and tertiary periods and is a sandy loam (Nwite and Okolo 2017). It is an Ultisol classified as Typic Haplustult.

Experimental design and field practices: The site was slashed and cleared of grasses in 2016 and total area of 11 m by 15 m (165 m^2) was mapped out for the experiment. The experiment was carried out on the same plots in both cropping seasons. The field was divided into 3 blocks with each block having 12 experimental units making a total of 36 plots. The experimental units were demarcated by 1m alley and each measured 3m x 3m (9m^2). The experimental design was a split plot in randomized complete block design (RCBD) with six treatments replicated three times. The treatments were mound+4 t ha^{-1} wood-ash (MW), flat + 4 t ha^{-1} wood-ash (W), ridge +4 t ha^{-1} wood- ash (RW) , flat (F0) Mound only (M0) and ridge only (R0).The tillage practices were the main plot while wood ash was the subplot treatment. The experimental plots were prepared manually with traditional hoes and wood-ash incorporated during land preparation. Castor seeds were at a spacing of 0.9m between blocks and 0.45m within blocks at a depth of 8cm. with plant density of 24,444 ha^{-1}. Weeding was carried out manually using hoe and cutlass at 3 weeks intervals till harvest. There was no incidence of pests and diseases and no other chemical input was. The same procedure was repeated in 2017 cropping season without application of the amendments to test the residual effect.

Field sampling and data collections: Topsoil sample (0-30 cm) were collected at random) from ten observation points .The auger samples were mixed and composite sub-samples used for analysis (Table 1). Core samples were collected using 98.2 cm^3 open-faced cores of area 19.5 cm^2, analysed separately and mean result used for data analysis. At harvest, four auger samples were collected from each plot and analysed for chemical properties. Similarly, four core samples were collected from each plot at harvest (the end of the study) for determination of physical properties. Castor seed germination was counted 14, 21 and 28 DAP. Ten plants were randomly selected, tagged and sampled for plant height at 45 and 90 day after planting and yield. Dry bulk density was measured at intervals of 30, 60 and 90 days after planting DAP. Data on volumetric water content were collected at intervals of 30 and 90 DAP. Harvesting started at 153 days after planting when the capsules containing the seed turned brown. The harvesting was carried out in the morning and in the evening and lasted for 62 days. he harvested spikes were air dried for 2-3 days and then thrashed to release the seed. The seed were weighed and expressed in t ha^{-1}.

Laboratory methods and procedures. The pre and post-harvest soil samples were air-dried and sieved with 2 mm sieve. All analyses were carried out using the soil fractions less than 2 mm. All analysis was carried out at Department of Soil Science and Environmental Management, Ebonyi State University Abakaliki, Nigeria. The soil organic carbon (SOC) was determined by the Walkley and Black method (Nelson and Sommers 1982). The total nitrogen by Bremmer and Mulvaney (1982) and soil pH in KCl by the glass electrode pH meter (Mclean 1982). The exchangeable cations were estimated by method described by Thomas(1982) and particle size distribution by the hydrometer method (Gee and Bauder 1986). Dry bulk density was calculated by the core method (Blake and Hartage1986). The woodash ash was analyzed for its nutrient content before application (Table 1) using standard laboratory method (Okalebo et al 2002). The data collected from the experiment were subjected to analysis by using Crop Stat software version 20.

RESULTS AND DISCUSSIONS

Initial properties of the soil and woodash: The soil was sandy loam comprising of 562, 368 and 70 g kg^{-1} of sand, silt and clay, respectively with pH of 4.6 (Table 1). The initial properties showed that wood-ash has higher nutrient status when compared to soil, hence the need to use wood-ash as soil amendment.

Bulk density: The soil bulk density among the different tillage practices and at 30 DAPS ranged between 1.10 and 1.24 Mg m^{-3} in 2016 and between 1.18 and 1.26 Mg m^{-3} in 2017. Lower bulk density values were observed in WA-amended tillage systems when compared with tillage practices alone. Non-significant differences in soil bulk density were observed in tillage practice without any

Table 1. Initial properties of the soil and wood-ash

Parameter	Unit	Soil	Wood-ash
Clay	g kg^{-1}	70	-
Silt	“	368	-
Sand	“	562	-
Texture		Sandy loam	-
Ph		4.6	-
Total N	g kg^{-1}	0.6	116.00
Organic C	g kg^{-1}	10.9	6.60
Na	$Cmol_{(+)}$ kg^{-1}	0.13	0.38
K	“	0.07	0.29
Ca	“	2.80	48.80
Mg	“	1.60	9.60
Bulk density	Mg m^{-3}	1.56	-

amendment. At later stage of crop development (90 DAP) non-significant treatment difference in soil dry bulk density was among the various treatments. Higher soil BD was in the second cropping season compared to the first cropping season. This could be as a result of non-application of WA. Anikwe and Nwobodo (2002) reported that lower soil BD increase plant feeding area, root proliferation and ensure adequate aeration. Tillage influences soil compaction and was more pronounced at the early stage of crop growth. The effect of tillage on compaction reduced with time. At high BD plant root growth can be limited. Increased BD with time has been reported by Anikwe et al (2003) and Nwite and Okolo (2017). The high BD values at later stage (90DAP) could probably be due to the breakdown of some of the organic matter in the soil matrix or because of increase in soil compaction.

Volumetric soil moisture content (VMC): The significant differences (p=0.05) in volumetric moisture content among the treatments was observe at 45 days after planting (Table 3). The highest VMC of 26.6 and 31.2 at 45 DAP and 90 DAP were observed in MW tillage in 2016. Volumetric moisture content ranged between 19.85-20.9 in tillage practices and 20.88-21.07 in tillage practices amended with woodash at 90 DAP in the first cropping season. The order of VMC decrease at 45 DAP in 2016 cropping season was MW>FW>RW>MO>RO>FO. Generally, higher moisture content was observed at 45 DAP in both seasons. Results from the study indicated that tillage influences water storage in the soil. Use of wood-ash as soil amendment in the study increased plant increased plant available nutrient in the soil thus increasing

Table 2. Effect of tillage practices and wood-ash on soil bulk density (Mg m^{-3}) at different days after planting

Treatment	30		60		90	
	2016	2017	2016	2017	2016	2017
FO	1.22	1.23	1.32	1.36	1.46	1.53
MO	1.21	1.24	1.30	1.34	1.42	1.50
RO	1.24	1.26	1.34	1.36	1.48	1.54
Mean	1.22	1.24	1.32	1.45	1.45	1.52
FW	1.14	1.20	1.24	1.28	1.40	1.49
MW	1.10	1.18	1.25	1.27	1.20	1.46
RW	1.12	1.21	1.26	1.28	1.38	1.47
Mean	1.12	1.20	1.25	1.28	1.33	1.47
F-LSD (P = 0.05)						
Tillage (T)	0.03	0.04	0.05	0.04	NS	NS
Wood-ash (WA)	NS	NS	NS	NS	NS	NS
T X WA	NS	NS	NS	NS	NS	NS

MW = Mound + WA; FW = Flat + WA; RW= Ridge + WA; FO = Fiat alone; MO = Mound alone and RO= Ridge alone, WA=wood ash. T=Tillage

Table 3. Effect of tillage practices and wood-ash on soil volumetric moisture content (VMC) at different days after planting

Treatment	2016		2017	
	45	90	45	90
FO	24.80	19.87	18.81	22.70
MO	26.60	20.99	17.78	22.00
RO	25.40	19.85	16.83	20.60
Mean	25.60	20.24	18.40	22.43
FW	29.90	20.88	25.30	20.30
MW	31.20	21.00	26.26	20.20
RW	28.00	21.07	22.94	20.80
Mean	29.70	21.19	24.83	20.43
F-LSD (P = 0.05)				
Tillage (T)	2.10	NS	3.45	NS
Wood-ash (WA)	1.41	NS	0.33	NS
T X WA	0.66	NS	1.02	NS

See table 2 for treatment details

plant height and canopy which protected the soil from moisture loss through evaporation, resulting to better edaphic condition for crop. Tillage practices + WA thus conserved soil moisture content which improved crop growth and development. Hamza and Anderson (2002) and Aboudrare et al (2006) reported significant increase in moisture content of different tillage methods relative to the control. Similarly Anikwe et al (2001) reported improved soil moisture content in tillage practices compared to the control. The result of this study differed from those of Lampurlanes et al (2002) who reported non-significant difference in moisture content between different tillage methods.

Soil chemical properties: The difference in soil l properties in WA amended tillage practices were observed in the first cropping season. The effect of the tillage practices alone was non-significant for the two cropping seasons. In 2016, Ca content in RW was higher than in MW, RW, FO, MO and RO. The Mg ranged between 2.4 - 3.8 cmol kg^{-1} in WA amended tillage practices and between 0.6-10.8 cmolkg-^{1} in tillage practices alone. Higher values of Na and K were observed in WA amended tillage practices compared to tillage practices in both seasons. Similarly application of WA to tillage practices showed positive residual effect on soil properties in next cropping season. The order of decrease in soil Ca content in 2017 cropping season was RW>MW>FW>MO>RO>FO. Nottidge et al (2006) reported high EC in wood ash amended soil compared to non-ash amended soil. Similarly, significant difference was observed in pH values in both cropping seasons. Soil pH ranged between 5.6 – 7.0 in 2016 cropping season and 4.9 – 7.3 in next cropping season and indicated WA when used as soil amendment reduced soil acidity. Ojeniyi et al (2001), Odedina et al (2003) and Mbah et al (2017) had shown that wood-ash application leads to remarkable rise in soil pH and cation content. Ayeni et al (2008) observed increased soil pH using cocoa pod ash. The increased pH following addition of ash could be attributed to the increases in negative charge on soil surface and the ratio of negative to positive ions in the colloidal complex. Mbah et al (2010) reported increased soil pH in WA amended plots. Thus, the addition of wood-ash on the tillage practices can contribute to the availability of basic cations, which favoured pH increase (Owolabi et al 2005)

Seed germination: The count of castor seed emergence started at 14 days after planting (Table 5). In 2016, wood ash amended tillage practices had higher seed emergence (40-42%) than tillage practices alone (26-30) at 14 DAP. At 21 DAP, woodash amended tillage practices had 80-87% seed emergence compared to 61-68% observed in tillage practices alone. At 28 DAP the 91-100% seed emergence was observed. The higher seed emergence was observed in wood ash (WA) amended tillage practices compared to non-wood ash(WA) amended tillage practices. At 14 DAP in 2017, seed emergence ranged from 24 -28% in tillage practices and 40-46% in WA amended tillage practices. The order of seed emergence at 28 DAP in 2017 was mound+wood ash (MW) > flat+wood ash(FW)= ridge+ wood ash (RW)> mound only (MO)= flat only (FO)> ridge only(RO).The higher seed emergence observed in WA amended tillage practices could be probably due to higher moisture content observed in this plots. Gul et al (2009) and Khan et al (2017) reported similar findings of higher seed emergence in tillage practices amended with WA compared to non-WA amended tillage practices. In the present study higher seed emergence may be due to increased production of root hairs due to favourable well-tilth soil which enhanced root proliferation, thus facilitating nutrient uptake.

Plant height and yield: The tillage practices only and tillage practices amended with WA significantly increased plant height at 45 DAP in the two planting seasons (Table 6). At 45 DAP, results indicated that plant heights in WA amended tilled plots were significantly taller than non-wood ash amended tillage practices during both season. The influence of tillage practices on plant height was not significant at later stage of plant development (90 DAP) probably because the soil physical condition have reverted to their pre-tillage conditions. At 90 DAP in 2016 plant height in FW was 11, 7, 65, 78 and 65% higher than observed plant height in MW, RW, FO, MO and RO, respectively. The order of plant height increase at 90 DAP in next cropping season was MW> FW,> RW >FO> MO> RO. Soretire and Olayinka (2015) reported increased plant height of cowpea when they used cow dung and wood ash as soil amendment. Similarly, Mbah et al (2010) observed higher maize plant height relative to the control. The results of the present Aihameid (2017) who reported that wood ash amended tillage practices led to higher plant height.

Castor seed yield significantly increased in tillage practices alone and tillage systems amended with WA in both cropping seasons (Table 6). The highest castor yield of 2.36 t ha^{-1} was observed in mound +WA tillage practice in 2016 cropping season. The yield observed in WA +tillage practices ranged between 1.65-2.36 t ha^{-1} while the yield obtained in tillage practices alone ranged between 0.59-0.79 t ha^{-1} in 2016 cropping season. The order of increase in yield in 2017 cropping season was MW>FW >RW>RO>MO>FO.

Table 4. Effect of tillage practices and wood-ash on selected soil chemical properties

Treatment	2016					2017				
	Ca	Mg	K	Na	pH	Ca	Mg	K	Na	pH
FO	2.1	0.8	0.11	0.27	5.8	2.7	0.8	0.08	0.18	5.0
MO	2.2	0.6	0.10	0.28	5.6	2.8	0.8	0.09	0.19	5.1
RO	2.0	0.6	0.10	0.28	5.7	2.8	0.7	0.10	0.15	5.0
Mean	2.1	0.67	0.10	0.28	5.7	2.77	0.8	0.09	0.17	5.0
FW	4.0	2.4	0.16	0.35	7.0	5.6	2.8	0.16	0.28	7.3
MW	8.0	3.8	0.23	0.38	6.8	8.0	5.6	0.11	0.39	7.2
RW	9.6	3.2	0.26	0.37	6.7	12.0	4.0	0.16	0.44	7.0
Mean	7.2	3.13	0.27	0.37	6.83	8.53	4.13	0.15	0.37	7.2
F-LSD (P = 0.05)										
Tillage (T)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wood-ash (WA)	5.7	1.6	0.18	0.06	1.3	6.6	2.8	0.6	0.38	1.0
T X WA	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

See table 2 for treatment details

Table 5. Effect of tillage practices and wood-ash on percent (%) seed emergence of castor at 14, 21 different days after planting

Treatment	2016			2017		
	14	21	28	14	21	28
FO	26	64	94	24	68	93
MO	28	68	92	27	65	93
RO	30	61	91	28	62	92
Mean	28	64.3	92.3	26.3	65	92
FW	42	80	98	40	78	96
MW	45	87	100	46	86	99
RW	40	86	95	43	84	96
Mean	42.3	84.3	97.7	43	82.7	97

See table 2 for treatment details

Table 6. Effect of tillage practices and wood-ash on plant height (m) at 45 and 90 DAP and yield (t ha^{-1}) at DAP

Treatment	Plant height				Plant yield	
	2016	2017	2016	2017	2016	2017
FO	1.15	1.00	1.58	1.52	0.79	0.47
MO	1.18	1.15	1.47	1.39	0.64	0.53
RO	1.20	1.21	1.54	1.43	0.59	0.57
Mean	1.18	1.12	1.54	1.43	0.67	0.52
FW	2.06	1.86	2.61	2.63	2.06	2.54
MW	1.86	2.00	2.35	2.67	2.36	2.69
RW	2.00	1.88	2.10	2.37	1.65	1.95
Mean	1.97	1.91	2.35	2.56	2.02	2.39
F-LSD (P = 0.05)						
Tillage (T)	0.16	0.09	NS	NS	0.10	0.08
Wood-ash (WA)	0.24	0.12	NS	NS	0.39	0.23
T X WA	1.00	0.31	NS	NS	1.00	0.26

See table 2 for treatment details

Generally, recorded yields were higher in WA amended tillage practices compared to tillage practices alone in 2016 and the residual (2017) cropping season.

CONCLUSION

Application of woodash as amendment in the tillage resulted in the improvement in soil physical in tillage practices and chemical properties in tillage practices amended with woodash and are good productivity indicators that lead to increased castor growth and yield. The effect of tillage practices amended with wood ash on soil properties, growth and yield of castor is tillage practice dependent. On the average observed improvement in soil and agronomic parameters were higher in mound tillage amended with woodash (MW) than other tillage practices. Similarly, application of woodash to tillage practices produced a positive residual effect on soil properties and castor yield. Castor production can be improved by use of woodash as soil amendment. Mound tillage amended with woodash is recommended for highest yield. Long term study is recommended to provide site-specific recommendations of the appropriate tillage practices for adoption in degraded Ultisol.

REFERENCES

Aboudrare A, Debacue O, Bouaziz AH and Cheli A 2006. Effects of soil tillage and fallow management on soil water storage and sunflower production in a semi-arid mediteranian climate . *Agricultural Water Management* **53**: 183-196.

Agbede TM and Adekija AO 2011. Evaluation of sweet potato (*Ipome abatata*) performance and soil properties under tillage methods and poultry manure levels. *Environmental Journal Food and Agriculture* **23**(2): 119-127.

Anikwe MAN, Mbah CN and Oluka SI 2001. The effects of seedbed preparation methods on soil physicochemical properties and yield of maize in sandy clay loam. *Proceedings of the International Conference and Annual General Meeting of the Nigerian Institute of Agricultural Engineers* **23**: 175-181.

Anikwe MAN and Nwobodo KCA 2002. Long term effect of municipal wastes disposal on soil properties and productivity in sites used for urban waste disposal in Abakaliki Nigeria. *Bioresources Technology* **83**(3): 241-250.

Anikwe MAN, Mbah CN, Ezeaku PI and Onyia VN 2007. Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (*Colocasia esculentus*) on an ultisol in southeastern Nigeria. *Soil and Tillage Research* **93**(2): 264-272.

Aihameid AA 2017. *Response of Soil Properties to 23-25 years of Diverse Crop Rotation and Tillage Systems in South Dakota, USA*. Theses and Dissertations, South Dakota, USA.

Akinola MO, Ojeniyi SO and Amusan AO 2012. Soil physical properties and soybean yield as influenced by tillage and ash (2008-2010). *Nigeria Journal of Soil Science* **22**(20): 255-259.

Anderson NP, Hart JM, Sullivan DM, Christensen NW, Horneck DA and Pirelli GI 2013. *Applying Lime to Riase pH for Crop Production*. OSU Extension Catalogue, Western Oregon, USA.

Ayeni IS, Adetunji MJ and Ojeniyi SO 2008. Comparative nutrient release from cocoa pod ash, poultry manure and NPK 20:20:10 fertilizer and their nutrient combination inoculation study. *Nigeria Journal of Soil Science* **18:** 114-123.

Blake GR and HartageKH 1986. Bulk density. In A.Klute (eds). *Methods of Soil Analysis. Part 1 American Society of Agronomy* **9**: 365-375.

Bremmer JM and Mulvaney CS 1982. Total nitrogen. In Page AL, Miller, RA, and Keeny D, Reds. *Methods of soil Analysis Part 2 Agronomy Monograph* **9**: 595-624

Gee GW and Bauder J W 1986. Particle size: In Klute A (eds). *Methods of Soil Analysis Part 1, 2 Agronomy Mongraph* **9**: 383-441

Griffith DR, Mannering JO, Gallawa HM, Person SD and Richey CB 1993. Effect of eight tillage planting systems on soil temperature, percent stand, plant growth and yield of corn on five Indian soils. *Agronomy Journal* **65**: 321-326.

Gul B, Marwat KB, Hassan G, Khan A, Hashim S and Khan SA 2009. Impact of tillage, plant population and mulches on biological yield of maize. *Pakistan Journal of Botany* **41**: 2243-2249.

Hamza MA and Anderson WK 2002. Improving soil physical fertility and crop yield on a clay loam in western Australia. *Australia Journal of Agricultural Research* **53**(5): 615-620.

Haynes PJ and Naidu R 1998. Influence of lime, fertilizer and manure content and soil physical condition. A review of nutrient cycling. *Agroecosystem* **51**: 123-137.

Kayode GG and Agbola AA 1993. Investigation on the use of macro and micro nutrients to improve maize yield in southeastern Nigeria. *Liming Resources* **4**: 211-221

Khan S, Shan M, Nawaz M and Khan M 2017. Impact of different tillage practices on soil physical properties, nitrate leaching and yield attributes of maize (*Zea mays* L). *Journal of Soil Science and Plant Nutrition* **17(**1): 240-252.

Khail MC and Hoogmoed A 1993. Soil management for crop production in the west African soils 111 – Emergency, establishment and yield of pearl millet. *Soil and Tillage Research* **25**(4): 301-315.

Lampurlanes J, Angas P and Cantero-Martinez C 2002. Tillage effects on storage during fallow and barley root growth and yield in 3350 science research essays on contrasting soils of semi-arid regions in Spain. *Soil and Tillage Research* **65**(2): 207-220.

Mbah CN, Nwite JN, Njoku C and Nweke AI 2010. Response of maize (*Zea mays* L) to different rates of woodash application in an acid ultisol in Southeastern Nigeria. *African Journal of Agricultural Research* **5**(7): 580-583.

Mbah CN, Njoku C, Okolo CC and Osakwe UC 2017. Amelioration of a degraded ultisol with hardwood biochar; Effects on soil physico-chemeical properties and yield of cucumber (*Cucumis sativus* L). *African Journal of Agricultural Research* **12**(21): 1781-1792.

Miller WR and Donahue RI 1992. *Soils: An Introduction to Soils and Plant Growth.* Prentice Hall, New Delhi, India.

Mclean EO 1982. Soil ph and lime requirement. In Page AL, Miller, RA, and Keeny D, Reds. *Methods of soil Analysis Part 2 . Chemical Amend Microbial Properties. Agronomy Series* **9** ASA, SSSA, Madison WI, USA.

Nelson DW and Sommers IE 1982. Total carbon and organic matter. In Page AL, Miller, RA, and Keeny D, Reds . *Methods of soil Analysis Part 2 Agronomy Monograph* **9**: 539-579.

Njoku C, Alu MO, Okafor OC, Nwite JN and Uchewa EN 2017. Water properties as influence by abattoir wastes in Abakaliki and Ezzamgbo Southeastern Nigeria. Indian *Journal of Ecology* **44**(3): 500-503.

Njoku C and Mbah CN 2012. Effect of burnt and unburnt rice husk dust on maize yield and soil physico-chemical properties of an ultisol in Nigeria. *Biological Agriculture & Horticulture* **28**(1): 49-60.

Nottidge DO, Ojeniyi SO and Asawalam DO 2006. Effect of different levels of woodash on soil chemical properties in an ultisol in southeastern Nigeria. *Nigeria Journal Soil Science* **16**: 109-114.

Nwite JN and Okolo CC 2017. Organic carbon dynamics and changes in some physical and chemical properties of soil and their effect on grain yield of maize under conservation tillage practices in Abakaliki Nigeria. *African Journal of Agricultural Research* **12**(26): 2215-2222.

Odedina SS, Odedina JN, Ayeni S, Arowojo SA, Adedeya SO and Ojeniyi SO 2003. Effect of types of ash on soil fertility, nutrient availability and yield of tomato and pepper. *Nigeria Journal of Soil Science* **15**: 90-95.

Ojeniyi SO, Adekiya AO and Amusan OAC 2012. Three years influence of tillage and poultry manure on soil physical properties and yield of cocoyam. *Nigeria Journal of Soil Science* **22**(2) 119-127.

Okalebo R, Gathua KW and Wooner PL 2002. *Laboratory Methods of Soil and Plant Analysis: A Working Manual*. TSBFCIAT and Sacred Africa, Nairobi, Kenya.

Olsen SR and Sommers LE 1982. Phosphorous In: Method of Soil Analysis. Part 2. (ed) page Miller AL. R.H., Keeney D.R. and Madison W.I. American Society of Agronomy

Owolabi O, Ojeniyi SO, Amodu AO and Hazan K 2003. Response of cowpea, okra and tomato to saw dust ash manure. *Mooe Journal of Agricultural Research* **4**(2): 178 -182.

Soretire AA and Olayinka A 2015. Responses of soybean (*Glycine max* L) to cow dung and woodash application in tropical acid soils of south west Nigeria. *Nigeria Journal of Soil Sci*ence **23**(2): 103-113.

Schneider EC and Gupta SC 1985. Crop emergence as influenced by soil temperature, matrix potential and aggregate size distribution. *Soil Science Society of America Journal* **49***:* 415-422.

Wasaya A, Tahir M, Mana FA, Ahmed M, Kaleem S and Ahmad J 2011. Improving maize productivity through tillage and nitrogen management. *African Journal of Biotechnology* **10**(82):19025-19034.

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Influence of *Pinus kesiya* on Soil Properties

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Abstract: The main aim of the present study was to determine microbial population and to analysis soil physical and chemical properties from rhizospheric and non-rhizospheric soil of *Pinus kesiya*. Microbial population (bacteria, fungus and actinomycetes) was observed higher in rhizoshepric soil compared to non-rhizospheric soil of *P. kesiya*. Among bacteria, fungus and actinomycetes soil microorganism, bacteria were found maximum in rhizosphere and non-rhizosphere soil followed by fungi and actinomycetes. According to soil physico-chemical characteristics analysis, soil rhizospheric showed richer in soil nutrients than the non-rhizospheric soil characteristics. In conclusion, it is evident that *P. kesiya* has ability to influence soil microorganism and improves the soil properties in the ecosystem.

Keywords: *Pinus kesiya*, Rhizosphere, Microbial population, Soil properties

Pinus kesiya Royle ex Gordon belongs to the family Pinaceae and is one of the most dominant plant species distributed in Meghalaya, Northeast India. *P. kesiya* is a tree reaching up to 30–35 m tall with a straight, cylindrical trunk. The bark is thick and dark brown, with deep longitudinal fissures. The branches are robust, red brown and the leaves are needle-like, dark green, cones are ovoid. Oleo resin of good quality is tapped from this tree. Rhizosphere is the zone interaction between living plant root and surrounding soil microbes. It is a unique environment where root and surrounding microbial activities takes place (Bashir et al 2016). Soil microorganisms has influenced by the release of root secreations of high organic nutrients, resulting in changes of soil microbial population and soil properties and are important subsurface components of terrestrialeco systems because they play a central role in nutrient cycling as important decomposers. Among them, some soil microorganisms like fungi play a key role in micro-aggregation of soil particles, thereby enhancing erosion resistance. Therefore, rhizosphere has a vital role in maintaining the ecological balance within the soil environment. Hence, this region provides beneficial for the growth of plants and vegetation in the forest. Previously, many researchers have studied on variety of organic substance release by plant is a key factor influencing the diversity of microorganisms in the rhizospheres of different plant species (Mimmo et al 2014, Jiang et al 2017, Wang et al 2017). Studies were conducted on the soil physiochemical and biological changes (Khan et al 2017, Zhang et al 2019) over the humid tropical regions of the world. Studies of microbial population and physico-chemical soil characteristics of *P. kesiya* of Meghalaya have not been investigated so far. The aims of this study areto estimate the microbial population in the rhizosphere and non- rhizosphere soil and to assess the soil physico-chemical properties of the rhizosphere and non -rhizosphere soil of *P. kesiya*.

MATERIAL AND METHODS

Study area: The study was conducted at Mairang, West Khasi Hills; Meghalaya from September 2017- May 2018 at an altitude of 1563 meter above sea level and geographical lies between 91.63○ 37' 48" E longitudes and 25.57○ 34' 12" N latitudes with mildly warm and more rainier during summer and its very cold and dry during winter. The average annual temperature in Mairang is 15.9°C and average precipitation is 3956 mm. Pre-monsoon rains started from late March with heavy rainfall and continue till September. The winter season can be characterised by low temperature, from cool to cold one. The temperature drops down to a minimum of 1 °C in the early period of January with occasional frost. Sometimes there is rain during the March which is helpful for the germination and development of most of the trees, plants, and herbs.**Collection of the soil:** Samples both from rhizosphere and non-rhizosphere soil were collected from Mairang during September 2017. Soil sample were collected from therhizosphere of *P. kesiya* of Mairang (25°37'12"N latitude and 91°37'48"E longitude) and West Khasi hills district of Meghalaya. The rhizospheric soil was collected from the root depth around 0-30cm from the ground level. Soil from non-rhizosphere (bulk soil) was also taken during the study. After collection soil sample was divided into two parts, one part was for determination of microbial population and another part was to analyse physico-chemical properties of soil.

Estimation of microbial population: Microbial population was analysed by dilution plate technique. 1g dried soil of rhizosphere and non- rhizosphere was serially diluted from 10^1 to 10^6 and 100 µl were plated on the prepared medias: Starch Casein Agar (SCA) for actinomycetes, Potato dextrose Agar (PDA) for fungus and Nutrient Agar (NA) for bacteria supplemented with rose bengal, nalidixic acid, nystatin (50 µg ml^{-1}) to inhibit the contamination by other microorganisms. Inoculated plates were incubated at 28ºC±2ºC in the BOD incubator. Total number of fungal, bacterial and actinomycetes colonies were counted and calculated as.

No. of colonies forming unit growth/ Volume of Broth x Dilution Factor x Conversion factor

Analysis of physico-chemical properties

Soil pH: The pH of soil was determined in soil and water (1:2.5) suspension using pH meter. This method is based on the measurement of electrical potential developed by anelectrode. The pH meter measures the voltage developed by the glass electrode and reference electrode. The scale is graduated in pH units as well as in mill volts. The pH value of the soil pH is a measure of its acidity as the negative logarithm of hydrogenions concentrated in water.

pH= -log10(H+)

Soil moisture content: Soil moisture content (in percent) is expressed as a ratio of the moisture present in the soil to the oven dry weight of the soil. It can be expressed on the dry weight basis, as

Mw= Fresh Weight-Dry Weight/Dry Weight x 100

Where, Mw = moisture content on dry weight basis (%)

Estimation of CHNS: Soil sample of 1-5g was hand-sieved through a 0.5 mm mesh sieve and was oven dried for one night at 120° C. the percentage of carbon, hydrogen, nitrogen and sulphur is dried soil sample were determined by using CHNS elemental analyzer at the Central Instrumentation Lab (CIL), Mizoram University.

Estimation of MPAES: Exchangeable K, Ca, Mg and Na was extracted with 1N ammonium acetate (NH4OAC) (pH 7.0) and determined by using Microwave plasma atomic emission spectrophometer (MPAES Agilent 4100).

Soil texture: Soil texture was determined following the hydrometer method (Bouyoucos 1962). The textural classification according to the United States Department of Agriculture (USDA) was followed to give the textural class of soil.

Determination of microbial biomass carbon: The soil samples for the various treatments were pre-incubated for 7 days at room temperature at 40 per cent moisture holding capacity ofsoil. After that period, chloroform fumigation was carried out. The CO2-C evolved at room temperature (28° C) over the 0-10 days from both control and chloroform fumigated soils was measured by method described by Brookes *et al* (1985).

Determination of carbon content of the root: The roots of the plant were taken to the laboratory and grinded it to powder. To determine the ash content 2g of powder sample was taken in a crucible and kept it in the Muffle furnace at 550° C for 2 hours. After 2 hours the crucibles were taken out and the residue was measured for ash content. Ash content in each sample was calculated as:

Ash content %=(W3−W1)/(W2−W1) × 100

Where, W1= Crucible weight, W2= Crucible + Sample weight,W3= Crucible + Ash content

Carbon content = 100- (Ash % + 53.28%)

RESULTS AND DISCUSSION

Soil health and microbial diversity have become vital issues for the sustainable agriculture program and environment eco-friendly (Kaur and Bhullar 2015). The plant rhizosphere associated microorganisms through various mechanisms, influence plant health and growth. The rate of decomposition and C and N release in the soil was varied with respect to plant litter components. The rate of organic decomposition and C and N release was fastest in leaf and fine root (<2 mm) components compared to branch and root (2-5mm) (Walling et al 2017). Fine roots are the typically primary roots that have function of water and nutrient uptake which are also hotspot for microbial diversity. In the present study, the rhizosphere soil existing characteristic bacterial, fungal and actinomycetes community that was different from that of the non-rhizosphere soil. The bacterial composition (60,000,000^10^4) was dominated in the rhizosphere soil followed by fungal (4,000,000^10^4) and actinomycetal communities (2,000,000^10^4). While in bulk soil, bacterial communities (30,000,000^10^4) were dominant followed by both fungal (1,000,000^10^4) and actinomycetal (1,000,000^10^4) (Table 1). Pinus *kesiya* rhizosphere zone may be rich in nutrients for microbes when compared to the non-rhizopsheric soil. It is well established that the bacteria population in the rhizosphere are higher than the bulk soil (Bahadur et al 2017).

The pH in the rhizosphere soil was much more acidic than the pH in the bulk soil (Table 2). The high acidity of the soil in the rhizosphere may be due to root exudation of the *P. kesiya*. The rhizosphere soil shows more organic carbon than that of the bulk soil (Table 2). Soil organic carbon were recorded significantly higher in cultivated land in surface soil (Kumar et al 2017). This may be due to the dense vegetation of *P. kesiya* which resulted in accumulation of litters on the

Table 1. Determination of microbial population

Plant species	Soil type	Microbial population		
Pinus kesiya		Fungus ml^{-1}	Bacteria ml^{-1}	Actinomycetes ml^{-1}
	Rhizosphere	4,000,000^10^{4}	60,000,000^10^{5}	2,000,000^10^{4}
	Non-rhizosphere	1,000,000^10^{4}	30,000,000^10^{5}	1,000,000^10^{4}

Table 2. Physical and chemical properties of rhizosphere and non-rhizosphere soil (Mean ±SE)

Soil properties	Rhizosphere soil	Non-rhizosphere soil
pH	3.7±0.01	4.99±0.1
Moisture content (%)	39.96±0.5	37.24±0.1
Organic Carbon (%)	2.55±0.08	2.22±0.06
Nitrogen (%)	0.624±0.01	0.574±0.01
Phosphorous (%)	0.0094±0.07	0.0012±0.00
Potassium (meq 100g^{-1})	1.72±0.00	0.88±0.00
Sodium (meq l^{-1})	0.06±0.00	0.02±0.00
Calcium (meq l^{-1})	0.17±0.00	0.07±0.00
MBC (mg kg^{-1})	413.034±2.4	241.511±4.5
Texture (%) Silt Sand Clay	17.67	17.22
	43.33	42.33
	(43.33)	46.00

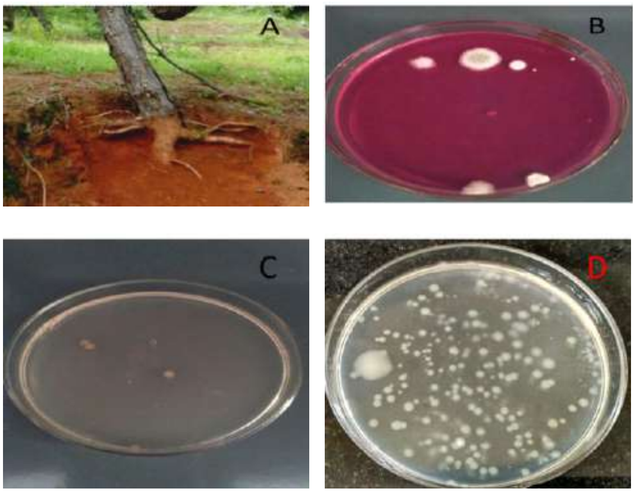

Fig. 1. A-*Pinus Kesiya*, B-Fungus population plate, C-Actinomycetes population plate, D- Bacteria population plate

ground and due to decomposition of the litter by the microoraganisms present in the soil. The rhizospheric soils show that the present of total nitrogen and soil moisture is higher than that of the bulk soil can be due to the organic matter and higher leaf litter accumulation in the forest floor. Higher content of nitrogen at the surface soil layer could be credited to the higher amount of organic matter at the surface soil layer as it leads to the increment of mineral is able nitrogen and phosphorus. The available phosphorous present in the rhizosphere soil was much higher than that in the bulk soil (Table 2).Phosphate is relatively immobile, and this may be the reason for the little variations noted along the depths. Exchangeable potassium, sodium and calcium is higher at the rhizosphere soil than the bulk. Gadermaier et al (2011) reported that the soil potassium was higher in the surface soil suggesting that it gets accumulated at the surface soil layer and it is closely related to the organic carbon of the soil.MBC was higher in rhizospheric soil and lower in bulk soil (Table 2). Previous studies also showed that the amount of root exudates released was positively correlated with microbial growth and SOC decomposition (Phillips et al 2011; Bengtson et al 2012). Rhizosphere of *P. kesiya* may be able to provide their favourable nutrients for surrounding microorganisms. Mean percentage of silt and sand was observed to be higher for rhizospheric soil than bulk soil. The mean percentage clay was seen tobe higher in the bulk soil (46%) (Table 2).

The rhizosphere soil properties are known to be influenced by the release of root exudates (Jones et al 2009). Therefore, rhizospheric microbial population is distinguished from the bulk soil. The chemical and physical properties of rhizosphere soils were lower than bulk soils. The results suggested that compounds released from *P. kesiya* roots into the soil may have great influenced soil microbial community and change its chemical and physical quality of the soil.

CONCLUSION

The soil microbes were closely associated with the rhizosphere of *P. kesiya* and microbial community composition reflected positive rhizosphere effect. Furthermore, level of soil properties in the rhizosphere soil of *P. kesiya* was observed higher than the nonrhizopshere soil. This may be due to their differences in root exudation of *P. kesiya*. The result of this study supports a significant role of rhizosphere of *P. kesiya* in influencing microbial population and changes soil properties. The introduction of *P. kesiya* may thus be able to improve soil fertility and microbial activity in the unfavourable soil conditions for enhancing sustainable agriculture crop production.

REFERENCES

Bahadur I, Maurya BR, Meena VS, Saha M, Kumar A and Aeron A 2017. Mineral release dynamics of tricalcium phosphate and waste muscovite by mineral-solubilizing rhizobacteria isolated from indo-gangetic plain of India. *Geomicrobiology Journal* **34**(5): 454-466.

Bashir O, Khan K, Hakeem KR, Mir NA, Rather GH and Mohiuddin R 2016. *Soil Microbe Diversity and Root Exudates as Important Aspects of Rhizosphere Ecosystem*. Springer International Publishing Switzerland 2016 K.R. Hakeem, M.S. Akhtar (eds.), Plant, Soil and Microbes, DOI 10.1007/978-3-319-29573-2_15.

Bengtson P, Barker J and Grayston SJ 2012. Evidence of a strong couplingbetween root exudation, C and N availability, and stimulated SOM decomposition caused by rhizosphere priming effects. *Ecology and Evolution* **2**: 1843–1852.

Bouyoucos GJ 1962. Hydrometer method improvement for making particle size analysis of soils. *Agronomy Journal* **54**: 179-186.

Brookes DC, Landman A, Pruden G and Jenskinson DS 1985. Chloroform fumigation and the release of soil nitrogen: a rapid direct extraction method for measuring microbial biomass nitrogen in soil. *Soil Biology and Biochemistry* **17**: 837-842.

Gadermaier F, Berner A, Fließach A and Kurt J 2011. Impact of reduced tillage on soil organic carbon and nutrient budgets under organic farming. *Renewable Agriculture and Food Systems* **27**: 68-80.

Jiang J, Song Z, Yang X, Mao Z, Nie X, Guo H and Peng X 2017. Microbial community analysis of apple rhizosphere around Bohai Gulf. *Scientific Reports* **7**: 8918.

Jones DL, Nguyen C and Finlay RD 2009. Carbon flow in the rhizosphere: Carbon trading at the soil-root interface. *Plant Soil* **321**: 5-33.

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Kaur M and Bhullar MS 2015. Changes in soil microflora with herbicides application in autumn sugarcane based intercropping systems. *Indian Journal of Ecology* **42**(1): 156-159.

Khan T, Mahbub MDA, Mitra S, Ali NM, Biswas A, Islam T and Saha ML 2017. Rhizosphere associated bacteria and soil physicochemical properties of tea garden. *Bangladesh Journal of Botany* **46**(4): 1389-1396.

Kumar A, Singh YK, Padbhushan R and Kohli A 2017. Effect of land use on fertility status of some old alluvial soils of eastern India. *Indian Journal of Ecology* **44**(2): 210-216.

Mimmo T, Buono DD, Terzano R and Tomasi N 2014. Rhizospheric organic compounds in the soil-microorganism-plant system: Their role in iron availability. *European Journal of Soil Science* **65**(5): 1-14.

Phillips RP, Finzi AC and Bernhardt ES 2011. Enhanced root exudation induces microbial feedbacks to N cycling in a pine forest under long-term CO_2 fumigation. *Ecology Letters* **14**: 187–194.

Walling W, Haucchum R and Tripathi SK 2017. Litter decomposition vis-a-vis carbon and nitrogen dynamics of *Tephrosia candida* components in different fallow periods following shifting cultivation in Mizoram. *Indian Journal of Ecology* **44**(4): 791-796.

Wang Z, Li T, Wen X, Liu Y, Han J, Liao Y and DeBruyn JM 2017. Fungal communities in rhizosphere soil under conservation tillage shift in response growth. *Frontiers in Microbiology*.

Zhang M, Wang N, Zhang J, Hu Y, Cai D, Guo J, Wu D and Sun G 2019. Soil physicochemical properties and the rhizosphere soil fungal community in a mulberry (*Morusalba* L.)/ alfalfa (*Medicago sativa* L.) intercropping system. *Forests* **10**: 167.

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Phosphorus Fractionation in Some Calcareous Soils in Sulaimani Gogveronrat, Kurdistan, Iraq

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Abstract: Information of phosphorus (P) fractions are important for evaluation of their status in soil and understanding of soil chemistry that influence soil fertility. To obtain such information, forms, amounts and distribution of P in different fractions of 30 calcareous soil samples from Sulaimani province, Iraq were determined by sequential extraction method and their relationships with each other and with soil characteristics were investigated. Phosphorous were separated into 5 pools: loosely bound (and pore water, L- P) P, redox-sensitive P (bound to iron and manganese), P bound to oxides of aluminum and non-reducible Fe, calcium-bound P, and mobile and immobile pools of organic P. The active $CaCO_3$ in soils ranged between the 28g ^{1}and 58 g $kg^{-1}$and the clay content ranged from 33 to 591 g kg^{-1}. The content of free iron oxides were low (6.54 g kg^{-1}).The average amount of total P was 2204 mg kg^{-1} soil. The amount of available P extracted by Olsen's method varied between 2.44 and 7.24 mg L^{-1}, while the labile P (L-P) from 130 to 897 mg kg^{-1}. The results showed that these calcareous soils were dominated by calcium P phases. The order of average extracted P was in the order NaOH-P (462.5 mg kg^{-1}) > Fe-P (422.6 mg kg^{-1}) > L-P (348.4 mg kg^{-1}) > Ca-P (335.2 mg kg^{-1}) > HCl-P (284.3 mg kg^{-1}).

***Keywords*:** Total phosphorus (P), Organic P, Available P, Calcium P, iron P. Sequential

Phosphorus (P) is an essential element for plant growth and maintenance of an adequate amount of soil P through an application of inorganic and/or organic P is critical for the sustainability of cropping systems. The availability and fractions of soil P may change due to long-term continuous P fertilization besides its yield increasing effect (Fan et al 2003, Lai et al 2003). Total and available phosphorus have been extensively carried out but little work is done on the distribution of the various discrete chemical forms of inorganic phosphate. The distribution of various forms of inorganic phosphorus in soils is affected by the activities of different ions in the soil, pH, age, drainage, fertilizer practices and mineralogical nature. In calcareous soils, soil inorganic P (Pi) represents the dominant component of the soil P pool in calcareous soils. Soil Pi was divided into various fractions such as Ca-P (HCl extractable P), Fe- and Al-P (non-occluded Fe- and Al-bound P), and occluded P However, in calcareous soils, the majority of Piexists in the various Ca-bound forms and there was a great difference in P availability among the Ca-P fractions. To better characterize Pi transformations, using a sequential extraction procedure, based on their availability and solubility. A wide variety of extraction procedures for soil and sediment P have been developed, varying with the aim of the study and the P fractions targeted (Lukkari et al 2007). The P forms commonly separated include soluble and loosely sorbed (labile) L-P, redox-sensitive iron (Fe) , aluminum (Al) bound P, and non reducible Fe (surface-bound), calcium (Ca)-bound P (apatite-P), and organic P. The aim of investigation is to identify the organic and inorganic pools of phosphorus, total P, and to characterize soil P reserves by using different extraction method and to assess the validity of a phosphorus fractionation procedure, in chemical characterization of soil P.

MATERIAL AND METHODS

The experiment was Bakrajo, University of Sulaimani, Iraqi Kurdistan Region, during July 2015 to June 2016. The calcareous soils in this investigation were collected from fields in Sulaimani governorate, Kurdistan region Iraq, where crop plants had responded to phosphorus fertilization (Fig. 1, Table 1). The soils were taken from (0-15) cm and (15-30) cm depths and l samples were air dried, grind and sieved to pass through 2mm sieve and stored in the plastic container for further analysis. Particle size distributions were determined according to international pipette method with removing carbonate (Kilmer and Alexander 1949). Soil pH was measured in 1:5 soil-water suspensions with a glass electrode (Jackson 1958) by using a Microprocessor pH meter model-pH 211-HNA Com. Italy. Electrical conductivity of soil extract (ECe) was measured in 1:5 soil-water dilution (Rahi et al 1991), by using EC meter, and model WTW 82362 Weilheim, Germany, after being adjusted to 25 °C.Soil organic matter was determined by Walkley and Black method as described by Richards (1945). Total calcium carbonate was determined with 1M HCl, and the excess of HCl was titrated with 1 M NaOH by using phenolphthalein indicator (Richards 1954). Active calcium carbonate was determined titremetrically using Droulinean procedure (Kozhekov and Yokovleva 1977). The extraction procedure used in this study principally follows the classical method of Chang and Jackson (1957) as modified by Lukkari et al (2007) and involved five fractionation steps.

RESULTS AND DISCUSSION

Soil pH ranged from7.02 to 8.42 with the average value 7.79. The soil reactions were slightly alkaline and this may be due to parent material rich in carbonate materials (Table 1). The soil pH was lower at the surface than sub-surface and this may be due to leaching processes. The results of electrical conductivity (ECe) indicated that all soil samples were non-saline soils because ECe of < 2 dS m^{-1} as to limits set proposed by Schoeneberger et al (2002). The values of EC ranged from 0.18 to 0.59 dS m^{-1} and the organic matter content ranged from 18.3 to 62.5 g kg^{-1}. There was little variation in the organic matter content between soils except for soil of surface layer from Halabja and this may be due to higher plant residue input on the soil surface and/or presences of root intense and activity (Abdalla 2014).The total carbonates were in high amounts and increased with soil depth which reflected the calcareous parent materials. The values of total $CaCO_3$ ranged between 82 and 318 g kg^{-1} soil. The active $CaCO_3$ showed the same pattern as the total carbonate distribution, which increased with soil depth. This type of distribution might reflect the sequence of decalcification and calcification processes within each soil sample. Free iron oxide ranged from 1.47 to 11.90 g $kg^{-1}$and increased with soil depth. The difference may be as a result of the variation in Fe content in parent rocks that soil had been developed.

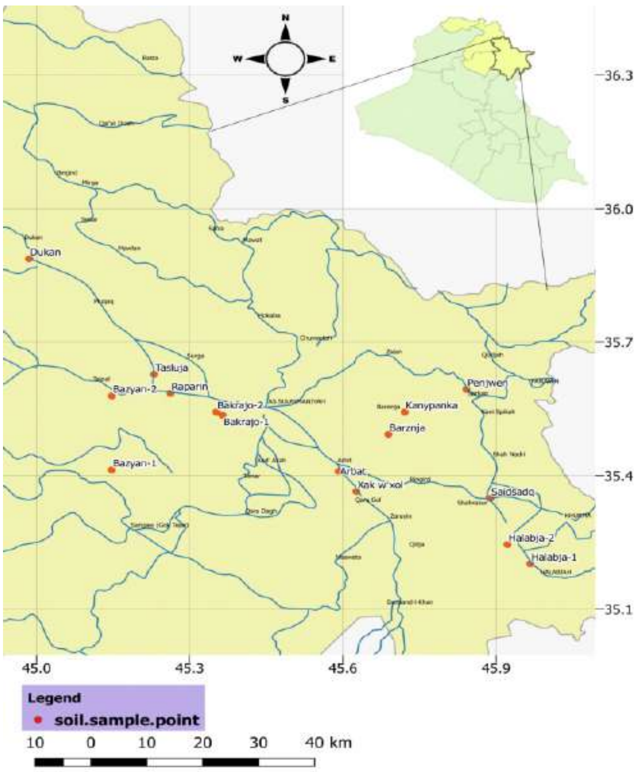

Fig. 1. Location map of the study area

Particle size distribution and texture classes indicated that the soil texture classes were predominantly ranged from loamy to clayey. The sand fraction ranged from 12.7 to 428.7 g kg^{-1} while the silt content ranged from 373 to 894.1 g kg^{-1}. Clay content ranged from 32.9 to 591.7 g kg^{-1} with the average 339.07 g kg^{-1}.The average of available P was 4.66 mg L^{-1} and high amount of available P was in soil from Halabja (1) (soil 3), and this may be due to high organic matter content. Generally, the P availability was higher in the surface soil as compared to subsurface soil and this may be due to higher fresh organic matter input and/ or higher root plant activity in the soil surface. There was a positive significant correlation between organic matter and available P in the study soils. The decreasing the pH value of the soil may cause an increase in P availability especially in alkaline soil. On the other hands, the coating of Fe and Al particles, by humus a positive cover, may reduce P adsorption. Total P ranged from 1405.6 and 3251.75 mg kg^{-1} soil (Table 2). The most of the soils containing a similar amount of total P with except soil No 15,which they have a much higher total P in the surface and subsurface. The values of total P in surface soils were slighter higher than subsurface soils, but only at three locations the values of total P in subsurface soil more than the values of total P in surface soil. This variation in the distribution of P within the soil depth may be due to the different rates of fertilization that had been added to the soils before the cultivation and /or it may be due to different plants uptakes or different amount of $CaCO_3$content.

The sequential extraction of P showed that in the 1st step, the soil sample was extracted with 0.46 M NaCl for 1 h to extract loosely adsorbed and pore water P (presented in results as L-P). The average was 417.54 and 279.24 mg kg^{-1} in soil surface and subsurface soils (Table 2). The L-P were higher in the most soil surface depth and maximum was in 897.4 mg kg^{-1} in the surface soil of Bazyan (1) area (soil 7) which was cultivated with cucumber crop. This may be due to the high addition of P fertilizer during growing season and the soil showed high content of available and total P in all soil samples. The L-P values in the subsurface soils were nearly very close to each other with little variation in the P content. Relationships between L-P and soil properties showed that it correlated negatively with clay and free Fe content. Nevertheless, it correlated positively with total and active carbonate and silt content (Table 3). The clay was the best variable to describe L-P variation. The L-P was highly positively correlated with total carbonate, while the correlation was very low between L-P and active carbonate. But, there were highly negatively correlated between L-P and clay content. In addition, the L-P was poorly negative significant correlated with total free Fe content and silt content. The L-P was not correlated with pH and OM. This indicates that the clay content might control the level of L-P in the soil solution and the variation may be due to the reactivity of clay minerals. The reactivity of clay content depends on the amount, type and the charge of the clay minerals present in soils.

The average P bound to hydrated oxides (Fe-P) was 422.42 and 422.8 mg kg^{-1}in the soil surface and , subsurface soil (Table 2). The values of Fe-P were higher in the most soil surface and the highest value was in the surface soil of Tasluja area (soil 10). This may be due to reactivity free Fe and Mn oxides and/or oxy hydroxides which depend on the type, size, and degree of crystalinity. On the other hands, the presences

Table 1. Some physicochemical properties of soil samples from Sulaimani province, Iraq

Soils		pH	ECe dS m^{-1}	OM (g kg^{-1})	Free Fe (g kg^{-1})	Carbonate		Soil particles (g kg^{-1})			Texture classes
No	Depth (cm)					Total	Active	Sand	Silt	Clay	
1	0-15	7.62	0.36	36.7	5.35	190	33	20.9	387.4	591.7	C
2	15-30	7.80	0.41	31.9	5.56	194	34	19.1	415.3	565.6	SiC
3	0-15	7.67	0.2	21.7	11.31	114	37	12.7	397.5	589.8	C
4	15-30	7.66	0.32	20.4	8.58	86	34	19.0	392.8	588.2	C
5	0-15	7.94	0.59	62.5	5.51	318	38	233.4	688.5	78.1	SiL
6	15-30	7.98	0.37	26.5	8.18	202	38	52.3	723.7	224.0	SiL
7	0-15	7.91	0.22	29.9	8.26	90	34	26.6	409.0	564.4	SiC
8	15-30	7.91	0.18	25.8	8.11	106	58	28.6	380.7	590.7	C
9	0-15	7.61	0.19	21.7	11.90	82	32	140.7	416.3	443.0	SiC
10	15-30	7.96	0.19	21.0	11.22	90	36	130.4	413.2	456.4	SiC
11	0-15	7.72	0.31	29.2	7.04	178	38	43.2	783.3	173.5	SiL
12	15-30	8.13	0.27	26.5	8.51	186	36	36.7	433.2	530.1	SiC
13	0-15	8.00	0.40	29.2	4.12	282	44	165.3	744.4	90.3	SiL
14	15-30	7.82	0.36	24.4	4.64	314	50	100.3	468.2	431.5	SiC
15	0-15	8.11	0.23	25.1	4.75	270	38	115.9	694.2	189.9	SiL
16	15-30	8.42	0.23	23.8	4.87	222	41	109.2	561.1	329.7	SiCL
17	0-15	8.00	0.34	19.0	3.82	162	34	431.5	404.0	164.5	L
18	15-30	8.10	0.30	18.3	3.70	174	33	428.7	373.0	198.3	L
19	0-15	7.40	0.23	27.8	6.16	218	38	274.8	442.4	282.8	CL
20	15-30	7.93	0.21	21.0	1.47	226	28	250.6	430.5	430.5	CL
21	0-15	7.77	0.20	29.9	5.23	170	43	24.5	421.5	554.0	SiC
22	15-30	8.02	0.20	28.5	6.06	190	34	31.8	490.3	477.9	SiC
23	0-15	7.12	0.20	21.0	7.10	206	43	73.0	894.1	32.9	Si
24	15-30	7.33	0.22	18.3	7.45	226	36	44.1	678.3	277.6	SiCL
25	0-15	7.82	0.21	29.9	6.21	202	43	138.5	808.3	53.2	Si
26	15-30	7.88	0.24	28.5	6.34	266	40	46.3	630.5	323.2	SiCL
27	0-15	7.02	0.24	22.4	6.38	210	48	45.4	681.4	273.2	SiL
28	15-30	7.94	0.23	21	6.81	218	43	40.5	657.3	302.2	SiCL
29	0-15	7.47	0.26	38	5.72	186	38	325.5	424.6	249.9	L
30	15-30	7.93	0.27	35.3	5.96	190	46	328.5	445	226.5	L

of fresh OM, which inhabited the crystallization of Fe oxides resulted in presences of ferrihydrite, which is more active than goethite and/or hematite, which are the most common Fe-oxides in soils. Fe-oxides usually exist in soils as discrete compounds, as coatings on soil particles, or as amorphous Fe hydroxyl compounds. the Fe oxides, and especially goethite, are very important in phosphate adsorption in soils. Goethite was usually carrying one singly coordinated OH per unit cell surface area. This would amount to a binding capacity which could easily coordinate with P while hematite did not contain any functional group (OH). Hematite mineral was dominated minerals present in arid and semi-arid soil (Schwertmann 2008). The oxide and hydrated oxide surfaces of Fe play a major role in phosphate adsorption in neutral soil.

The present study indicate that NaBD may extract some P from surfaces of $CaCO_3$ particles. Jensen et al (1998) also concluded that the specificity of the NaBD step for Fe-bound P decreased with increasing $CaCO_3$ content. Part of P in the NaBD- extractable pool might originate in the Ca-bound form and could cause overestimation of the content of Fe-P The findings of Lukkari et al (2007) support the assumption that NaBD is selective in distinguishing between the reducible and nondeductible metals. The statistical analyses between NaBD-P and total free Fe, pH, OM, silts, clay and carbonate equivalents showed that there was no significant correlation between NaBD-P and some soil properties (Table 3). This

Table 2. Phosphorus fractionation of studied soil samples (mg kg^{-1})

Location	Soil depth	L-p	Fe-P	NaOH-p	Ca-P	HCl-P	Accumulative –P	Total-P	% P recovery
1	0-15	385.9	594.5	412.4	644.5	203.9	2241	2979	75
2	15-30	135.7	477.3	292.5	530.9	22.1	1458	2017	72
3	0-15	289.0	397.0	469.3	209.9	20.0	137	2011	69
4	15-30	129.9	237.7	736.0	302.4	173.9	1415	2318	68
5	0-15	544.5	54.4	251.6	397.5	620.2	1868	2429	77
6	15-30	211.3	484.6	167.7	533.8	165.1	1563	2104	74
7	0-15	249.9	348.1	868.3	343.7	33.9	1844	2066	89
8	15-30	328.3	517.3	646.0	40.6	309.9	1896	2049	90
9	0-15	240.4	483.1	746.1	50.7	138.9	1659	2014	82
10	15-30	239.9	272.4	851.3	119.7	15.0	1483	1953	77
11	0-15	446.9	502.6	310.7	478.4	60.8	1799	2117	85
12	15-30	208.5	296.1	646.3	191.2	326.2	1668	2039	82
13	0-15	897.4	704.9	404.5	233.8	346.0	2586	2818	92
14	15-30	466.0	577.9	377.5	49.7	395.0	1867	2289	82
15	0-15	620.8	348.5	13.42	410.8	347.2	1768	2269	77
16	15-30	419.2	322.6	64.8	254.6	744.8	1806	2130	85
17	0-15	263.1	300.9	543.3	348.3	830.4	2286	2207	103
18	15-30	259.3	408.6	221.1	20.74	362.2	1272	1406	90
19	0-15	269.7	760.8	294.5	145.0	418.8	1889	1953	97
20	15-30	337.9	746.6	103.0	14.1	306.1	1508	1565	96
21	0-15	313.6	330.0	427.9	523.4	388.4	2083	2133	93
22	15-30	324.3	525.2	545.7	261.1	13.0	1687	2085	80
23	0-15	391.5	283.9	398.9	789.1	373.8	2237	2763	81
24	15-30	220.4	233.7	208.6	434.4	316.6	1414	1529	92
25	0-15	505.9	514.2	609.9	341.4	310.9	2282	2357	97
26	15-30	288.7	222.0	650.4	423.7	284.9	1870	1879	100
27	0-15	416.6	273.9	573.1	510.6	187.9	1964	2104	93
28	15-30	296.5	559.8	501.5	401.9	212.0	1972	2217	89
29	0-15	416.9	439.1	784.0	576.6	380.1	2659	3100	84
30	15-30	304.7	370.1	756.0	374.8	230.2	2036	3252	63

may be due to the low present of reducible Fe and Mn minerals in these soils since the soils were present in the arid area, low in organic carbon and alkaline reaction. The soils of these areas were young and not highly developed soil and the free Fe content was being very low. The NaOH-P values varied from 13.42 to 868.26 mg kg^{-1} with an average 473.86 mg kg-1 in the soil surface, while the value ranged from64.76 to 851.26 mg kg^{-1} with average 451.23 mg kg^{-1} in subsurface soil (Table 2). The values of O-P were higher in the most soil surface and the highest value of O-P was 868.26 mg kg^{-1} found in the surface soil of Halabja (2) area (soil 4). This may be due to the highest amount of OM content on the soil surface than the subsurface soils and the NaOH extraction was mainly extracted Po during the procedure. Part of the Pi extracted in NaOH might be bound by non-reducible Fe oxides present in small amount, and some of it might be bound to Fe complexes with a humic material. The most of the fractionation sequences for calcareous soils extracted with NaOH attributed to Fe- and Al-P and this fraction constituted a small fraction of P in calcareous soils (Adhami et al 2007). The NaOH-P constituted a 20.97 per cent of O-P and may be a portion of Pi, which usually constituted lower proportion in a neutral to slightly basic soils but constituted ahigher portion of Pi and Po in more acidic.

The statistical analysis shows that the relationship between NaOH-P and soil properties were positively correlated with total free Fe, clay, OM and active carbonate; while it was negatively correlated with total carbonate, silt and pH (Table 3). The NaOH-P was highly significant correlated with total free Fe content and total $CaCO_3$. This may be due to remove P bound to the surface Fe and Al minerals, and OM which can be extracted with NaOH solution. Tyler (2002) studying 110 soils of northeast Sweden observed that Fe-P fraction constituted about 50 per cent of inorganic P in most acid soils but less than 1% in moderately alkaline (calcareous) soils.

The extraction was used to extract Ca-P, mainly from apatite minerals (Ca-P). The HCl was assumed to extract P from the surfaces of apatite minerals and dissolve some other Ca-containing minerals. The results of extraction with 0.5 MHCl indicate that values for surface soil varied from 50.70 to 789.08 mg kg^{-1} while subsurface soil ranged from 14.06 to 533.84 mg kg^{-1}. The Ca-P was higher in the most soil surface and the highest value (789.08 mg kg^{-1}) was in the surface soil of Arbat area (soil 12). The very high P in the HCl extracts suggests that carbonates may be dominant over apatite. The statistical analysis showed relationships between Ca-P and soil properties correlated positively with silt, total and active carbonate, and organic matter, while it correlated negatively with clay, total free Fe and pH (Table 3). The Ca-P was significant correlated with pH and silt content. The detrital apatite varied from zero to 830.4mg kg^{-1} in soil surface and zero to 744.8 mg kg^{-1} in subsurface soil. The values of HCl-P were higher in the most soil surface, and the highest value of HCl-P (830.4mg kg^{-1}) was in the surface soil of Dukan area (soil 9). This may be due to the variation in the carbonate content and/or different surface area of silt content (g kg^{-1}) carbonate minerals, and it may be due to the different rates of added fertilizers every year. These values were generally higher than the value for soils of Iran. Adhami et al (2007) reported that the average content of HCl-P in 16 calcareous soils of Iran was 125 mg kg^{-1}. Saavedra and Delgado (2005) observed that the average content of HCl-P in 17 agricultural soils of South West Spain was 14 mg kg^{-1}. It was believed that P extracted with a dilute acidic solution (e.g. 0.25 MHCl*)* was primary Pminerals such as hydroxyl fluorapatite (Adhami et al 2007).

The HCl extraction (HCl-P) was associated with Ca phosphates and the primary mineral apatite in the soil. Hence, in neutral to alkaline soils, P ions will rather precipitate as Ca-P: dicalcium or octa calcium phosphates, hydroxyl apatite and eventually least soluble apatites, and 1 M HCl extracts Pi associated with apatite or octa calcium P. Residual-P is the most recalcitrant and includes the occluded forms of Pi (Berg and Joern2006, Tiessen and Mior 2008). The residual P calculated by the difference between total Pextracted by fusion and total accumulated P extracted by five sequential steps and ranged from zero to 37.63 per cent. The proportion of residual P present in the studied soils may depend entirely on the rate of added P every year, physical and chemical properties of soils and periods of fertilizer applications especially long time. The rate of P applied typically influences the changes in the various soil P fractions. Zhang et al (2004) determined that the R-P increased with increasing rate of fertilizer on soils. Also, at high rates of manure application, the more recalcitrant fractions of soil P can accumulate (Zheng et al 2004, Kuo et al 2005). In order to better comprehend patterns in sequential extraction schemes, fractions are generally expressed as a proportion of total recovery for P. The abundances of the principal P compounds expressed as percentages of total P in the soil, soils were fractionated according to the procedure described by Lukkari et al (2007). Recoveries of P were considered not to be good, for most of the soils. The percent total recovered P ranged from 62.61 to 103.60 per cent and indicated that the R-P might be 15 per cent on average which may be occluded in minerals that cannot be extracted by HCl extraction. The mean of L-P was 348.39 mg kg^{-1}, which accounted for 15.80 per cent of the sum of the fractions. The proportion of L-P values ranged from 5.60 to 31.85 per cent of total P. The amount and percentage of this fraction were obviously much higher than those reported by (Adhami et al 2007) for 16 calcareous soils of the south of Iran. This may be due to the addition of P fertilizer every year these results were in agreement with results of many researchers had found that soil P availability would increase after long-term P fertilizer application (Zhang et al 2004). The highest proportion of Pi extracted with HCl, which was associated with Ca, an account on average (29.22%) of total P present in soils (Fig. 2). These values of Ca-P were low, because the studied soils were calcareous. The average value of Ca-P percent in soils was (15.20%). In the presence of Ca the formation of mono-, di-, and tricalcium phosphate minerals would be dominated form of P in the calcareous soils. On the other hands, the proportion of O-P present in the calcareous soil in arid soil usually was very low. The average value of O-P percent in the studied soils was (20.77%), but this may be higher because NaOH may extract some of the Fe-P.

Table 3. Simple correlation coefficients (R) between inorganic P-fractionations and soil properties of studied soil samples

Soil properties	L-P	Fe-P	O-P	Ca-P	HCl-P
pH	0.094ns	0.031ns	-0.167ns	-0.418ns	0.212ns
Clay	-0.533**	0.070ns	0.033ns	-0.209ns	-0.461**
Silt	0.520**	-0.134ns	-0.333ns	0.409*	0.100ns
Organic matter	0.324ns	-0.184ns	0.24ns	0.289ns	0.141ns
Total free Fe	-0.403*	-0.256ns	0.531**	-0.077ns	-0.548**
Total Lime	0.589**	0.044ns	-0.587**	0.164ns	0.545**
Active lime	0.344*	0.031ns	0.122ns	0.031ns	0.150ns

ns = not significant; * = significant at 0.05; ** = significant at 0.01

Table 4. Simple correlation coefficients (R) between phosphorus fractionations

	L-P	Fe-P	NaOH-P	Ca-P	HCl-P	Accumlated total P
L-P	1					
Fe-P	0.21ns	1				
NaOH-P	-0.269ns	-0.185ns	1			
Ca-P	0.061ns	-0.311ns	-0.057ns	1		
HCl-P	0.29ns	-0.186ns	-0.348*	-0.234ns	1	
Accumulated total P	0.48*	0.143ns	0.171ns	0.368*	0.142ns	1
Total P	0.427*	0.030ns	0.288ns	0.49*	0.103ns	0.606**

ns = not significant; * = significant at 0.05; ** = significant at 0.01

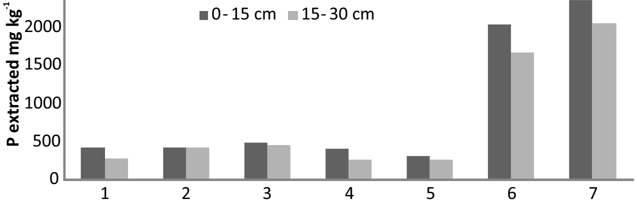

Fig. 2. Distribution of percentage sequential phosphate extracted from the studied soils samples

CONCLUSION

The high content of available and total phosphorus in all samples and this may be due to high addition of P fertilizer during the growing season. The available form correlated positively with total and active carbonate and negatively correlated with the clay content. This indicates that the clay content might control the level of P in soil solution. In the sequential extraction highest proportion of inorganic phosphorus was associated with calcium mainly as di-, tri, and octa calcium phosphate in addition to autogenic apatite. The organic phosphorus present in these calcareous soils was very low.

REFERENCES

Abdalla Zh O 2014. *Characterization and Classification of soils and land use suitability in Some Selected area from Iraqi Kurdistan region. Master thesis*. Soil and Water Sciences Department, University Sulaimani, Iraq: pp 150.

Adhami E, Memarian HR, Rassaei F, Mahdavi E, Maftoun M, Ronaghi AM and Fasaei RG 2007. Relationship between phosphorus fractions and properties of highly calcareous soils. *Soil Research* **45**(5): 255-261.

Berg A and Joern B 2006. Sorption dynamics of organic and inorganic phosphorus compounds in soil. *Journal of Environmental Quality* **35**(5):1855-1862.

Chang S and Jackson ML 1957. Fractionation of soil phosphorus. *Soil Science* **84**(2): 133-144.

Cornell R and Schwertmann U 1979. Influence of organic anions on the crystallization off errihydrite. *Clays and Clay Minerals* **27**(6): 402-410.

Fan J, Hao MD and Wang YG 2003. Effects of rotation and fertilization on soil fertility on upland of loess plateau. *Research Soil Water Conservation* (in Chinese) **10**(1): 31-36.

Jackson M 1958. Phosphorus determination for soils. *Soil Chemical Analysis* 134-182.

Jensen HS and Thamdrup B 1993. Iron-bound phosphorus in marine sediments as measured by bicarbonate-dithionite extraction. Proceedings of the *Third International Workshop on Phosphorus in Sediments*: *Springer*, 47-59.

Kilmer VJ and Alexander LT 1949. Methods of making mechanical analyses of soils. *Soil Science* **68**(1): 15-24.

Kuo S Huang B and Bembenek R 2005. Effects of long-term phosphorus fertilizationand winter cover cropping on soil phosphorus transformations in less weathered soil. *Biology and Fertility of Soils* **41**(2): 116-123.

LaiL, Hao M and Peng L 2003. The variation of soil phosphorus of long-term continuous cropping and management on loess plateau. *Research Soil Water Conservation* **10**: 68-70.

Lukkari K, Hartikainen H and Leivuori M 2007. Fractionation of sediment phosphorus revisited. I: Fractionation steps and their biogeochemical basis. *Limnology and Oceanography: Methods* **5**(12): 433-444

Rahi HS, Khzai II and Al-Obaidi MA 1991. *Soil Chemical Analysis*. Mosul University press.

Richards L 1954. Book Reviews: Diagnosis and Improvement of Saline and Alkali Soils. *Science* **120**: 800.

Ruban V, López-Sánchez J, Pardo P, Rauret G, Muntau H and Quevauviller P 1999. Selection and evaluation of sequential extraction procedures for the determination of phosphorus forms in lake sediment. *Journal of Environmental. Monitoring* **1**(1): 51-56.

Ruiz J, Delgado A and Torrent J 1997. Iron-related phosphorus in over fertilized European soils. *Journal of Environmental Quality* **26**(6): 1548-1554.

Samadi A and Gilkes R 1998. Forms of phosphorus in virgin and fertilized calcareous soils of Western Australia. *Soil Research* **36**(4): 585-602.

Saavedra C and Delgado A 2005. Iron-related phosphorus in eroded sediments from agricultural soils of Mediterranean areas. *Geoderma* **125**(1): 1-9.

Schoeneberger PJ, Wysocki DA, Benham EC and Broderson WD 2012. Field Book for Describing and Sampling Soils. National Soil Survey CenterNatural Resources Conservation Service, U.S. Department of Agriculture, pp 875

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Schwertmann U 2008 .*Iron oxides*. Encyclopedia of soil science: Springer, pp. 363-369.

Sharpley AN, Sims J and Pierzynski GM 1994. Innovative soil phosphorus availability indices: Assessing inorganic phosphorus. Soil testing: *Prospects for improving nutrient recommendations.* (soil testing process), pp. 115-142.

Tiessen H and Moir JO 2008. Characterization of available P by sequential extraction -M.R and E.G. Gregorich, E.G. *Soil Sampling and Methods of Analysis* 2nd ed. Boca Raton, Florida: Taylor and Francis Group, pp 293-306.

Tyler G 2002. Phosphorus fractions in grassland soils. *Chemosphere* **48**(3): 343-349.

Uhlmann D, Röske I, Hupfer M and Ohms G 1990. A simple method to distinguish between polyphosphate and other phosphate fractions of activated sludge. *Water Research* **24**(11): 1355-1360.

Zheng Z, MacLeod JA, Sanderson JB and Lafond J 2004. Soil phosphorus dynamics after ten annual applications of mineral fertilizers and liquid dairy manure: Fractionation and path analyses. *Soil Science* **169**(6): 449-456.

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Horizontal Variability of Some Soil Properties in Wasit Governorate by Using Time Series Analysis

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Abstract: The study was conducted at in two pedons of Wasit Province and soil samples were collected from three depths (0-30, 30-60 and 60-90 cm. The results showed the variability of physical and chemical properties. Sand property was the most variant one as the highest coefficient variation was 114.22 per cent followed by clay. The EC also showed the highest variation (65.91%) followed by the organic matter. Theee appropriate model for describing the variability of soil properties was the moving average MA (1) model which was prevalent at all depths, followed by the autoregressive AR (1) model. In most properties, the values of forecasting do not approach their rates at previous locations. The results of autocorrelation diagram indicated that most of the soil properties have no spatial variability except for some properties in the surface depth, some of which are soil organic matter, pH and EC; while there was no spatial variability for all properties except for clay, EC and CEC in the middle depth (30-60 cm). As for the lower depth (60-90 cm), there was spatial reliability for the clay only which didn't exist at other depths.

Keywords: Horizontal variability, Time series, Autocorrelation, Forecasting

The scientific basis of soil survey is based on knowing soil types, locations, areas and distribution across pedological perspective with identifying its best usage. Pedologists cannot always recognize soils at every point of landscape they deals with, therefore, in their scientific and technical work, they prepare and separate soils from each other depending on specific properties according to this perspective, in which types, degrees and methods of these surveys are known to the specialists. Wang (2000) reported that studying spatial variability is an attempt to develop an effective management system regarding fertilizer requirements in particular and water in general. The advancement of technology has helped in this area, as it becomes possible to provide accurate estimation for one of the samples and its relationship with the accuracy of properties measurement and predicting the properties of unassigned (unexamined) sites. Al-Quraishi (2012) referred that it is possible to study and predict soil properties by studying horizontal variability by using time series analysis. Time series is defined by Bree (2002) as a sequence of values for a phenomenon which is random with time or in order upon the place.(Naqqar and Al-Auwad 2011) reported that analyzing time series is of importance in concluding a standard model used to predict expected soil properties by using the method based on model a time series. A lot of studies which used analysis and prediction by using time series have been found but they are all of an economic nature. The methodology of this research depends on building prediction models following (Boxe and Jenkines 1976) method which is the most method used in modern analysis of time series. This method is presented in several stages including the stages of examining the stability of time series, applying necessary conversions to make them stable, defining the appropriate model out of models of Autoregressive Integrated Moving Average (ARIMA) family and estimating and inspecting the model to verity its suitability to the time series, then moving to the stage of prediction by using the selected model (Yaffe and McGee 2000) illustrated that analyzing time series is an operation of separating the components of the time series one from the other in order to determine the effect of each component on the values of examined properties. The aim of the research is to know the spatial variability of the soil properties due to the importance of spatial variability in the interpretation of the method of obtaining the samples wise ease, accuracy and less cost.

MATERIAL AND METHODS

The study zone was chosen at Wasit Governorate between (45°46'00") to (46°1500") longitudes to the east and between (32°30'00") to (32°44'00) latitudes to the north. . Samples were obtained from each depth by Auger (drilling machine) from three depths (0 – 30 cm), (30 – 60 cm) and (60 – 90 cm) in order to study the variability of these soils properties. These samples were, then, brought to the laboratory of college of agriculture at Al-Qasim Green University to conduct the necessary laboratory analysis on them as these samples were dried aerobically then sieved out with a (2)mm sieve. The following properties were estimated: 1- Physicalp Properties: Partical size distribution of soil components for sand, silt and clay was estimated by pipette method according to the method described by Black, (1965). 2- Chemical properties: The electrical conductivity and soil reaction in soil extract was estimated as: water percentage 1:1 following the method described in Black, (1965) using multi-purpose pH meter device. Organic matter was estimated by wet oxidation following the method mentioned as described by Jackson(1958) and the total soil content of calcium carbonate was estimated by using hydrochloric acid following the method mentioned in (Hesse 1972), while the reciprocal capacity for positive ions was estimated by the method of blue methyl described in (Savant 1994)

Statistical Analysis

Time Series Analysis which includes: Building time series models that describe variability of properties as these models were postulated. Some of these models are:

a) Autoregressive Model AR (P): The mathematical formula of this model is written as follows:

$$zt = Ø_1 z_t - _1 + Ø_2 z_t - _2 + \dots + Ø_p zt - p + αt$$

where (t = 0, 1 , 2, …), Zt are random variables for time series at the time (t); while the distance is ti as i>0.

αt: is the random fault which is naturally distributed with arithmetic mean equals zero and variability of ($α^2_α$)

Ø: is the coefficient of the model whose values determine the stability of the model if the roots of the equation Ø(B):O lie outside the boundaries of a monocular circle whose radius is equal to one $|Ø_i|$<l i = 1,2,…..P.

b) Moving Average Model MA (q): In this model, the current value for the time series (Xt) is expressed in terms of the weighted sum of previous values of errors (αt , $αt_{-1}$,…). The mathematical formula for the (q) rank autoregressive model is written as follows:

$$Zt = αt - Ø_1 αt - _1 - Ø_2 αt - _2 \dots + Ø_α αt - q$$

c) Mixed Autoregressive – Moving Average Model: This model is more flexible in representing the time series data, therefore, the AR(P) model is merged with MA(P) to obtain a new model called the Mixed Model which is symbolized by ARMA(p, q) and its mathematical formula is written as follows:

$$Zi = Ø_1 zt - _1 + Ø_p z_1 - p + αt - _1 \dots + Ø_α αt - q$$

After that, the model will be identified; and then comes the stage of model estimation and diagnostic checking. These stages are conducted according to the time series models building which are expressed by Box and Jenkins (1976) - The autocorrelation will be calculated with the distance according to the following formula:

$$P_k = E\,[\,(Zt - M)\,(Zt + _k - M)\,]$$

Where Pk is: the autocorrelation, E is: prediction, Zt is: observations, K is: distance and lag and M are the arithmetic average.

After that, a correlograms drawn which represents the autocorrelation with distance (lag) in order to know the distance of correlation. The statistical analysis program (SPSS) has been used in statistical analysis of time series. The appropriate model is diagnosed by using the functions of error variation and Akaikes information criterion (AIC) where the model which has the less error variation and Akaikes information criterion (AIC) is selected, taking into account the low number of given information according to Akekicriterion as it as follows:

Or the AIC is Akaikes information criterion, n is the number of notes, Ln is the natural logarithm, $α^2α$ is the error variation and L is the number of given information. Then, the model is estimated by using computer and verifying its appropriateness for testing the calculated t with tabular t depending on freedom degrees for each model; then, examining the appropriateness depending on autocorrelation function. The last stage is the stage of forecasting or prediction which is determined in this study by three values appended to each property of study soil.

Coefficient Variety (C.V.) has been calculated as follows:

C.V. = $\frac{SD}{x}$ *100, where SD is the standard error (standard deviation) and X is the average.

RESULTS AND DISCUSSION

The morphological description for the horizons of the study pedons explained that the soils of the study site are of fresh sedimentary parent material transferred by Tigris sediments which has been formed under arid climate and plane to approximately plane topography. There is no difference in natural plants at the site of the study soil, as *Imperatacy lindrica, Alhajimaurorum* plants in most sites were prevalent. The depths texture was tend to fineness with sub angular blocky structure. as the soil is included with order soils Entisols under the sediment suborder Fluvent within the great group of hyperthermic arid climate Torrifluvents and subgroup the typical (Typic Torrifluvent); while for the series classification, it was included in the series.

Horizontal variability in soil components: The soil components of sand, silt and clay varies from one site to another and also among depths, as the range of average percentage for sand component is 11.04 – 18.0 per cent where the lowest average was in the middle depth 30 – 60 cm and the highest average was in the lower depth 60 – 90 cm, while the range of average percentage for silt is 48.50 – 52.79 per cent where the lowest percentage was in the middle depth and the highest percentage was in surface depth 0 – 30 cm (Table 1 and 2). The range of average of clay at those depths was 32.27 – 40.21 per cent where the lowest average was in the lower depth and the highest average was in the middle depth of soil components. The values of coefficient variety C.V. for soil depths ranged between middle and high as the C.V. values for sand were 114.22, 96.98, 105.12 per cent as its variability is classified high according to Wilding et al (1994) , if the C.V. is ranged between 0 – 15, its variability is low; and if the range of C.V. is between 15 – 75 per cent, its variability is medium; while the variability is high when the range of C.V. is more than 75 per cent.

The distribution of sand was positively strained at all depths and reached to 1.49, 1.69and 1.35 for each depth respectively which indicates that the values are abnormally distributed as it tends to right. The appropriate model that describes sand variability was the moving average MA (1) model at surface and middle depths, while the autocorrelation AR (1) model is the appropriate to describe its variability at the lower depth. The values of forecasting or prediction varied from its original locations which refer to sedimentation operations and variability of sand component. The variability of silt was low or medium at the depths of study soils as the C.V. for these depths were 18.07, 11.05 and 16.35 per cent respectively and it was negative strained at all depths as its values were tend to left which indicates that they are abnormally distributed, which means that silt decreased by increasing of depth. The appropriate model that describes its variability at the depths of study soils was the autocorrelation AR (1) model at all depths. The values of forecasting were varied and decreased at subsequent locations. The reason behind the low variability of silt is due to the homogeneity or convergence of variability among different depths. The clay has medium variability at all depths which was 27.63, 22.62 and 37.07 per cent sequentially. The distribution of clay at the depths of study soils was negatively strained at all depths which means that the values tend to left and abnormally distributed. The appropriate model that describes clay variability was the autocorrelation AR (1) model at surface depth, while the moving average MA (1) model is the appropriate one at the middle and lower depths. The values of forecasting also varied at subsequent locations

Horizontal variability of chemical properties: The chemical properties of the soil of study zone varied at different depths(Tables 1,2). Soils are classified as average saltiness as the electrical conductivity values were ranged between 8.21 – 11.95 dS m^{-1} where the lowest value of electrical conductivity was at the middle depth and the highest value was at the lower depth. The variability of electrical conductivity (EC) was high, as the coefficient variety for soil depths was 61.62, 45.26 and 65.91, respectively. The high variability was at the surface and lower depths due to agricultural processes and the variation of land water levels. The distribution of electrical conductivity was positively strained at all depths as the values tend to the right and abnormally distributed which proves the increasing of electrical conductivity by increasing of depth. The appropriate model that describes electrical conductivity variability was the moving average MA (1) model at surface and middle depths while the mixed model ARIMA (1,1) was at the lower depth which proves the variability of electrical conductivity (EC) in soils of study. The values of forecasting were not approaching their previous value which means the increasing of saltiness by time.

The reaction of soil pH is one of the invariability properties as the coefficient variety at the depths of study soils was 2.14, 1.72 and 2.63 per cent where the low variability for this property is observed because the study

Table 1. Statistical analysis for physical properties by using time series analysis

Property	Depth (cm)	Selected model	Estimation	Error variation	Akaikes criterion
Sand	0 – 30	MA (1)	-0.268	326.24	125.47
	30 – 60	MA (1)	-0.119	114.64	110.82
	60 – 90	AR (1)	0.360	358.0	126.77
Silt	0 – 30	AR (1)	0.943	90.99	107.59
	30 – 60	AR (1)	0.996	29.26	91.71
	60 – 90	AR (1)	0.997	66.14	103.12
Clay	0 – 30	AR (1)	0.891	91.03	107.60
	30 – 60	MA (1)	-0.960	82.70	106.25
	60 – 90	MA (1)	-0.782	143.09	113.93

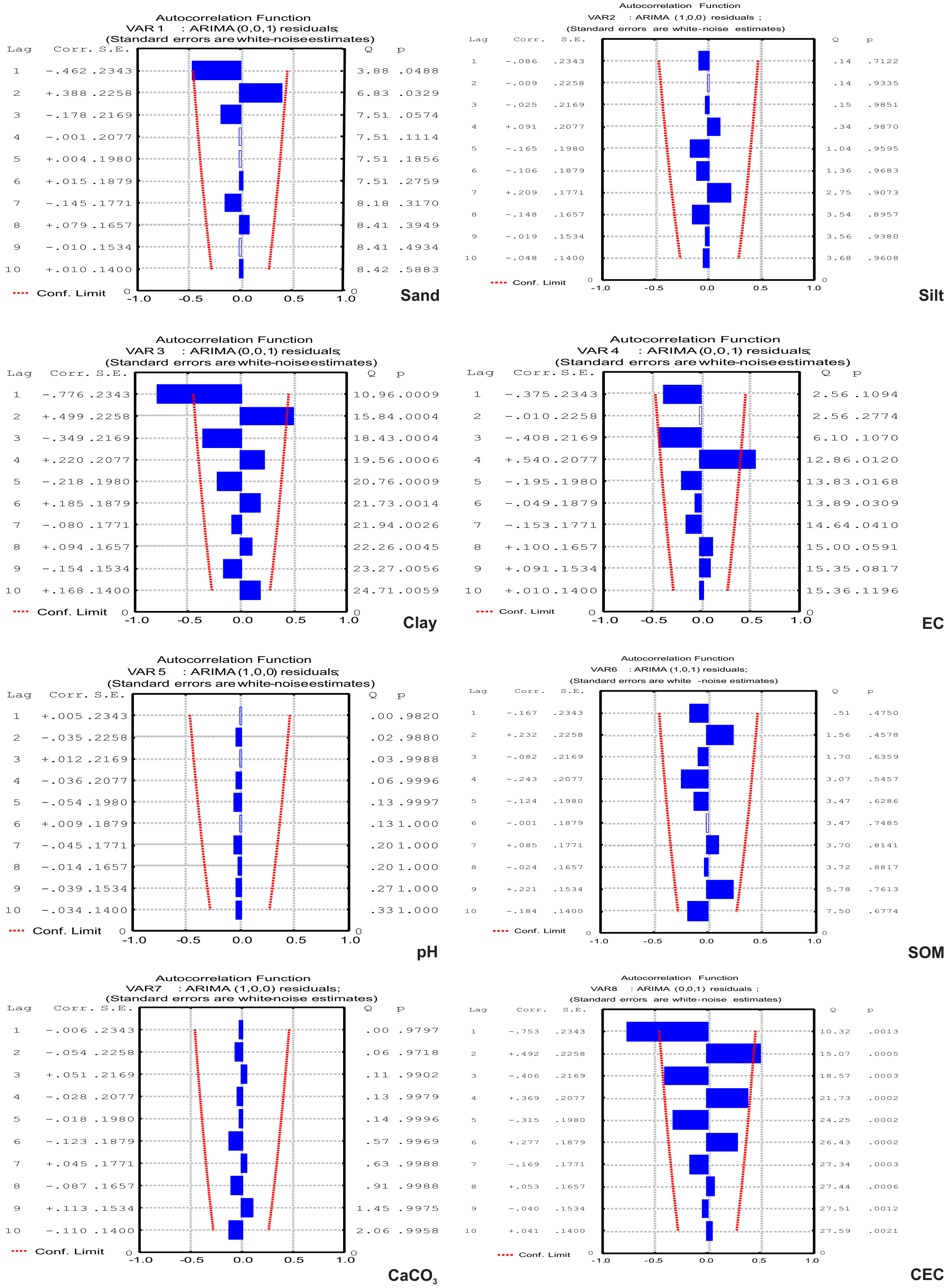

Fig. 2. Correlograms Autocorrelation of some soil characteristics to subsurface depth 30 – 60

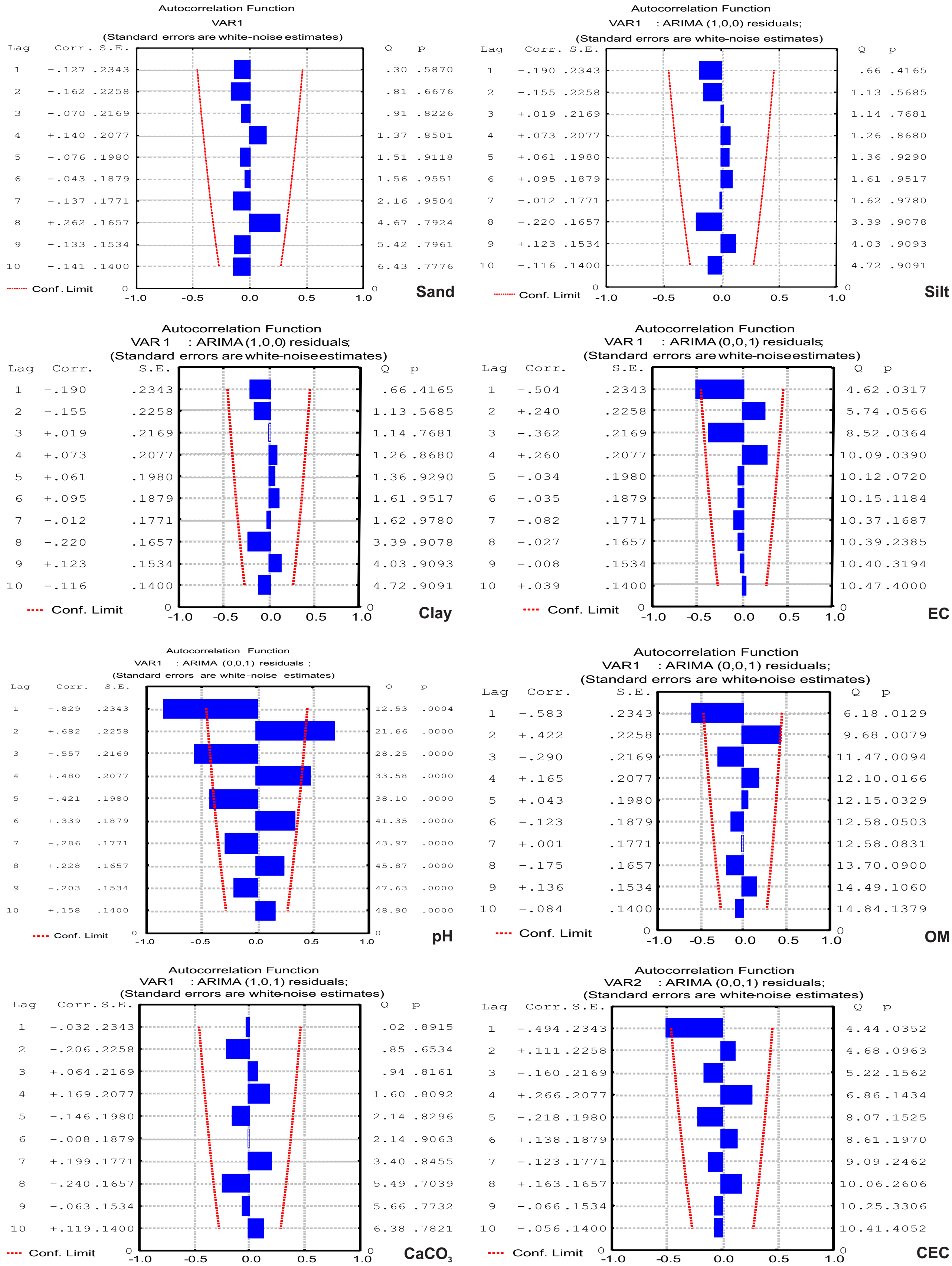

Fig. 1. Correlograms autocorrelation of some soil characteristics to surface depth

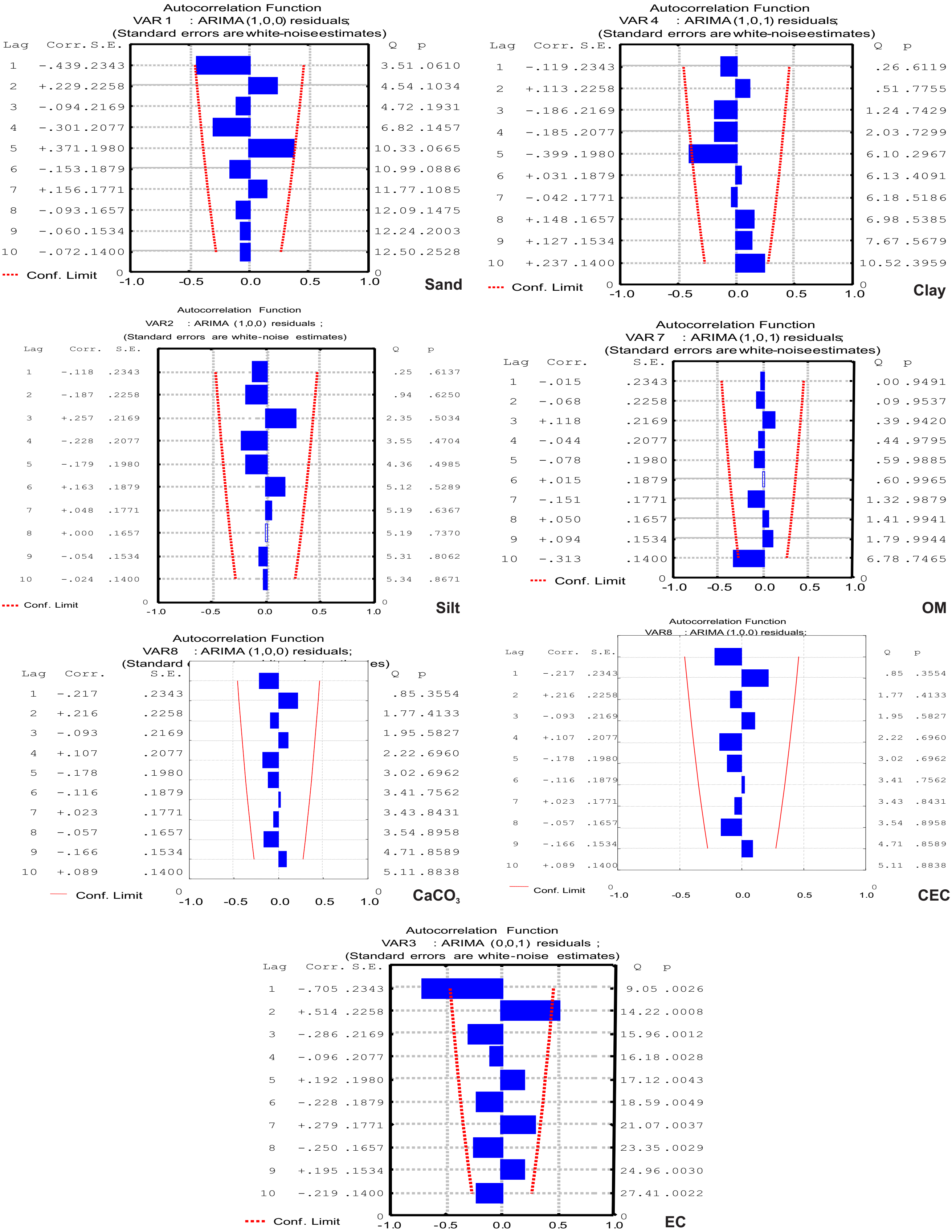

Fig. 3. Correlograms autocorrelation of some soil characteristics to subsurface depth 60 -90 cm

Table 2. Classical statistical analysis for physical properties

Property	Depth (cm)	Average	C.V.	Sekwenss	Forecasting		
Sand	0 – 30	15.81	114.22	1.49	11.39	12.0	15.4
	30 – 60	11.04	96.98	1.69	10.49	10.40	10.51
	60 – 90	18.0	105.12	1.35	2.52	0.91	0.33
Silt	0 – 30	52.79	18.07	-0.27	33.28	31.56	35.09
	30 – 60	48.95	11.05	-0.28	49.30	49.10	48.90
	60 – 90	49.73	16.35	-1.73	53.82	53.66	53.49
Clay	0 – 30	34.53	27.63	-0.321	16.03	14.27	12.71
	30 – 60	40.21	22.62	-0.26	22.46	20.20	22.45
	60 – 90	32.27	37.07	-1.03	30.21	32.40	30.33

soils are considered as arid and semi-arid zones soils which are of high calcium carbonate that affects the soil pH and remains fixed by time (Table 2). The distribution of soil pH was positively skwenss at surface and middle depths and negatively strained at lower depth. The appropriate model that describes its variability was the moving average MA (1) model at surface and middle depths while the autocorrelation model AR (1) was the appropriate one to describe its variability at lower depth. The values of forecasting for subsequent locations were close to their averages. Its variability of organic material in soil is high as the range of coefficient variety values at the depths of soil was 49.84, 49.72 and 331.62 per cent sequentially due to agricultural processes and the additions that happen to the soil. The distribution of organic material in soil was negatively skwess at surface depth which means that the values are tend to the left and irregularly distributed by increasing of depth, while it was positively distributed at middle and lower depths which means that the values are tend to the right. The appropriate model that describes its variability was the moving average MA (1) model at surface and middle depths while the autocorrelation model AR (1) was the appropriate one at lower depth. The values of forecasting were close to their averages for subsequent locations. The variability of total calcium carbonate component in soil was low and medium as the range of coefficient variety values was 22.19, 5.87 and 13.70% sequentially. It has been observed that its variability at surface depth is higher than other two depths due to agricultural processes and irrigation. The carbonate in soil was negatively strained distributed at all depths.

The values of forecasting were varied and did not approach the previous values. The appropriate model that describes its variability was the mixed model ARMA (1,1) at surface and middle depths, while the autocorrelation model was the appropriate one to describe its variability at lower depth.

The values of cation exchange capacity (CEC) was of medium variability as the coefficient variety was 18.62, 17.40 and 16.28 per cent sequentially while its distribution in soil was negatively strained at surface and middle depths and positively strained at lower depth (Table 2). The values of forecasting were close to previous values. The appropriate model that describes the variability of CEC was the moving average MA (1) model at surface and middle depths while the autocorrelation model was the appropriate one to describe the variability of CEC at lower depth. The results (Fig. 1-3) showed that most properties doesn't have spatial variability but there was a spatial variability for clay and soil reaction SOM, pH at surface depth 0 – 30 cm as it was more than 0.5.There was a spatial variability for silt, CEC at middle depth while there was no spatial variability for other properties at these depths except the lower one where there was a spatial variability for silt only.

CONCLUSION

The soil varied in their properties, and the most variable physical property was in the sand and followed by clay, while for chemical properties, the saltiness EC was the most variable one followed by the organic contents. The rate of moving average model which is appropriate for properties is the highest as it reached 62.5 per cent from surface depth. The rate of MA (1) at the middle depth was 75 per cent, while at the lower depth, the autocorrelation AR (1) model was the prevalent with a rate of 62.5 per cent.

REFERENCES

Black CA 1965. *Methods of soil analysis Amercan*. Society of Agronomy. Mono .No.9 part 2.

Box GEP and Jenkins GM 1976. *Time series analysis, Forecasting and control*. Holden -Day. San Francisco, cal, 575 pp.

Hesse PR 1971. *A text Book of Soil Chemical Aanalysis*. John Murray. LTD. London, British.

Jackson ML 1958. Soil chemical analysis. University of Wisconsin Madison.

Muhaimad Abdel Halim Ali Sulaiman 1999. *Spatial and temporal variations of some characteristics of soils in the middle of the* *sedimentary plain of Iraq*. Ph.D. thesis collage of Agriculture University of Baghdad

Naqqar Osman and AlAuwad Munther 2011. Methodology prediction (An applied study on the number of the students in the fristgrade of education in Syria). *Journal Damascus University of Economic and Legal* **27**(3): 124-126.

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Quraishi Amal Radhi Jubeir 2012. *Spatial variability of the properties of some soils in the center of the sedimentary plain using the concepts of geological statistics.* Ph.D., collage of Agriculture University of Baghdad ,Iraq .

Yaffe R and McGee M 2000. Introduction to Time Series Analysis and Forecasting. San Diego (California): Academic Press.

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Assessment of Biogeochemical Soil Variability using a Geo-statistical Approach: A Case Study in the Steppe Crimea

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Abstract: Soil monitoring within the lands of steppe zone (first few centuries) being currently under development makes it impossible to identify the effects of agrogenic evolution symptoms for material composition of the soils. Therefore, the areas with centuries-long agriculture are of great research interest, which include steppe soils at the northern Black Sea coast in the ancient period of Greek colonization of land. The present study aimed to develop an approach to simulation of the spatial variability of soil quality (SQ) using geo-statistical modeling. The raster models of continuous distribution of soil quality parameters, which have been developed using modules Spatial Analyst, and Geo-statistical Analyst have established soils qualitative differences with due account for the length of their treatment, source of potential nutrients for plants and specificity of parent rocks. We have fixed the land boundaries, which differ in farming duration using different ensembles of chemical elements with the same procedures geo-statistical analysis of the spatial variability of three types of indicators of the soil quality. A methodical approach to the identification of agricultural areas with different duration and biogeochemical transformation of soils, which the authors have proposed in this article, uses objective geo-statistical analysis procedures and has the ability to analyse in-depth patterns previously unavailable in research. This makes it possible to recommend this approach for use in the interpretation of soil-ecological monitoring data in ancient land areas with complex soil cover and history of land use.

Keywords: Soil ecology, Biogeochemistry, Soil quality, Long-term agriculture, Geo-statistical modeling

The distribution of scattered elements in the pedosphere, the biological cycle of chemical elements, the role of macro-elements and trace elements in plant nutrition, physiological and biogeochemical aspects of metabolism trace elements and their sources in plant organisms are of great importance in the development of modern geochemical ecology. The soil and ecological monitoring of agricultural land allows assessing and controlling the state of the soil cover, to forecast possible changes in the soil based on an ensemble of sensory indicators of fertility with the focus on fertilizer elements. But such monitoring for long-term exploited soils should be supplemented by periodic diagnostics of trace elements deficiency in agricultural lands and its correction by adding micronutrients to compensate for the loss of the most rapidly consumed trace elements is required (Zelenskaya et al 2018). Steppe ecosystems of East-European plain during the Holocene history were about 4500 years under anthropogenic load of varying intensity (Lisetskii and Pichura 2016). However, the most significant transformation of soils occurred during their agricultural development. This is reflected in the properties of fallow lands (Lisetskii et al 2012) and, in particular, in the change of trace elements (Lisetskii et al 2016, Zelenskaya et al 2018). Effects of long-term agriculture on soil properties studied in various aspects (Saiz et al 2016, Sandor and Homburg 2017, Borisov et al 2018, Chernysheva et al 2018, Gollany and Venterea 2018). Multidisciplinary investigations of the soil agrogenesis influenced by ancient arable agriculture require the search for research objects that are rare in safety (ancient terraces, land plots with preserved borders, etc.) (Homburg and Sandor 2011, Korobov and Borisov 2013, Lisetskii et al 2016).

The objects of the study that differ in agrogenesis duration must have similarity in the type of parent rock, mineralogical and granulometric composition (Lisetskii and Chepelev 2014). To conduct a comparative analysis of the results of the agrogenic-related soil evolution, which differ in the duration of farming it is necessary to solve the key problem – to use an objective method to delimit multi-temporal arable lands. In this regard, the agricultural district (*chora)* of Kerkinitis in ancient Crimea is of great research interest among ancient policies the northern Black Sea coast. The ancient Greek polis Kerkinitis was located on the site of the modern city of Yevpatoriya. An agrarian district was directly adjacent to the city and it was characterized by land division into plots with its own characteristics, which distinguished it from other *chora* delimitation and in particular from *chora* of Tauric Chersonesos.

The ideas about the size of the agricultural district Kerkinitis, which have developed up to date, are contradictory. At an early stage (from the second half 6 c. BC to mid 4 c. BC) the *chora* Kerkinitis was localized near the city, but it is assumed (Scheglov1984) thatin4–2 c. BC the already vast rural district was divided into allotments. Kutajsov (1990),which summarized the views of Wąnsowicz(1974) and Shcheglov(1978), noted that the *chora* Kerkinitis occupied the space of the Black Sea coast not only in the Western but also in the Eastern direction within a radius of about 3 km from the walls of Kerkinitis. However, the coastal strip of 1-1.5 km wide within which there are saline soils is probably not included in the agricultural zone. It is also important to note that the water level of the Black Sea near what is now Yevpatoriya was -2 m in the mid-1st millennium BC and therefore the coastline might have been located 50-100 m offshore from the present one (Kutaisov and Smekalova 2016). The agricultural zone of the policy, as previously thought (Kutajsov 1990), extended to watersheds with fertile steppe soils by no more than 2.5–3.0 km, and the cultivated area could be about 1300–1400 ha. However, in the follow-up works (Kutajsov 2004) this statement was revised: The Kerkinitis county could cover about 80–90 km^2 and ran as a strip of up to 7 km wide along the Black Sea for 65 km. Only arable lands for the main crops (wheat and barley) could occupy 5050–5519 hectares (Kutajsov 2013).

The specific features of the ancient agricultural technologies which have changed for a long time are reflected in the structural and functional pattern of the modern arable soils (we will call them as old-arable ones). Periodic plowing of the same plots with rest periods have largely modelled the future agricultural practices, which are summarized, and we can call them as conservation agriculture (Bitew and Abera 2019); what is important for maintaining of a soil health. The information role of old-arable and long-fallow soils (without the current period of agriculture) is determined by possible diagnostics of evolutionarily significant changes in the material composition of soils as a reflection of the accumulated effects of agricultural practices of the past. Ge-ostatistics methods have become widely used in environmental science (Webster and Oliver 2007, Pelletier and Dutilleul 2018, Ver Hoef 2018, Lu et al 2019, Ghorbanzadeh et al 2019). They are promising for soil cover research. A new method has recently appeared to solve visualization problems, geo-statistical modeling and simulation of the spatial variability of soil (Heuvelink and Webster 2001, Bourennane et al 2003, Paterson et al 2018, Paul et al 2019, Hou et al 2019, Iticha and Takele 2019). The present study aimed to develop an approach to simulation of the spatial variability of soil quality for lands with different farming times in the Steppe Crimea using geo-statistical modeling.

MATERIAL AND METHODS

Lands to the north-west of Yevpatoriya is a part of the Crimean southern steppe agropedological province with plains wavy landscape with heights from 5 m a.s.l. (in the south) to 35 m a.s.l. (in the north). Among the parent rocks loess and residual carbonate rocks dominate. The study site was chosen for the comparative analysis of soils in such a way as to cover both the proposed area of ancient agriculture and the more remote areas with the same types of soil which were certainly a part of the area of the current (150–165 years) agricultural development. Thus, when arranging field studies we initially assumed the existence of qualitative heterogeneity of soil properties, first of all, quite conservative components of the material composition, which could preserve some evidences of the agriculture prehistory in the form of relict features. The field studies were carried out on the site with an area of 5.4 thousand hectares (Fig. 1A) which is located northwest of Yevpatoriya. The field-testing mesh had the size of 560 m. The use of topographic maps of different years and archival satellite images allowed determining10 arrays of vineyards and gardens on the territory of the field test site (Fig. 1A). Within these areas where deep tillage, including plantation ploughing, was probably used no testing was carried out. We also avoided ancient necropolises (over 30 kurgans marked on maps) and areas with anthropogenic disturbances (pits and clusters of stones). We also excluded the areas with modern buildings. As a result, we determined the location of 127 points of soil samples on the arable land, which was promising for the cultivation of grain crops. In the field, there were occasionally short-term (1–5 years) deposits in the fields of rotation, which were included in the sampling. However, any old deposits (n=6) were excluded from the analysis. The modern methods of satellite images interpretation (Smekalova and Terekhin 2018) have allowed establishing traces of ancient land management, which include the boundaries of both lands and plots within them.

Soil samples were taken from a layer of 3–10 cm. For each sample, the soil colour and the content of macro-elements and trace elements were determined. Chemical analyses of soils included the following standard procedures: the organic matter (OM) after Tyurin; the pH values (H_2O) were determined by a potentiometric method; the content of mobile phosphorus and exchange potassium after Machigin. Colours (dry) were described using the Munsell-System (Munsell 2000). Wavelength-dispersion X-ray fluorescence spectrometer was used to determine the contents of chemical elements. Concentrations of macro-elements and trace elements in soils (18 metals and oxides) were determined by the technique of measuring metal mass fraction and oxides in powdered samples. The resulting oxide concentrations were recalculated for the content of elements.

For 121 soil samples, we have developed a database on organic carbon content (Corg), 18 chemical elements and by integrated indicators of soil quality regarding the content of nutritional elements for plants, accumulation of chemical elements in the soil relative to the rock and geochemical "plowed-out" soils. The values of the content of chemical elements were standardized for comparability according to the formula.

$$x_{norm} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad ....(1)$$

Soil quality (SQ) indicators were calculated using normalized values (1)

$$SQ = (x_1 \times x_2 \times ... \times x_n)^{1/n} \quad ....(2)$$

Where x_1, x_2 … x_n are the normalized values of the content of chemical elements.

An integrated soil quality (SQ) assessment characterizes soil quality differences with due account for the duration of their treatment, source of potential nutrients for plants and parent rock specificity. Therefore, to show spatial differences in soil cover different lists of elements were used. The SQ1 indicator is calculated by the content of nutrients for plants (Corg, P, Mn, Cu, Ni, Zn, V, Co, Cr, Sr, Ti, Ca, K, Mg, Fe and Si) which have been determined by consolidation of special works on this problem (Kovda 1985, Protasova and Kopayeva 1985, Orlov and Bezuglova 2000, Dobrovolskiy 2003, Kiriluk 2006, Mengel 2008, Bityutsky 2011).The SQ2 indicator reflects accumulation of chemical elements in the soil relative to the parent rock (Perelman, 1989, Dobrovolskiy 2003, Lisetskii et al., 2016). In this case, formula (2) included as a parameter x_i the coefficient of soil accumulation: KS(i)=Si/Pi. A list of elements (i) for soils(S) and for two types of parent rock (P) has been determined by the value of KS(i) >1:

– for soils on loess-type rocks: Corg, P, K, Cu, Mn, Si, As;

– for soils on carbonate rocks: Corg, Cu, Co, K, Mn, P, Si, Al, Ti, Pb, Fe, Ni, Zn.

The SQ3 indicator characterizes biogeochemically "ploughed-out" soils as it has been determined by the ratio of actually recorded concentrations of chemical elements in arable and virgin soils on two types of parent rock:

– for soils on loess-type rocks: Corg, Ti, Al, Mn, Fe, Si, K, Co, Ni, Cu, Zn, Pb, Zr, Rb, Ba, Cr, V;

– for soils on carbonate rocks: Corg, Mn, P, K, Ni, Cu, Pb, Rb, Ba, V.

To visualize the results obtained raster models of spatial distribution of soil properties for the three above indicators were developed. Mapping was done using geoinformational software ArcGIS 10.5 and modules “Spatial Analyst” и “Geo-statistical Analyst”. A vector layer was created with the use of the coordinates of 121 selection points; its attribute base was filled with calculated indicators SQ1, SQ2, SQ3. A deterministic method of inverse distance weighted was used to interpolate the data. The parameters of the interpolation model were chosen in such a way as to minimize standard deviation of interpolated values. As a result, we obtained raster models of continuous distribution for soil quality indicators. The values of indicators SQ1-SQ3 were ranked using equal intervals because their distribution is close to normal.

RESULTS AND DISCUSSION

The watersheds of the steppe are represented by southern carbonate black soils on loess clays and loams (codes on the soil map 70L, 71L, 88L). In the north-west and south-east of the field test site there are carbonate crushed black soils on eluvium carbonate rocks (code 79ek). Arable soil horizons are generally characterized by close to neutral reaction of the soil solution (pH=6.8–7.0), low humus content (2.6–2.7%), high content (by Machigin) of mobile phosphorus (0.2–0.4 mg kg^{-1}) and exchangeable potassium (3.8–4.1 mg kg^{-1}).The land use and management practices have evolved over a long period of time in the rural area of Kerkinitis. After the initial period of Greek colonization when land resources were in excess which allowed the use of fallow farming system, there came the stage of regulated land use related with consolidation of land plots among civil population. This stage came from the turn of the third–fourth quarter of 4 c. BC thanks to the transfer of land management traditions of from Tauric Chersonesos (Kutajsov 2013). The values of soil quality which characterize the concentration of the most important 16 nutrients for plants (SQ1) are most widely represented in the area with values SQ1 = 0.31-0.40 **(**Fig. 1, B). This area contains traces of land surveying which in ancient times undoubtedly represented a continuous zone of regulated land management in the centre of the field test site but not a set of fragments as in Fig. 1, A. Land plots of square shape were limited by dividing ditches (Kolesnikov and Jacenko 1999, p. 307-309), and strictly regular planning composition of land management is related with the Chersonesean stage of land use in 4-2 c. BC when plots had a crop rotation: steam–winter crops–spring crops (Kutajsov 2013). The central zone of the research area is used to characterize the result of centuries-old agriculture, which basically levelled the initial soil-genetic differences in the territory (soils on loess and carbonate eluvium). However, the previously detected traces of earlier irregular land management within *chora* of Kerkinitis (from the second half of 6 c. to the middle of 4 c. BC) as well as the assumed existence of a complex agricultural system at the initial stage of development (Kutajsov 2013) make it possible to suggest that lands located directly at the city walls were used less efficiently or for a short time for crop production. A complex agricultural system which was used in 6 c. BC and to the middle of4 c. BC in the near *chora* Kerkinitis seemed to be not involved in the consolidation of land boundaries. The lands in the area to the northwest of the city being less fertile according to the SQ1 0.36-0.32 and lower **(**Fig. 1, B) estimates appeared to have been in the later Chersonesean stage of land use being predominantly used for grazing. The ethnographic data indicate to the usual practice of allocating a buffer zone of land between the settlement and the arable land for regular grazing of livestock. Previously, the authors (Buryak and Poletaev 2019) were able to justify the assumed ancient land boundary of the rural area (in 6 km to NW from Kerkinitis **(**Fig. 1, A)) based on geochemical properties of soils with the use of methods of geostatistics and geoinformation analysis. An analysis of the map of distribution probability of multi-temporal boundaries of the arable land has allowed to identify the border of two agricultural zones which according toFig. 1, B is close to the location of the south-eastern boundary of the isoline SQ1=0.36. However, according to the spatial distribution of SQ1 values we have identified three zones on the territory of the field test site: two areas of the least agrogenic amended soils (in the north-west of the field test site and in the south-east (with rare saved land marking)) and the wide central strip with nearly continuous belt of demarcated land and reflection of biogeochemical progradation soil according to the values of SQ1.

Taking into account soil-genetic differences the Fig. 1, C shows the features of selective accumulation of chemical elements in the soil in relation to parent rock (for loess by seven chemical elements, for carbonate eluvium 13 chemical elements). This map chart shows the distribution of the upper accumulative horizon of genesis different soils on the territory of biogeochemical potential. However, the agrogenic load being different in duration had also made its corrections in the pattern of biogeochemical heterogeneity. The difference between SQ2 and SQ1 is due to the involvement of additional elements such as Al, Ni, Pb and As, in its calculation, i.e. mainly pollutants, and the fact that the calculation of SQ1 takes into account the content of Ca, Sr, Mg, Cr and V. The largest area (69%) is occupied by a zone with SQ2 values from 0.32 to 0.46. These soils reflect the results of biological removal of organic carbon, macroelements and trace elements over the prehistory of agriculture. The main part of the territory of the field test site is characterized by a decrease in soil cover contrast due to the formation of

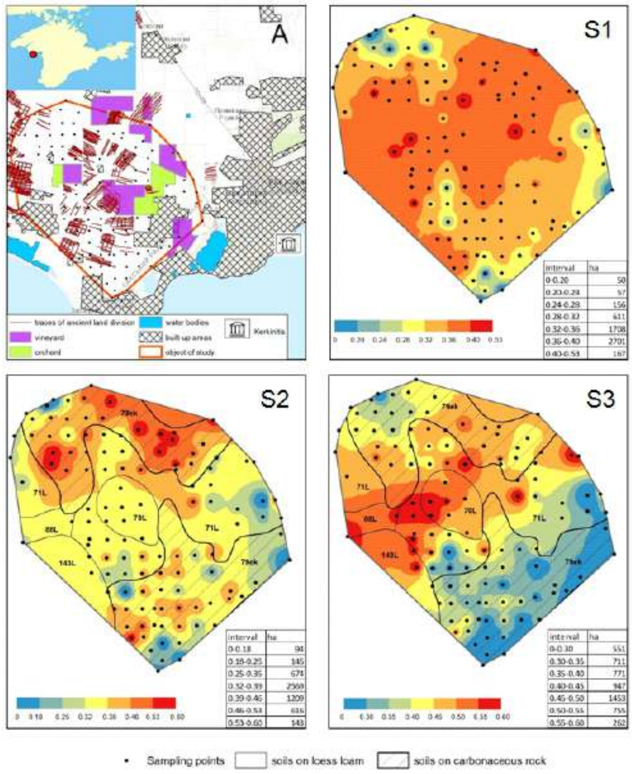

Fig. 1. The results of the geostatistical analysis of biogeochemical indicators at the research site: the location of the object of study (A); B-D-raster models of the distribution of soil properties: B-S1, C-S2, D-S3

geochemical homogeneity of the upper soil horizon under the influence of long-term agriculture. It is noteworthy that within the near-field *chora* there are focal zones with SQ2 values of >0.39 which are sometimes crossed by marking borders. The areas with the highest values of SQ2 (> 0.39) in the Northwest of the field test site clearly show a zone of new period agricultural development (last 150-165 years without prehistory). The location of this border can serve, as a confirmation of Kutajsov (2004) is opinion about wider territorial coverage by ancient agriculture than it was previously thought. In particular, for the territory of our field test site the area of lands with ancient history is 64%.

The duration of biological removal of 17 chemical elements (for loess soil) and 10 chemical elements (for soils on carbonate eluvium) characterizes the value of SQ3 **(**Fig. 1, D) which is represented in the predominant areas with values 0.45-0.50 (27%) and 0.50-0.55 (14%) and geographically close to the areas that form the value of SQ1=0.36-0.40 (49.6%) on **(**Fig. 1, B). These areas include clear traces of ancient land management. It is noteworthy that the lands being close to the city of Kerkinitis (soils on carbonate eluvium) can be regarded in terms of SQ3<0.40 as the least geochemically degraded ones (concentration of 9 chemical elements and Corg is closest for them with virgin conditions), although they are poorer in quality than the soil in the centre and in the northwest of the area under study. Thus, the position of the is oline with SQ3<0.40 values shows that the suburban lands, which were extensively used at least in 4-2 c. BC. occupied 37 per cent of the total area within the boundaries of the field test site.

CONCLUSION

The history of land use in the rural district of Kerkinitis suggested that those lands which had been initially (more than two centuries) influenced by the fallow farming system and subsequently (at 4-2 c. BC) became permanently used within the ownership of land would be most degraded. The intensity of agricultural impacts on the soil increased in the system of strictly ordered ancient land management due to increased requirements for commercial nature of crop production. However, the maximum values of soil quality, which are calculated according to the content of 16 most important nutrients for plants, are noted in the area of ancient regulated land use. This shows the role of agriculture in biogeochemical progradation of old arable soils due to more intensive soil weathering. At the same time, the initial soil-genetic differences in the territory are levelled, which allows us to conclude that the contrast of soil cover is reduced under the influence of long-term farming. This was especially clear when assessing the anthropogenic effects on soil quality of the selective accumulation of chemical elements in the soil in relation to parent rock, including a number of pollutant elements. The use of different ensemble chemical elements with the same geostatistical analysis procedures for the spatial variability allowed to establish the boundaries of the area of the current stage of agriculture (150–165 years) and the area of lands with ancient prehistory (64% of the research area). The proposed methodological approach to identify agricultural areas with different duration and biogeochemical transformation of soils uses objective procedures of geo-analysis and has heuristic capabilities, which makes it possible to recommend it for geoarchaeological studies for other areas of the ancient world and for analysis of soil-ecological monitoring results in areas with complex soil cover and with land use history.

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REFERENCES

Bitew Y and Abera M 2019. Conservation agriculture based annual intercropping system for sustainable crop production: A review. *Indian Journal of Ecology* **46**(2): 235-249.

Bityutsky NP 2011. *Trace elements of higher plants*, Publishing House of St. Petersburg University, St. Petersburg, Russia, p. 368.

Borisov AV, Kalinin PI, Korobov DS and Idrisov IA 2018. Soils of agricultural terraces with retaining walls in the mountains of dagestan. *Eurasian Soil Science* **51**(1): 22-31.

Bourennane H, Salvador-Blanes S, Cornu S and King D 2003. Scale of spatial dependence between chemical properties of topsoil and subsoil over a geologically contrasted area (Massif central, France). *Geoderma* **112**(3-4): 235-251.

Buryak Zh A and Poletaev AO 2019. Ancient land use and land management in Crimea: remote analysis, soil-geomorphological characteristics and dating, pp. 107-160. In: F N Lisetskii (ed). *Crimea: The History of Interaction between Man and Nature*. Nova Science Publishers, Inc., NY, USA.

Chernysheva E, Khomutova T, Fornasier F, Kuznetsova T and Borisov A 2018. Effects of long-term medieval agriculture on soil properties: A case study from the Kislovodsk basin, Northern Caucasus, Russia. *Journal of Mountain Science* **15**(6): 1171-1185.

Dobrovolskiy VV 2003. *Basics of Biogeochemistry*, Academy, Moscow, Russia.

Ghorbanzadeh N, Salehi A, Pourbabaei H, Tolarod AAS and Alavi SJ 2019. Spatial variability of soil microbial indices in common alder COMMON ALDER (*Alnus glutinosa*) stands using a geo-statistical approach in northern Iran. *Journal of Forestry Research* **30**(2): 679-688.

Gollany HT and Venterea RT 2018. Measurements and models to identify agroecosystem practices that Enhance soil organic carbon under changing climate. *Journal of Environmental Quality* **47**(4): 579-587.

Heuvelink GBM and Webster R 2001. Modelling soil variation: past, present, and future. *Geoderma* **100**(351): 269-301. https://doi.org/10.1016/S0016-7061(01)00025-8

Homburg JA and Sandor JA 2011. Anthropogenic effects on soil quality of ancient agricultural systems of the American Southwest. *Catena* **85**(2): 144-154.

Hou J, Yang J and Tan J 2019. A new method for revealing spatial relationships between shrubs and soil resources in arid regions. *Catena* **183**: 104-187.

Iticha B and Takele C 2019. Digital soil mapping for site-specific management of soils. *Geoderma* **351**: 85-91.

Kiriluk VP 2006. *Trace elements in the components of the biosphere of Moldova*, Pontos, Kishinev, Moldova.

Kolesnikov AB and Jacenko IV 1999. Le territoireagricole de ChersonesosTauriquedans la region de Kerkinitis. *Territoires des Cites Grecques* **34**: 307-311.

Korobov DS and Borisov AV 2013. The origins of terraced field agriculture in the Caucasus: new discoveries in the Kislovodsk basin. *Antiquity* **87**: 1-18.

Kovda VA 1985. *Biogeochemistry of the soil cover*, Nauka, Moscow, Russia, p. 264.

Kutaisov VA and Smekalova TN 2016. Coastal geoarchaeology of Kerkinitis (Northwestern Crimea). *Mediterranee* **126**: 79-89. http://dx.doi.org/10.4000/mediterranee.8262

Kutajsov VA 2004. *Kerkinitida in the Ancient Period*, Corwin Press, Kiev, Ukraine.

Kutajsov VA 1990. *The ancient city Kerkinitis*, NaukovaDumka, Kiev, Ukraine.

Kutajsov VA 2013. *The Antique Polis of Kerkinitis*, Publishing house “Predprijatie Fenix”, Simferopol, Ukraine.

Lisetskii FN 2012. Soil reproduction in steppe ecosystems of different ages. *Contemporary Problems of Ecology* **5**(6): 580-588. http://dx.doi.org/10.1134/S1995425512060108

Lisetskii F and Chepelev O 2014. Quantitative substantiation of pedogenesis model key components. *Advances in Environmental Biology* **8**(4): 996-1000.

Lisetskii F and Pichura V 2016. Steppe ecosystem functioning of East-European plain under age-long climatic change influence. *Indian Journal of Science and Technology* **9**(18): 1-9. http://dx.doi.org/10.17485/ijst/2016/v9i18/93780

Lisetskii FN, Smekalova TN and Marinina OA 2016. Biogeochemical features of fallow lands in the steppe zone. *Contemporary Problems of Ecology* **9**(3): 366-375. http://dx.doi.org/10.1134/S1995425516030094

Lisetskii FN, Marinina OA, Gadzhiev RS and Vorobyeva EY 2016. Rationale for indicators of arable farming duration (based on research findings in the county of the antique polis of Kerkinitis). *Social Sciences (Pakistan)* **11**(13): 3361-3365. https://doi.org/10.3923/sscience.2016.3361.3365

Lisetskii FN, Sudnik-Wojcikowska B and Moysiyenko II 2016. Flora differentiation among local ecotopes in the transzonal study of forest-steppe and steppe mounds. *Biol Bull* **2**: 169-176. http://dx.doi.org/10.1134/S1062359016010106

Lu B, Brunsdon C, Charlton M and Harris P 2019. A response to 'A comment on geographically weighted regression with parameter-specific distance metrics'. *International Journal of Geographical Information Science* **33**(7): 1300-1312.

Mengel K 2008. Nutrient potentials. *Encyclopedia of Earth Sciences Series*, 494-500.

Munsell Soil Color Charts: year 2000 revised washable edition, GretagMacbeth, New Windsor, 2000.

Orlov DS and Bezuglova OS 2000. *Biogeochemistry*, Phoenix, Rostov on Don, Russia, p. 320.

Paterson S, McBratney AB, Minasny B and Pringle MJ 2018. Variograms of Soil Properties for Agricultural and Environmental Applications. *Pedometrics. – Springer, Cham*, 623-667.

Paul OO, Sekhon BS and Sharma S 2019. Spatial variability and simulation of soil organic carbon under different land use systems: geostatistical approach. *Agroforestry Systems* **93**(4): 1389-1398.

Pelletier B and Dutilleul P 2018. Coregionalization analysis with a drift (CRAD): A methodological review with companion testing procedures, software and applications. *Environmental and Ecological Statistics* **25**(1): 5-29.

Perelman AI 1989. *Geochemistry*, Higher School, Moscow, Russia, p. 528.

Protasova NA and Kopayeva MT 1985. Rare and trace elements in Central Russian Upland soils. *Soviet Soil Science* **17**(1): 55-64.

Saiz G, Wandera FM, Pelster DE, Ngetich W, Okalebo JR, Rufino MC and Butterbach-Bahl K 2016. Long-term assessment of soil and water conservation measures (Fanya-juu terraces) on soil organic matter in South Eastern Kenya. *Geoderma* **274**: 1-9.

Sandor JA and Homburg JA 2017. Anthropogenic soil change in ancient and traditional agricultural fields in arid to semiarid regions of the Americas. *Journal of Ethnobiology* **37**(2): 196-217.

Scheglov AN 1984. *Kerkinitis. In Ancient states of Northern Black sea region*, Nauka, Moscow, Russia, p. 55-56.

Shcheglov AN 1978. *North-western Crimea in the Ancient Era*, Nauka, Leningrad, Russia.

Smekalova TN and Terekhin EA 2018. New evidences about social-military organization of Tauric Chersonesos as reflected in the structure of its cadaster [Noi date privindorganizareamilitara a cetatenilor Chersonesului Tauric, reflectateînstruct uracadastruluiluifunciar]. *Stratum Plus* **6**: 89-105.

VerHoef JM 2018. Kriging models for linear networks and non-Euclidean distances: Cautions and solutions. *Methods in Ecology and Evolution* **9**(6): 1600-1613.

Wąnsowicz A 1974. Zagospodarowanieprz estrzennepanst wgrekich:OlbiaPontyjska, ChersonesTauryzki, Krolestwo Bosporanskie. *Archeologia (Warszawa)* **25**: 10-19.

Webster R and Oliver MA 2007. Geostatistics *for environmental scientists, second edition*, Wiley, Chichester, England, p. 330.

Zelenskaya E, Pichura V and Domaratsky Y 2018. Priorities of agroecological monitoring of the composition of soil trace elements taking into account the peculiarities of its formation over time. *Journal of Engineering and Applied Sciences* **13**(14): 5807-5813. http://dx.doi.org/10.3923/jeasci.2018.5807.5813

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Development and Analysis of Flow Characteristics of Mini Sharp Crested Weir Energy Conservation

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Abstract: Study was conducted on three weirs of each 15 cm crest height with upstream bed reduction of 30°, 45° and 60° up to 10 cm height were installed individually under each test run in the hydraulic flume permanent set up and the water surface profiles for each case were drawn, to determine the flow characteristics which include critical depth (minimum specific energy), location of critical depth and to compute froude number for different discharges under free flow conditions. Under each test run, the results indicated that the location of critical depth for all weirs at different discharges is away from the weir. Coefficient of discharge varied from 0.16-0.93 as per decrease in discharge levels, froude number obtained indicates the jump is an undular jump (F_r =1-1.7) for 20, 15 and 10 l/s and oscillating jump for 5 l/s (F_r=2.5-4.5) and energy loss attained more for 5 l/s (exceeded 2.0 cm) as compared to other discharges (within 0.5 cm). Out of the three geometries tested for the weirs, 15 cm crest height with 30° reduced sharp crested rectangular weir performed better in terms of all parameters including cost of design which will enable a significant contribution while installation of water measurement in small scale irrigation system.

Keywords: Weirs, Sharp crested, Critical depth, Hydraulic flume and rectangular weir

Irrigation facility is regarded as the key element of irrigated agriculture. Efficient application is possible by accurate measurement of irrigation water. The present rate of development of water resources is not enough to meet the requirements of increasing population any improvement in the efficiency of utilization of existing water resources acquires greater importance. To improve water management, it is strongly recommended that the irrigation water can be accurately measured and regulated at all important points in an irrigation system. Most of the problems that are commonly encountered in measurement of water in field channels can be eliminated by critical flow conditions artificially in the measuring devices. Effective use of water for crop irrigation requires that flow rates and volumes be measured and expressed quantitatively. The accurate measurement of flow rates in open channels is critical for hydrologic research and applications, water-resources management, irrigation and drainage. For this reason, various flow-measuring structures are used such as weirs, flumes or gates. A flow-measurement structure is generally designed to act as a control in the channel and to provide unique relationship between the upstream head and the discharge.

The lower triangular part of the weir handles the normal range of discharges at the measurement structure while the upper part measures the occasional higher peak flows (Martinez and Reca2005).Semi-circular crested weirs of two different diameters and conducted an experiment on the weirs at different discharges 22, 14 and 6 l/s), the hydraulic characteristics of semi-circular crested weirs are studied using simplified model incorporating streamline curvature effects, comparing their predictions with experimental data. It was concluded that critical depth occurs at only one location in the throat section for all possible conditions tested (Hariram 2009). Rama murthy (2007) conducted study on the slit weir concept is extended to permit one to measure both very low and very high discharge rates accurately and concluded that the discharge coefficient can be represented solely as a function of the Reynolds number. Tigrek (2008) proposed an equation for discharge-brink depth based on experimental data, covering both super critical and subcritical flows with a smooth and rough bottom and validity of the equation has been verified with experimental data. The agreement between the predicted and observed values enhances utility of the proposed relationship under field conditions. There are several types of weirs present for the flow measurement, but the sharp-crested weirs may be formed by means of a metallic plate which embedded in concrete are because they are normally the only type used in the measurement of irrigation water for accurate discharge. The sharp edge in the crest causes the water to spring clear of the crest, and thus accurate measurements can be made. Several methods are available for calibrating weirs, against measured flows against another calibrated flow-measurement structure, pre-calibration of the measuring structure in the laboratory and model studies. The pre-calibration of the measuring structure in the laboratory or the model studies can provide complete and accurate calibration. Hence the objective of the study was to develop of sharp crested rectangular weirs with 30°, 45° and 60° edge angles, determine flow characteristics which include critical depth, location of critical depth, coefficient of discharge and water surface profile on the crest for different discharges and weir types under free flow conditions and to compute the Froude number and energy loss for different discharges under free flow conditions.

MATERIAL AND METHODS

The experiments were conducted in College of Agricultural Engineering, Bapatla. A commercial make of hydraulic flume with motorized bed slope alteration facility was utilized for this purpose. Hydraulic flume of 10 m long and 0.3 m wide with motorized bed slope alteration facility flume was fabricated using thick M.S sheets and reinforced by MS angles, the members were welded on both sides (Fig. 1). It consists of two sections namely inlet steady section and actual test section. Two gates placed at either ends of flume are operated by rack and pinion arrangement, used to control the depth of flow.

An additional accessory of rectangular notch of 15 cm crest length and 25 cm height was provided after steady to measure water passing into the flume and to maintain a constant head over the crest during the time of experimentation. A water re-circulation system was provided to have a closed-circuit operation for the experimentation. Components are sump, mono block pumps, inlet pipe, hydraulic flume, collection tank and return underground channel. A collection tank of 2 m length, 1 m width and 0.5 m height was placed on ground at the tail end of the hydraulic flume.

Irrigation channel whose capacity ranges from 1 to 30 l/s was used for experimental purpose. The discharge rate through the flume is calculated as

$$\text{Discharge (L/s)} = \frac{\text{Volume of water collected}}{\text{Time taken}} \quad ...(1)$$

Volume of water collected = 1000 L

Three weirs with 15 cm crested height each and one weir head sharp-crested reduction of 30°, 45° and 60° were prepared with teakwood with fine finish and were painted to have uniform roughness over the entire section and to prevent from any damage due to submergence in water. It consists of different series with various levels of the selected variables combined into factorial set of treatments. The following are the levels of experimental variables (Konstantinos 2012). Weir-I with crest height 15 cm and 30°, 45 and 60° up stream bed reduction upto 10 cm crest height. Similarly, four discharges were selected to suit to field channels. 20, 15, 10 and 5 l/s. Depth of the water levels were 17.82 14.71, 11.22 and 7.07 cm.

Experimental procedure

Initially for 20 l/s discharge, the water surface levels with distance were recorded at 5 cm intervals along the center line of hydraulic flume by moving the point gauge on the rails. The starting of the water surface profile measurement is from 106 cm before and 169 cm after the sharp edge of the weir. The process of recording the water surface profiles was repeated with remaining three discharges of 15, 10 and 5 l/s. The sharp crested weir-I has been tested and replaced by weir-II once and followed by weir-III by taking all precautions as in the installation of weir-I.

Continuity equation (Ghanshyam Das 2010).

$Q = AV = A_c V_c$

$V_c = Q/A_c$ ---------- (2)

From Bernoulli's equation

$H_1 = H = y + v^2/2g$ --------- (3)

Where Q= volume rate of flow (m^3 s^{-1}), V=Average velocity (m s^{-1}), A=cross-sectional area of flow (m^2), H=total energy head (m), g=Acceleration due to gravity (m s^{-2}), y= Water depth, m

Substitution of (2) in (3) gives

$$H_1 = H = y + \frac{Q^2}{2gA^2} \quad \text{or}$$

$$\frac{dH}{dy} = \left(1 - \frac{Q^2}{gA^3}\right)\frac{dA}{dy} = \left(1 - \frac{V^2}{gA}\right)\frac{dA}{dy}$$

The water area dA near the surface is equal to Body, then the equation becomes

$$\frac{dH}{dy} = 1 - \frac{V^2 B}{gA}$$

At the critical state of flow, the above equation therefore gives

$$\frac{V_c^2}{2g} = \frac{A_c}{2B_c} \quad ...(4)$$

Where $A_c = B_c$ Substituting (1) in (3)

$$Y_c^3 = \frac{Q^2}{gB_c^2} \quad ...(5)$$

where, the subscript 'c' relates to critical condition. Froude number ($\frac{V_c}{\sqrt{gy_c}}$),

$F_r = 1$ at critical conditions. Critical depths for four discharges and three contractions have been computed from equation (5).

The coefficient of discharge for different weirs for different discharges is calculated based on the following formula (Ghanshyam Das 2010).

Equation for discharge of a rectangular notch is

$$Q=2/3\ C_d\sqrt{2g}\ L.H^{3/2} \quad ...(6)$$

Where Q=Discharge (l/s), L=Width of the flume (cm) and H=Head flow w.r.t crest level (cm).

Froude number was calculated for different discharges for different weir

Sequent depth ratio:

$$\frac{y_2}{y_1}=\frac{1}{2}(\sqrt{1+8F_r^2}-1 \quad ...(7)$$

Where y_1 = depth of water before the jump (cm) and y_2 = depth of water after the jump (cm).

The energy loss for different weirs for different discharges is calculated based on the following formula

Where y_1 = depth of water before the jump (cm) and y_2 =depth of water after the jump (cm).

$$\Delta E=\frac{(y_2-y_1)^3}{4y_1y_2} \quad ...(8)$$

RESULTS AND DISCUSSION

The location of critical depth is away from the weir with respect to its sharp edge as the discharge increased from 5 to 20l/s (Fig. 2). This is due to increase in the velocity of flow with increase in discharge. For weir-I the location of critical depth increased from 5.5 to 16.7 cm from the sharp edge of the weir as the discharge increases from 5 to 20 l/s. For weir-II critical depth increased from 11 to 18.5 cm and discharge increases from 5 to 20 l/s and weir-III the depth increased from 9.8 to 17.9 cm, discharge increases from 5 to 20 l/s.

For 5 l/s discharge the calculated co-efficient of discharges were 0.16, 0.17 and 0.16 for weir-I, II and III and 20 l/s discharge the calculated co-efficient of discharges were 0.92, 0.93 and 0.93 for weir-I,II and III respectively. As compared the above values it is known that C_d increases with increase in discharge from 5 to 20 l/s due to increase in velocity.

The co-efficient of discharge increased with increasing of discharge for all the weirs. For 5 l/s, C_d values varied like 0.16, 0.17, 0.16 and for 10 l/s it remained as constant value that is 0.37 and for 15 l/s it varied like 0.63, 0.59, 0.63 and for

Fig .1. Hydraulic flume used for experimentation

Table 1. Average discharges through hydraulic flume for maximum and minimum flow conditions

State of flow	Time required (sec)	Discharge (l/s)	Average discharge (l/s)
Maximum	37.46	26	25
	39.00	25	
	40.67	24	
Minimum	200.67	5	4
	260.00	4	
	289.00	3	

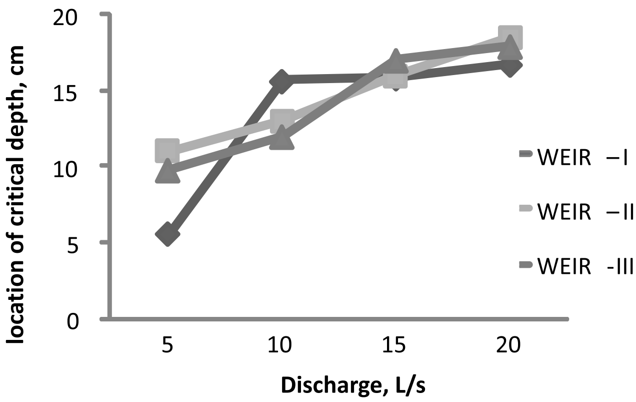

Fig. 2. Relationship between discharge and location of critical depth under free flow conditions

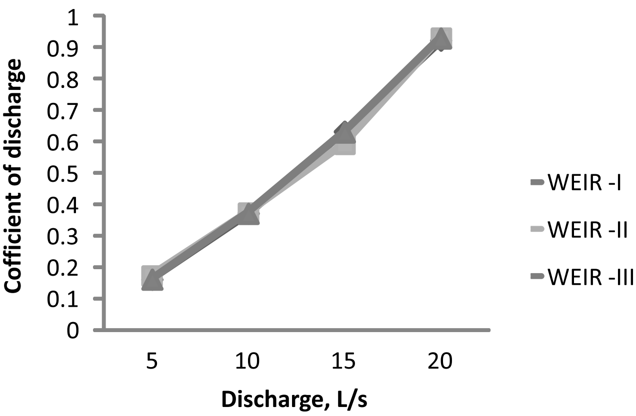

Fig. 3. Coefficient of discharge (C_d) values for different discharges for different Weirs

Table 2. Values of location of critical depth, coefficient of discharge, froude number, energy loss for weirs (I, II, III)

Discharge (l/s)	Critical depth (cm)	Locatio of critical depth (cm)			Coefficient of discharge (C_d)			Froude Number ($F_r = \frac{V_c}{\sqrt{g y_c}}$)			Energy loss (ΔE)		
		Weir I	Weir II	WeirIII	Weir I	Weir II	WeirIII	Weir I	Weir II	Weir III	Weir I	Weir II	Weir III
5	3.05	5.5	11	9.8	0.16	0.17	0.16	4.02	3.79	3.22	4.75	2.73	2.03
10	4.83	15.6	13	12	0.37	0.37	0.37	1.72	1.35	1.35	0.578	0.0422	0.0363
15	6.34	15.8	16	17	0.63	0.59	0.63	1.41	1.23	1.21	0.083	0.0179	0.0137
20	7.68	16.7	18.5	17.9	0.92	0.93	0.93	1.34	1.15	1.14	0.058	0.0072	0.0059

20 l/s it increased like 0.92, 0.93, 0.93 for weir-I, weir-II, weir-III respectively. For each weir as the discharge increases C_d values also increased. It can be concluded that C_d value increases with increase in discharge due to higher velocity and less friction. Hence weirs can be operated at higher discharges at field channels.

Table 3. Cost analysis of development of different sized sharp crested rectangular weirs

Weir	Quantity (cu.ft)	Cost (Rs)
Weir-I	0.1125	867.00
Weir-II	0.0794	613.00
Weir-III	0.0476	368.00

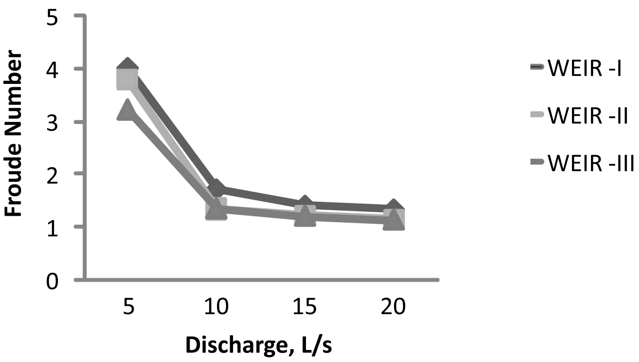

Fig. 4. Relationship between discharge and Froude number under free flow conditions

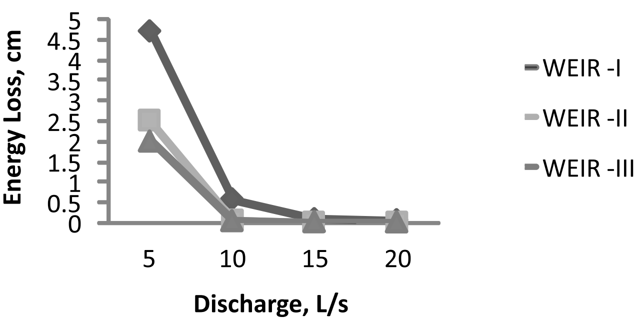

Fig. 5. Relationship between discharge and energy loss under free flow conditions

For discharge 20 l/s the froude number decreased from 1.34 to 1.14, for 15 l/s the froude number decreased from 1.41 to 1.21, for 10 l/s , the froude number decreased from 1.72 to 1.35, for 5 l/s the froude number decreased from 4.02 to 3.82 for weir-I to weir-III respectively. It is finally concluded that jump is an undular jump (i.e., F_r=1-1.7) for 20, 15 and 10 l/s and oscillating jump for 5 l/s (*i.e.,* F_r =2.5-4.5). It is concluded that, energy loss for undular jump is moderate and for oscillating jump it is about 50 per cent hence more energy loss can be obtained, in turn which decreases the erosion. For weir-I, froude number values are more compared to other two weirs.

For all the weirs energy loss is very high at 5 l/s and remains constant for remaining discharges. More energy loss is beneficiary, hence from the above values weir-I can be taken as more efficient among the three weirs used. The cost of teak wood for making of weirs is about Rs. 6471.50/- per cubic feet. Total volume of wood required for making three weirs is about 0.2395 cu.ft. So the total cost of production for three weirs is Rs. 1850/-.

CONCLUSIONS

The results indicated that the location of critical depth for all weirs at different discharges is away from the weir with respect to its sharp edge (location length increased with increase in discharges), coefficient of discharge varies from 0.93- 0.16 as per decrease in discharge levels which reduces the erosion due to decrease in velocity, from computed froude number the jump is an undular jump for 20, 15, and 10 l/s discharges which represents the energy loss as moderate and it is an oscillating jump for 5 l/swhich represents more loss of energy (about 50%). The three geometries tested for the weirs, 15 cm crest height with 30° reduced sharp crested rectangular weir (weir-I) performed better in terms of all parameters including cost of design which will enable a significant contribution while installation of water measurement in small scale irrigation system. At field level, it can be adapted with thick metallic material or concrete.

REFERENCES

Baddour RE 2008. Head-discharge equation for sharp-crested polynomial weir. *Journal of Irrigation and Drainage Engineering, ASCE* **134**(2): 260-262.

Castro-Orgaz O, Giraldez JV and Ayuso JL 2008. Critical flow over circular crested weirs. *Journal of hydraulic Engineering, ASCE* **134**(11): 1661-1664.

Gate Youngkyu Kim, Gyewoon Choi, Hyoseon Park and Seongjoon Byeon 2015. Hydraulic jump and energy dissipation with sluice. *Water* **7**(1): 5115-5133.

Ghanshyam Das 2010. *Hydrology and Soil Conservation Engineering*. Publisher- PHI Learning Pvt. Ltd., New Delhi. 341-463.

Gonalez CA and Chanson H 2007. Experimental measurements of velocity and pressure distributions on a large broad-crested weir. *Flow Measurement & Instrumentation* **18**(3/4): 107-113.

Hamed Azimi, Hazhar Hadad, Zakarya Shokati and Mohammad Sajad Salimi 2015. Discharge and flow field of the circular channel along the side weir. *Canadian Journal of Civil Engineering* **42**(4): 273-280.

Hariram Ch. Ratna Raju and Yogitha P 2009. Studies on critical flow conditions in semicircular crested weirs. *Unpublished B.Tech Thesis submitted to College of Agricultural Engineering*, Bapatla. ANGRAU.

Konstantinos X Soulis 2012. Field calibration of weirs using partial volumetric flow measurements. *Journal of Irrigation and Drainage Engineering ASCE* **138**: 481-484.

Martínez J, Reca J and Morillas 2005. Design and calibration of a compound sharp crested weir. *Journal of Hydraulic Engineering* **131**(2): 112-116.

Reg Herschy 1995. General purpose flow measurement equations for flumes and thin plate weirs. *Flow Measurement Instrumentation* **6**(4): 283–293.

Raouf E Baddour 2008. Head-discharge equation for sharp-crested polynomial weir. *Journal of Irrigation and Drainage Engineering ASCE* **134**(2): 260-262.

Ramamurthy AS, Junying Qu, Chao Zhai and Diep Vo 2007. Multislit weir characteristics. *Journal of Irrigation and Drainage Engineering ASCE* **133**(2): 198-200.

Sai Gangadhara Rao. 2010. *Flow characteristics of semicircular bottom contraction weirs for accurate water measurement in open channels.* Unpublished M.Tech. thesis submitted to College of Agricultural Engineering, Bapatla, ANGRAU.

Satyanarayana TV and Satyanarayana T 1993. Flow Characteristics of modified trapezoidal broad crested weirs for low discharges. *Indian Journal of Agricultural Engineering* **3**(1-2): 39-46.

Tigrek SC, Ersen Firat and AMetin Ger 2008. Use of brink depth in discharge measurement. *Journal of Irrigation and Drainage Engineering ASCE* **134**(1): 89-94.

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Algal Diversity in Rice Fields of Southern Assam, North-East India

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Abstract: Algal diversity in two rice fields of different surrounds in Hailakandi district, southern Assam, North-East India has been explored. The study documents the algal community structure in response to seasonal variation of physicochemical parameters of the water in the rice fields. A total of 92 algal species belonging to 53 genera under five classes has been recorded. The highest algal diversity was in the rice field at Mukamtilla, with tea garden as surround in pre-monsoon season (2.33). The species *Oscillatoria sancta, O. willei*, *O. earlei, O. limosa, Spirogyra mirabilis, Oedogonium* sp. and *Zygnema pectinatum* were the most dominant algae. The habitat was acidic with a significant variation among the seasons. The dissolved silica content of ricefield water was the most important environmental variable affecting the algal community structure. The species *Oscillatoria sancta*, *O. willei* and *O. earlei* were positively while *Oedogonium* sp. and *Zygnema pectinatum* were negatively correlated with the dissolved silica content.

Keywords: Algal diversity, Physicochemical parameter, Rice field, Hailakandi

Algae serve as the primary producers of wide variety of ecosystems and are most diverse and ubiquitous organism. They contribute to the natural soil formation, soil surface stabilization, improve texture, moisture balance, nutrient conservation and shares different food webs (Soare and Dobrescu 2010, Arguelles and Monsalud 2018). They also exhibit a huge range of adaptability with distinctive modifications in varying environmental conditions (Kumar et al 2018). Algal diversity has been reported from most of the diverse tropical terrestrial and aquatic habitats in different seasons (Arguelles and Monsalud 2018, Al-Jibouri et al 2018, Devi and Rout 2018). Rice fields furnish an ideal environment for the growth of blue green algae which contribute to the nitrogen economy of the soil. Species such as *Anabaena, Aulosira, Cylindrospermum, Nostoc, Scytonema, Tolypothrix, Westiellopsis* are the widespread nitrogen fixing, heterocystous forms in the rice-fields (Rao et al 2008, Thajamanbi et al 2016). In addition to harbouring algae, rice fields tend to serve as carbon sinks maintaining the carbon balance in the atmosphere (Arguelles and Monsalud 2018). Information on distribution and diversity of algal community in an agro-ecosystem is also useful in conservation of soil, its fertility, biotic component and sustainable management (Ray and Thomas 2012). The North-East region of India has been recognised as a biodiversity hot spot with extremely rich biological diversity. Hailakandi district, situated in the southernmost part of the state of Assamin North East India, believed to have derived its name from Bodokachari language, 'kandi' meaning 'temporary paddy lands' and 'Sailkandi' meaning 'Sali paddy' or 'winter rice'. Major part of agricultural area of the district is covered by rice fields. The rural economy in the district is primarily dependent on rice productivity. Rice cultivation in the wetlands during the dry season of the year is a common practice in the district. On the other hand, in the organized sector, tea is the main industry of the district and rice cultivation at the lowland areas inside the tea gardens is also a common practice. In NE India, algal diversity have been reported from a number of rice fields (Borah et al 2014, Das and Sarma 2015, Thajamanbi et al 2016). Although, rice is widely cultivated in the district, no concerted and systematic effort has so far been made to investigate the occurrence and distribution of different types of algae in the rice fields. Accordingly, the present study intends to explore the algal community structure in the rice fields with two different surrounds in Hailakandi district in the state of Assam, North-East India.

MATERIAL AND METHODS

Selection of study sites: The study was carried out during 2010 to 2012. Two rice fields with different surrounds were selected in Hailakandi district, Assam, North-East India. The rice field (N24°39'39.586' and E92°32'1.167'') at Mukamtilla (S-I) was located inside a tea garden, affected by biofertilizers and pesticide application (Plate 1A). The cultivation begins during monsoon period (June to August) and harvested in winter (December to February). The ricefield (N24°44'48.122'' and E92°33'52.514'') at Asiali beel (S-II) is a seasonal wetland, where cultivation begins only when water level decreases during winter. The crop is harvested in pre-monsoon period (March to May) with no information on external input of fertilizers and pesticides.

Physico-chemical analysis of water samples: The four characteristic seasons encountered are viz. monsoon (June to August), post monsoon (September to November), winter (December to February) and pre-monsoon (March to May). The surface water samples from different study sites were collected in triplicate for physico-chemical analysis. The pH was measured by electrometric method. Free CO_2 (f-CO_2) and total alkalinity (TAlk) were determined using the standard method (APHA, 2012). Dissolved oxygen (DO) of water samples were estimated using Winkler's method, soluble reactive phosphorous (SRP) by ascorbic acid method and dissolved silica (D-Si) was analyzed by molybdate blue method following Wetzel and Likens (1979). Nitrate was determined by Brucine method (Suess 1982).

Collection and identification of algae: Algal samples growing on the rice fields were collected randomly in three replicates for (i) live sample observation; (ii) preservation (4.5% formalin) and (iii) quantitative analysis. Temporary slides were prepared from the fresh as well as preserved samples to study the algal population by optical microscopy. Microphotographs with micrometric measurements were taken for each algal species by a Leica application suit (LM1000 LED). Algal species were identified by following the standard keys (Prescott 1951, Desikachary 1959, Sarode and Kamat 1984). For quantitative analysis, the algal cells were counted by Lackey's drop method (Trivedy and Goel 1986). A colony as well as a filament more than ¾ was considered as one individual.

Statistical analysis: The diversity indices like Shannon-Wiener diversity index_H, Simpson's dominance index_D and Pielou's evenness index_J were calculated. The algal abundance data were subjected to Principal Component Analyses (PCA).The datasets of algal abundance (dominant species) and environmental variables were subjected to Canonical Correspondence Analysis (CCA).

RESULTS AND DISCUSSION

Habitat characterization: In the study, a significant variation of water temperature (WT), pH, total alkalinity (TAlk), free-CO_2 (f-CO_2) and soluble reactive phosphorous (SRP) was observed among the seasons (Table 1). The highest WT was in monsoon in S-I (26.91C). As expected, the winter months experienced the lowest temperature of the year. In both the sites, pH was acidic (pH5.66-6.80). In site, S-I highest pH was observed in monsoon (6.80) followed by pre-monsoon, winter and post monsoon. A weakly acidic pH of the rice fields was similar to the findings of Guo et al (2018). In site, S-II pH was in the order of winter pre-monsoon> monsoon > post-monsoon. The magnitude of pH in the rice fields might be due to the amount of organic matter, since organic reducing substances also reduce the oxidized forms of inorganic compounds. A significant difference in WT and pH among the seasons was observed. In S-I, winter (10.45 mg l^{-1}) months experienced the highest dissolved oxygen content, which was nearly equal to the monsoon. Similar DO content was observed in pre-monsoon and post-monsoon. Similarly, in site S-II, the highest DO was observed in winter (9.68 mg l^{-1}) whereas the lowest was in post-monsoon (8.93 mg l^{-1}). A significant difference in DO content was observed in between the study sites although seasonal variation was not significant. The DO content in the rice fields might have been affected by the WT. The lowest WT in winter could comparatively hold a higher DO content in the study sites. A raise in DO in monsoon might be due to the well aeration of water due to rain. A marked seasonal difference in total alkalinity, free CO_2 and SRP was observed during the study

Plate 1. Overview of the study sites Mukamtilla (A) and Asiali beel (B)

period. In both the sites, a comparatively low alkalinity was observed in monsoon season. In S-I, the highest alkalinity was observed in winter (44.86 mg l^{-1}), whereas in S-II, the pre-monsoon season experienced the highest alkalinity of the year (53.56 mg l^{-1}). In the rice fields, the reaction between the organic acids/carbonic acid and minerals might have formed dissolved HCO_3^-, and this could result in the increase in alkalinity in winter. Irrespective of the sites, f-CO_2 was lowest during monsoon (1.43-1.60 mg l^{-1}). In S-I, f-CO_2 was highest during winter (5.10 mg l^{-1}), whereas post-monsoon experienced the highest f-CO_2 in S-II (4.18 mg l^{-1}). In S-I, dissolved silica (d-Si) content was in the order of winter (3.97 mg l^{-1}) < monsoon < post monsoon < pre-monsoon. A low d-Si content in winter might be due the low temperature of the season causing dissolution and precipitation of silica. The D-Si content varied significantly among the sites and seasons with a maximum value (8.06 mg l^{-1}) from S-II during pre-monsoon. In S-II, the silica content was in the order of post-monsoon (6.92 mg l^{-1}) < winter < monsoon< pre-monsoon. A fair content of d-Si in the rice fields might have contributed to the growth of rice plants as already evidenced (Riotte et al, 2018). Highest NO_3-N content (0.037 mg l^{-1}) was in S-I in pre-monsoon. In S-II, highest NO_3-N was found in post-monsoon (0.022 mg l^{-1}). In S-I, SRP ranged from 0.028 mg l^{-1} to 0.148 mg l^{-1}. In S-II, SRP was in the order of winter (0.016 mg l^{-1}) < post-monsoon < monsoon < pre-monsoon. A comparatively low NO_3-N and SRP concentration were noticed in monsoon, which might be effected by rain. The NO_3-N concentration increased with decline in water level in subsequent seasons aided by high rate of organic decomposition.

Distribution of algal community: A total of 92 algal species belonging to 53 genera under five classes had been observed in the rice fields (Table 2, Plate 2). Thirty (30) species belonging to 18 genera of chlorophyceae, 34 species belonging to 16 genera of bacillariophyceae and 24 species belonging to 15 genera of cyanophyceae were recorded in the rice fields. Charophyceae and euglenophyceae with two species each formed a small component of the algal community. The highest number of species (6) were observed under the genus *Navicula* followed by *Oscillatoria*. These two genera along with some other genera also recorded as the most dominant from vegetable crop fields of Cachar district (Devi and Rout 2018). The members of the genera *Oscillatoria, Navicula* and *Spirogyra* were observed at both the sites during all the seasons. The species *Spirogyra* and *Oscillatoria* have been recorded as the most commonly encountered algae from the rice fields of Cachar district in southern Assam (Rout and Dey 1999) out of a total of 16 algal species encountered. In the present study, a total of 56 algal species belonging to 38 genera under five classes viz. chlorophyceae (13), charophyceae (2), bacillariophyceae (18), euglenophyceae (2) and cyanophyceae (21) were recorded in the rice field of site S-I. In site, S-II, a total of 63 algal species belonging to 39 genera under five classes viz. chlorophyceae (25), charophyceae (2), bacillariophyceae (24), euglenophyceae (2) and cyanophyceae (10) were documented. A total of 34 species of cyanobacteria under 10 genera were reported from Karimganj district of southern Assam (Thajamanbi et al 2016)). Algal species like *Mougeotia* sp., *Oocystis* sp., *Scenedesmus dimorphus, S. quadricauda, Eunotiapseudoparallela, Frustulia jogensis, Gyrosigma* sp.,

Table 1. Water parameters of study sites (Mean ± SD)

Sites	Parameters /seasons	WT (˚C)	pH	DO (mg l^{-1})	TAlk (mg l^{-1})	FCO_2 (mg l^{-1})	Silica (mg l^{-1})	Nitrate (mg l^{-1})	SRP (mg l^{-1})
S-I	PM	21.39±5.11	6.61±0.36	9.59±0.68	42.14±11.14	2.89±0.28	7.70±1.07	0.037±0.03	0.148±0.17
	M	26.91±2.02	6.80±0.62	10.43±0.69	25.09±2.69	1.60±0.55	5.84±1.33	0.017±0.01	0.028±0.01
	PO	21.10±1.27	5.74±0.01	9.67±2.89	41.64±15.31	3.91±4.43	7.40±0.45	0.018±0.00	0.033±0.01
	W	18.52±1.51	6.50±0.48	10.45±0.82	44.86±4.61	5.10±2.27	3.97±3.84	0.022±0.01	0.076±0.06
S-II	PM	24.50±2.12	6.41±0.38	9.50±0.83	53.56±10.71	2.22±1.27	8.06±1.81	0.009±0.00	0.164±0.19
	M	26.57±3.44	6.27±0.69	9.19±2.07	31.16±2.10	1.43±0.78	7.29±0.03	0.018±0.00	0.026±0.01
	PO	19.88±0.88	5.66±0.29	8.93±1.41	32.94±1.73	4.18±1.56	6.92±0.51	0.022±0.00	0.019±0.02
	W	19.88±0.63	6.52±1.09	9.68±2.08	34.17±3.26	3.70±2.13	7.26±3.58	0.020±0.01	0.016±0.01
Sites	F-value	0.43	0.78	4.50*	0.45	1.49	5.37*	3.9	0.9
	P-Value	0.51	0.38	0.04	0.51	0.23	0.02	0.05	0.35
Seasons	F-value	35.31**	3.68*	0.99	12.57**	10.53**	2.76*	0.58	12.18**
	P-Value	0.001	0.02	0.4	0.001	0.001	0.04	0.63	0.001

*and **indicates significant difference at $p<0.05$, 0.001; PM=pre-monsoon, M=monsoon, PO=post-monsoon, W=winter, WT=water temperature, DO=dissolved oxygen, TAlk=total alkalinity, FCO_2= free carbondioxide, SRP=soluble reactive phosphate

Table 2. Seasonal distribution of algal taxa of the study sites

Name of the algal taxa	Sites	Mukamtilla				Asiali beel			
	Seasons /Species code	PM	M	PO	W	PM	M	PO	W
Class: Chlorophyceae									
Chlorococcum sp.	G1	-	-	-	-	+	-	-	+
Cladophora crispata (Roth) Kuetzing	G2	-	-	+	+	+	-	-	+
Closterium dianae Erenberg.	G3	-	-	+	-	-	-	-	-
Closterium ehrenbergii Menegh	G4	-	-	-	-	+	+	+	+
Closterium sp.	G5	+	+	+	-	+	+	+	+
Coelastrum microporum Naegeli	G6	-	-	-	-	-	+	-	-
Cosmarium botrytis Meneghini ex Ralfs	G7	-	-	-	-	-	+	+	+
Cosmarium granatum Brob.	G8	-	-	-	-	-	-	+	+
Cosmarium sp.	G9	-	+	+	-	-	+	-	+
Cosmariumsubimpressulum Borge.	G10	-	-	-	-	-	-	+	-
Cosmarium subprotumidum Nordstedt	G11	-	-	-	-	+	-	-	-
Cosmarium venustum Brébisson	G12	-	-	-	-	-	-	-	+
Cylindrocapsa sp.	G13	+	-	-	+	+	-	-	-
Elakatothrix sp.	G14	-	-	-	-	-	-	-	+
Euastrum sp.	G15	-	-	-	-	-	-	+	+
Mougeotia sp.	G16	+	-	-	+	-	-	-	-
Netrium sp.	G17	-	-	-	-	-	-	-	+
Oedogonium sp.	G18	-	+	-	+	-	+	+	+
Oedogonium verrucosum Hallas	G19	-	-	-	-	-	-	+	-
Oocystis sp.	G20	-	+	-	-	-	-	-	-
Pediastrum tetras (Ehrenb.) Ralfs	G21	-	-	-	-	-	+	+	-
Scenedesmus dimorphus (Turp.) Kuetzing	G22	-	+	-	-	-	-	-	-
Scenedesmus quadricauda G. M. Smith	G23	+	-	+	+	-	-	-	-
Scenedesmus sp.	G24	+	+	+	+	-	+	+	+
Spirogyra crassa Kuetzing	G25	-	+	+	-	+	+	+	+
Spirogyra fluviatilis Hilse in Rabenhorst	G26	-	-	-	-	+	+	+	+
Spirogyra mirabilis (Hass.) Kuetzing	G27	+	+	+	-	+	+	+	+
Tetraëdron hastatum (Reinsch) Hansgirg	G28	-	-	-	-	-	-	-	+
Uronema sp.	G29	-	-	-	-	-	-	-	+
Zygnema pectinatum (Vaucher) C. A. Agardh	G30	-	-	-	-	-	+	+	+
Class: Charophyceae									
Chara sp.	Ch1	-	+	+	+	-	-	+	+
Nitella sp.	Ch2	-	-	+	+	-	-	-	+
Class: Bacillariophyceae									
Achnanthes inflata (Kuetz.) Grun.	B1	-	+	+	-	+	-	-	+
Cylindrotheca sp.	B2	-	-	-	+	-	-	-	-
Cymbella cistula (Hemp.) Grun.	B3	-	+	+	+	+	-	-	-
Cymbella laevis Naeg.	B4	-	-	-	-	+	-	-	+
Eunotia alpina (Naeg.) Hustedt	B5	-	-	-	-	-	-	+	+
Eunotia camelus (Ehr.) A˚. Berg	B6	-	-	-	-	+	-	-	+
Eunotia pectinalis v. *minor* (Kuetz.) Rabh	B7	-	-	-	-	-	+	-	+
Eunotiapseudoparallela A˚. Berg.	B8	+	+	+	+	-	-	-	-
Frustulia jogensis Gandhi	B9	-	+	-	-	-	-	-	-
Gomphonema hebridense (Greg.) Her	B10	+	-	+	-	-	+	-	-
Gomphonema sp.	B11	-	-	-	+	+	+	+	+

Cont...

Gyrosigma sp.	B12	-	+	+	+	-	-	-	-
Hantzschia amphioxys (Ehr.) Grun	B13	-	-	-	-	-	-	+	-
Melosira islandica v. *helvetica* O. Muell.	B14	-	-	-	-	-	+	+	+
Melosira juergensii Agardh	B15	-	-	-	-	-	+	-	-
Navicula confervacea Kuetz.	B16	-	-	-	-	+	+	+	+
Navicula cuspidata Kuetz. f. *danaica* Grun.	B17	-	-	-	-	+	-	+	+
Navicula laterostrata Hustedt	B18	+	+	+	+	-	-	-	-
Navicula mutica v. *linearis* Gonz. et Gandhi	B19	-	+	-	+	-	-	-	-
Navicula radiosa v. minutissima (Grun) Cleve	B20	+	+	+	+	+	+	+	+
Navicula radiosa v. tenella (Breb. Ex. Kutz.) Grun.	B21	-	-	-	-	+	+	+	+
Navicula subrhynchocephala Hustedt	B22	-	-	-	-	-	+	-	+
Nitzschia lorenziana v. *subtilis* Grun	B23	-	-	+	-	+	-	-	+
Nitzschia palea (Kuetz.) W. Smith	B24	-	-	-	-	-	-	+	+
Nitzschia recta Hantzsch	B25	-	-	-	-	+	-	-	+
Pinnularia brevicostata Cleve	B26	+	-	+	-	+	-	-	+
Pinnularia interrupta W. Smith	B27	+	+	-	+	-	-	-	-
Pinnularia legumen v. *interrupta* Gandhi	B28	-	+	-	-	-	-	-	-
*Pinnularia sudetica*v. *communata* (Grun.) Cleve f. *obtusata* Gandhi	B29	-	-	-	-	-	+	+	-
*Pinnularia termis*v. *terminata* (Ehr.) A. Cl.	B30	-	-	-	-	+	-	-	+
Pleurosigma sp.	B31	-	+	+	-	-	+	+	-
Surirella sp.	B32	-	-	+	+	-	-	-	-
Synedra ulna (Nitz.) Ehr.	B33	+	+	+	+	+	-	-	+
*Synedra ulna*v. *subaequalis* Grun.	B34	-	-	-	-	+	+	+	+
Class: Euglenophyceae									
Euglena sp.	E1	-	+	-	+	-	+	+	+
Phacus sp.	E2	-	+	-	+	-	+	+	-
Class: Cyanophyceae									
Anabaena affinis Lemmermann	C1	-	-	+	-	-	-	+	+
Anabaena unispora Gardner	C2	+	+	+	+	-	-	-	-
Aphanothece sp.	C3	-	-	+	+	-	-	-	-
Calothrix sp.	C4	-	-	+	+	-	-	-	-
Chroococcus sp.	C5	-	-	+	-	-	-	-	-
Cylindrospermumstagnale (Kütz) Born. et Flah.	C6	-	-	+	+	+	-	-	+
Gloeocapsa aeruginosa (Carm.) Kuetzing	C7	-	-	-	-	+	-	-	-
Gloeothecerupestris (Lyngb.) Bornet in Wittrock & Nordstedt	C8	-	-	+	-	-	-	-	-
Lyngbya martensiana Meneghini	C9	-	+	+	-	-	-	-	-
Lyngbya sp.	C10	-	-	-	-	+	+	+	+
Nostoccoeruleum Lyngbye ex Born. et Flah.	C11	+	+	+	+	+	-	-	+
Nostoc linckia (Roth) Bornet & Thuret	C12	-	+	-	-	-	-	-	-
Oscillatoria earlei Gardner	C13	+	+	+	-	+	+	-	+
Oscillatoria formosa Bory	C14	+	-	+	-	-	-	-	-
Oscillatoria limosa (Roth) C. A. Agardh	C15	+	+	+	+	+	+	+	+
Oscillatoria prolifica (Grev.) Gomont	C16	+	-	+	+	-	-	-	-
Oscillatoria sancta (Kuetz.) Gomont	C17	+	+	+	-	+	+	-	-
Oscillatoria willei Gardner em. Drouet (after Gardner)	C18	+	+	+	-	-	-	-	-
Phormidium sp.	C19	+	+	+	+	-	-	-	-
Rhaphidiopsis sp.	C20	-	-	+	-	-	-	-	-
Scytonema frémyiu nom.	C21	+	-	-	+	-	-	-	-
Spirulina major Kuetzing	C22	-	-	-	-	-	-	-	+
Spirulina sp	C23	-	-	+	+	-	-	+	+
Stigonemapaniforme (Ag.) Born et Flah.	C24	-	-	-	+	-	-	-	-

(PM=pre-monsoon, M=monsoon, PO=post-monsoon, W=winter, +=present, -=absent)63 39 chl (25), charo (2), bac (24), eug (2), cya (10)

Navicula laterostrata, N. mutica, Pinnularia interrupta, P. legumen, *Surirella* sp., *Anabaena unispora, Nostoc linckia, Oscillatoria formosa, O. prolifica, O. willei, Phormidium* sp. were restricted only to site, S-I. However, *Chlorococcum* sp., *Closterium ehrenbergii, Coelastrum microporum, Cosmarium subprotumidum, Elakatothrix* sp., *Euastrum* sp., *Cymbella laevis, Gloeocapsa aeruginosa, Lyngbya* sp., *Spirulina major* were confined to site, S-II. In site, S-I, *Closterium dianae, Nitzschia lorenziana*, *Chroococcus* sp., *Gloeothecerupestris* and *Rhaphidiopsis* sp. were found to colonize only in post-monsoon period. *Gomphonema* sp. and *Stigonemapaniforme* were observed only in winter. In site, S-II, *Closterium ehrenbergii, Closterium* sp., *Spirogyra crassa, Spirogyra fluviatilis, Spirogyra mirabilis, Gomphonema* sp., *Navicula confervacea, Navicula radiosa, Synedra ulna*,*Lyngbya* sp., *Oscillatoria limosa* were found to grow throughout the year. *Coelastrum microporum* was observed only in winter period. A total of 24 species of cyanobacteria have been documented in the rice fields of which 8 species were heterocystous. The cyanobacterial growth was supported by the optimum range of physico-chemical parameters (Selvi and Sivakumar 2011). Pertinent to mention herein that rice field ecosystems are the ideal niche for growth and proliferation of algae particularly the blue green ones contributing to the nitrogen economy.

The seasonal variation of algal diversity in the rice fields were also calculated (Table 3). During pre-monsoon and monsoon, higher diversity was observed in site S-I compared to that in site, S-II. This might be due to the enhanced nutrient content that entered into the rice field of site, S-I through runoff from the surrounding tea garden area favoring algal growth. Highest algal diversity was recorded from the same site during pre-monsoon when there was no disturbance due to agricultural activity. Least diversity was observed in site, S-I during post-monsoon due to the dominance of blue green algae or cyanophyceae. In site, S-II the algal diversity was higher during winter and pre-monsoon due to the decrease in water level of the wetland, which facilitated the algal growth. In comparison to pre-monsoon, the diversity was observed to be less in winter. This is ascribed to the disturbance in algal growth due to tillage practice.

Effect of environmental factors on algal colonization: Principal Component Analysis (PCA) was used to identify the dominant species from the study sites. The abundance of the algae was described with PCA axes. For site, S-I, PC axes 1 and 2 explained 67.98 per cent of the variance (Fig. 1), whereas for site, S-II, it described 78.15 per cent of the total variance in the species cell count biplot (Fig. 2). It was observed that in site, S-I, the members under the genus of *Oscillatoria* were more dominant. Among them,the species *Oscillatoria sancta* was the most abundant followed by *O. willei* and *O. earlei.* In site, S-II, *O. limosa* was the most abundant alga followed by the members of chlorophyceae like *Spirogyra mirabilis*, *Oedogonium* sp. and *Zygnema pectinatum* etc. The abundance and diversity of algae in the rice fields are closely related to the environmental changes (Al-Shami et al 2010). The primary result of a CCA is an ordination diagram, which is a graph with a coordinate system shaped by ordination axes. Twenty dominant species computed from PCA were selected for analysis, and the associations between the occurrence of algal species and

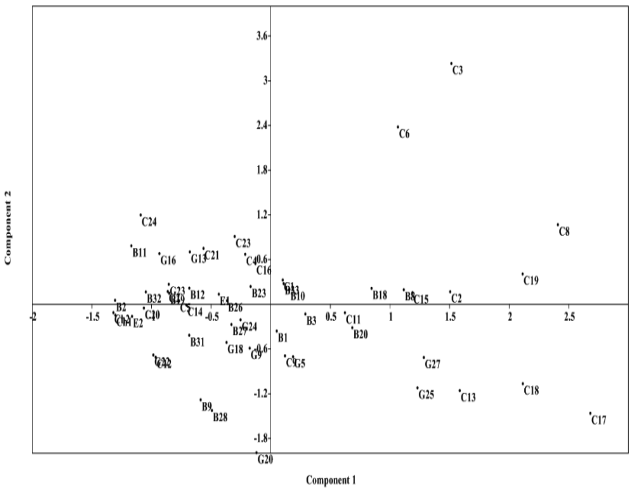

Fig. 1. PCA scatter diagram of algal species abundance in Mukamtilla rice field (species codes as in Table 2)

Table 3. Variation of diversity indices at the study sites (Mean ± SD)

Diversity index	Seasons/Sites	PM	M	PO	W
Shannon-Wiener Diversity Index (H)	S-I	2.33±0.05	1.81±0.27	1.24±1.25	1.52±0.77
	S-II	2.01±0.23	1.57±0.44	1.43±0.61	1.88±0.38
Simpson's dominance Index (D)	S-I	0.13±0.02	0.30±0.10	0.54±0.48	0.38±0.32
	S-II	0.25±0.06	0.35±0.20	0.35±0.15	0.26±0.13
Pielou's evenness index (J)	S-I	0.83±0.03	0.58±0.06	0.37±0.36	0.56±0.31
	S-II	0.63±0.06	0.51±0.12	0.46±0.18	0.57±0.10

the physicochemical environmental variables in both the rice fields were explored. It explains the environmental variables plotted as lines emanating from the center of the graph along with the points for taxa. The lines representing the environmental variables indicate the direction of maximum change of that variable across the diagram and the position of the species points indicates the ecological preference of the species. In site, S-I, algal species were ordinated towards the right as well as left side of the plot. The CCA axes 1 and 2 explained 87.77 per cent of the variance in the species-environment biplot (Fig. 3). The parameters F-CO_2 and di-Si were closely related to the pattern of community variations. *Oscillatoria sancta*, *O. willei* and *O. earlei* were positively related with silica content and negatively with f-CO_2. In right ordination of the plot (positive), *Phormidium* sp. was closely related with total alkalinity and f-CO_2. Towards the left ordination of the plot, species abundance like *Oscillatoria earlei*, *O. sancta* and *O. willei* were highly regulated by WT. This showed the pronounced effect of water temperature on regulating algal communities in the rice field. *Navicula radiosa* was associated with SRP and pH of the rice field.Taraldsvik and Myklestad (2000) emphasized pH as an important factor in regulating diatom growth. For site, S-II, CCA axis 1 and 2 explained 86.68 % of total variance (Fig. 4). The d-Si content was the most important variable in the data set. *Anabaena affinis*, *Spirulina* sp., *Cylindrocapsa* sp., *Oedogonium* sp. and *Zygnema pectinatum* preferred to grow in the rice-fields with low d-Si and SRP concentration. *O. earlei* and *O. sancta* were positively related with d-Si content of the rice field water, which was similar tosite, S-I. Role of cyanobacteria in biosilicification was also reported (Benning et al 2005). It has been observed that each species flourished at its optimum nutritional requirement, which was invariably different for each species even under the same genus. This explains the Shelford's Law of Tolerance. Therefore, species separated their niches to minimize competition which can be

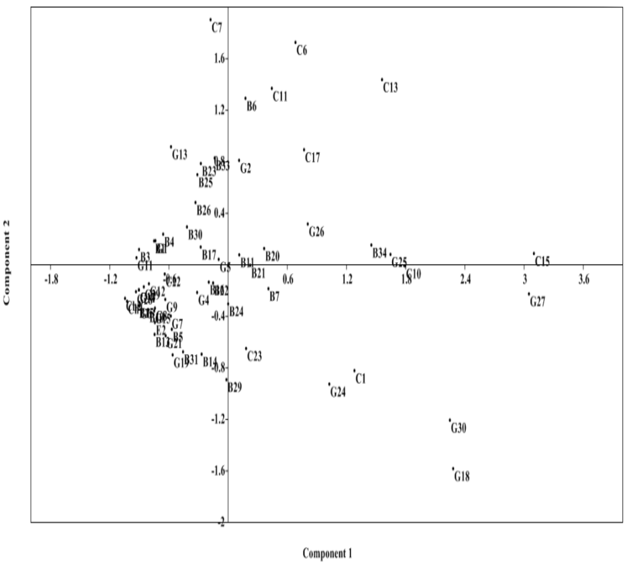

Fig. 2. PCA scatter diagram of algal species abundance in Asiali beel rice field (species codes as in Table 2)

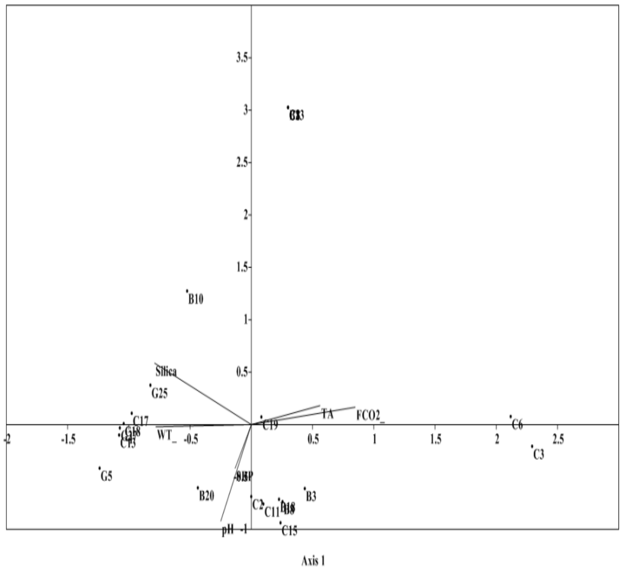

Fig. 3. Ordination diagram for CCA showing the association of algal species with environmental variables for Mukamtilla rice field (Species codes as in Table 2; WT- water temperature; DO-dissolved oxygen; FCO_2-free carbon dioxide; Talk-total alkalinity; SRP-soluble reactive phosphate)

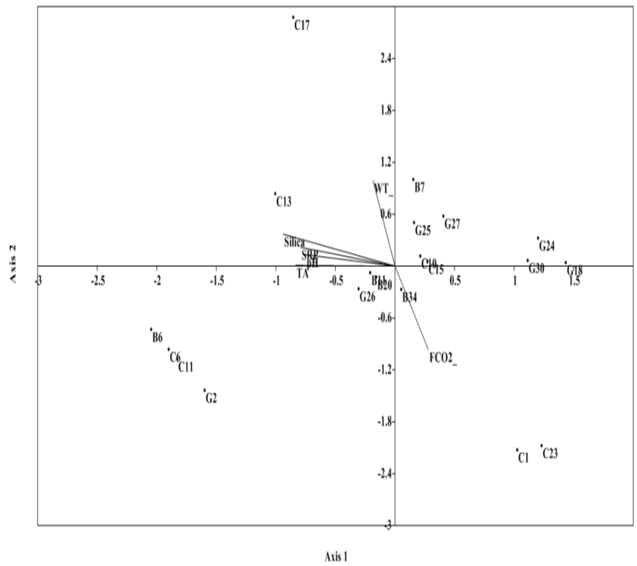

Fig. 4. Ordination diagram for Canonical Correspondence Analysis showing the association of algal species with environmental variables for Asiali beel rice field (Species codes presented in Table 2; WT- water temperature; DO-dissolved oxygen; FCO_2- free carbon dioxide; Talk-total alkalinity; SRP-soluble reactive phosphate)

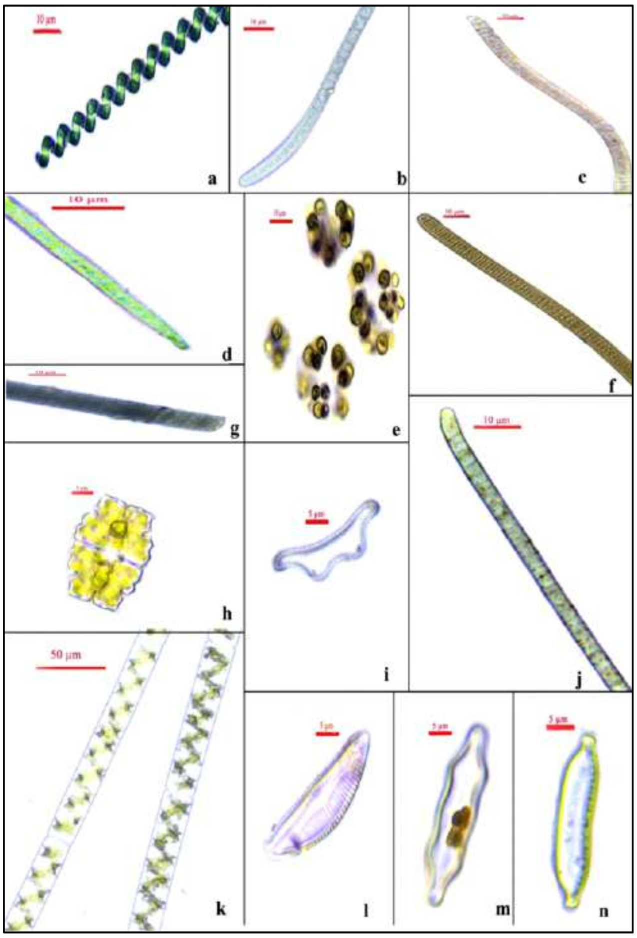

Plate 2. A. *Spirulina major,* **b.** *Oscillatoria willei,* **c.** *Oscillatoria formosa* Bory, **d.** *Oscillatoria earlei,* **e.** *Gloeocapsa aeruginosa*, **f.** *Oscillatoria sancta,* **g.** *Oscillatoria limosa*, **h.** *Euastrum* sp., **i.** *Eunotia camelus,* **j.** *Oscillatoria prolifica,* **k.** *Spirogyra mirabilis*, **l.** *Cymbella laevis,* **m.** *Navicula mutica,* v*linearis,* **n.** *Hantzschia amphioxys*

attributed to the physiological adaptability. Study of algal ecology is rather important for conservation and potential biotechnological application of algae (Kumar and Sahu 2012).

CONCLUSION

The study portrays the richness of algal communities in the rice fields of Mukamtilla and Asiali beel in southern Assam. The highest algal diversity (2.33) observed in Mukamtilla rice field was mostly due to the runoff from the surrounding tea garden adding to the external fertilizer input.However, the species richness was highest in the wetland of Asiali beel. Bacillariophyceae was the most dominant colonizer followed by chlorophyceae, cyanophyceae, charophyceae and euglenophyceae. Rich colonization of bacillariophyceae might have added to the silicon-sink of the rice fields. D-Si, water temperature, pH, SRP and F-CO_2 were also found to be the most important factors in regulating the species specific algal abundance in the study sites. In absence of external fertilizer input, rice productivity in Asiali beel might be attributable to the intrinsic capability of the agro-ecosystem, aided by the nitrogen fixing microorganisms. This is inevitably important for a sustainable agriculture in such agro-ecosystems. Also, an understanding of algal distribution and diversity in response to environmental factors is a pre-requisite to conserve natural communities by protecting the sites of phycological relevance.

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REFERENCES

Al-Jibouri KDW, Hassan FM and Hakman AA 2018. Ecological and taxonomical study of Epipelion Community in Diyala river in Diyala Province- Iraq. *Indian Journal of Ecology* **45**: 680-688.

Al-Shami SA, Che Salmah MR, Siti Azizah MN and Abu Hassan A 2010. The influence of routine agricultural activities on the quality of water in a tropical rice field ecosystem. *Applied Ecology and Environmental Research* **8**: 11-18.

APHA 2012. *Standard Methods for Examination of water and wastewater*. 22nd ed. pub. APHA, AWAA, WPCF, Washington DC, USA.

Arguelles EDLR and Monsalud RG 2018. Morphotaxonomy and Diversity of terrestrial microalgae and cyanobacteria in biological crusts of soil from paddy fields of Los Baños, Laguna (Philippines). *Philippine Journal of Systematic Biology* **11**: 25-36.

Benning LG, Phoenix V and Mountain B 2005. Biosilicification: The role of cyanobacteria in silica sinter deposition, pp 131-150. In: Gadd G M, Semple K T and Lappin-Scott H M (eds). *Micro-organisms and Earth systems – advances in geomicrobiology*. Cambridge University Press.

Borah D, Rout J and Thajuddin N 2014. Polyphasic characterization of *Nostoc commune* (Cyanobacteria, Nostocaceae) isolated from rice growing agro-ecosystems of Dima Hasao district of Assam, North-East India. *Phytotaxa* **161**: 111-120.

Das K and Sarma GC 2015. Survey and identification of genus *Nostoc* and *Anabaena* in the rice fields of Jorhat district, Assam. *International Journal of Plant, Animal and Environmental Sciences* **5**: 159-168.

Desikachary TV 1959. Cyanophyta. Monograph. I.C.A.R. New Delhi. India

Devi LB and Rout J 2018. Diversity of soil algae from vegetable crop fields of Cachar District, Assam, India. *Indian Journal of Ecology* **45**: 689-696.

Guo X, Li H, Yu H, Li W, Ye Y and Biswas A 2018. Drivers of spatio-temporal changes in paddy soil pH in Jiangxi Province, China from 1980 to 2010. *Scientific Reports* **8**: 2702.

Hoffman L, Ector L and Kostikov I 2007. Algal flora from limed and unlimed forest soils in the Ardenne (Belgium). *Systematics and Geography of Plants* **77**: 15-90.

Kumar A and Sahu R 2012. Diversity of algae (Cholorophyceae) in paddy fields of Lalgutwa Area, Ranchi, Jharkhand. *Journal of Applied Pharmaceutical Science* **2**: 092-095.

Kumar GE, Thanzeeha KV, Sasikala K, Pradeepkumar G, Sivadasan KK and Abdul Jaleel V 2018. A preliminary study on the diversity of planktonic algae of Kaanam River, Kannur, Kerala, India. *Phykos* **48**: 13-16.

Lukesova A and Frouz J 2007. Soil and Fresh Water Micro-Algae as a Food Source for Invertebrates in Extreme Environments, pp 387-397. In: Seckbach J (ed). *Algae and Cyanobacteria in Extreme Environments*. Springer, Netherlands.

Naik UG, Nayak VV and Kusuma N 2012. Diurnal variation of phytoplankton in the Kali Estuary, Karwar, West Coast of India. *Indian Journal of Ecology* **39**: 52-57.

Prescott GW 1951. Algae of Western Great Lakes Area. Ottokoeltz. Sci Publisher West Germany

Rao DB, Srinivas D, Padmaja O and Rani K 2008. Blue-green algae of rice fields of South Telangana region, Andhra Pradesh. *Indian Hydrobiology* **11**:79-83.

Ray JG and Thomas TB 2012. Ecology and diversity of green-algae of tropical oxic dystrustepts soils in relation to different soil parameters and vegetation. *Research Journal of Soil Biology* **4**: 42-68.

Riotte J, Sandhya K, Prakash NB, Audry S, Zambardi T, Chmeleff J, Buvaneshwari S and Meunier JD 2018. Origin of silica in rice plants and contribution of diatom earth fertilization: Insights from isotopic Si mass balance in a paddy field. *Plant and Soil* **423**: 481–501.

Rout J and Dey A 1999. A study of algal flora from rice field of Irongmara (Barak Valley, Assam). *Phykos* **38**: 19-25.

Sarode PT and Kamat ND 1984. Fresh water Diatoms of Maharastra. Saikripa Prakashan, Arungabad.

Selvi TK and Sivakumar K 2011.Cyanobacterial diversity and related physico-chemical parameters in paddy fields of Cuddalore district, Tamilnadu. *International Journal of Research in Environmental Science and Technology* **1**: 7-15.

Shelford VE 1911. Ecological succession: stream fishes and the method of physiographic analysis. *The Biological Bulletin* **21**: 9-34.

Soare LC and Dobrescu CM 2010. Preliminary data on edaphic algae in the city of Pitesti (Romania). *Fascicula Biologie* **17**: 186-189.

Suess MJ 1982. Examination of water for pollution control: A reference Handbook, 3 vols. Pergamon Press.

Taraldsvik M and Myklestad S 2000. The effect of pH on growth rate, biochemical composition and extracellular carbohydrate production of the marine diatom *Skeletonema costatum*. *European Journal of Phycology* **35**: 189-194.

Thajamanbi M, Rout J and Thajuddin N 2016. Blue green algae from rice fields of Karimganj district, Assam, North-East India. *International journal of Life Science and Pharma Research* **6**: 23-32.

Trivedy RK and Goel PK 1986. *Chemical and Biological Methods for Water Pollution Studies*. Environmental Publication. Karad, India

Wetzel RG and Likens GE 1979. *Limnological Analyses*, Pub .W.B. Saunders Company, Philadelphia.

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Effect of Different Land Configuration and Establishment Methods on Productivity of Aerobic Rice

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Abstract: Field investigation was carried to study the effect of different land configurations and establishment methods on yield attributes and yield of aerobic rice. The yield attributes *viz.,* productive tillers, panicle length and weight, grain and straw yield were significantly influenced by raised bed system. Transplanting of 14 days old seedling in saturated soil performed better yield attributes and yield over direct seeding and 21 days old seedling. Interaction of raised bed and transplanting of 14 days old seedling has registered higher yield parameters and yield (4756 and 6874 kg ha^{-1} grain and straw yield, respectively) of aerobic rice.

***Keywords*:** Aerobic rice, Land configuration, Establishment method, Yield attributes and yield

Rice (*Oryza sativa* L.) is a major source of food crop for more than half of the world population and 90 per cent of the rice area worldwide is in Asia. Transplanting of rice seedlings under puddled field condition is commonly practiced establishment method of rice cultivation in India. Even though, it is common practice, flooded and irrigated rice systems consumes two-three times more water than other cereals, such as maize and wheat. Future predications on water scarcity limiting agricultural production have estimated that by 2025 about 2 million ha of Asia's irrigated rice fields will suffer from water shortage. Since conventional method of rice cultivation requires more than 45 per cent of 90 per cent of total freshwater availability (Bouman 2001, Bouman et al 2005, Peng et al 2006). Hence, the major challenges are to produce more rice, increase water productivity and reduce water input in the fields. There is need to be develop new rice cultivation technology which requires less amount of water compared to conventional method of rice production. A new development in water-saving technologies is the concept of "aerobic" rice (Bouman et al 2004). In aerobic system rice has been grown under un puddled, aerobic soil conditions in uplands with supplemental irrigation. The yield obtained from aerobic rice is lesser compared to conventional method of rice cultivation because of adverse environmental conditions such as poor soils, low rainfall, high weed infestation, low use of external inputs, and low yield potential of upland rice cultivars (Maclean et al 2002). The aerobic rice cultivation was practiced in most part of the countries, agronomic management practices to be optimized depending upon the environmental conditions of the region. Among them, land configuration and establishment method for aerobic rice is an important management practice to obtain higher yield parameters and yield in aerobic rice. In this study an attempt has been made to study the different land configuration for aerobic rice production *viz.,* ridges and furrows, raised bed and flat bed system. Direct seeding is the common establishment method in aerobic rice practiced in many countries (Singh et al 2006). The major problem in the direct seeding is poor germination of seeds due to unfavorable conditions. To overcome this, transplanting of healthy and sturdy seedlings under saturated soil condition could be an alternative to direct seeding with minimum use of labour requirement. Keeping these the present study was conducted to study the effect of different land configurations and establishment methods on yield attributes and yield of aerobic rice.

MATERIAL AND METHODS

Field experiment was conducted at Agricultural College and Research Institute, Madurai during *kharif* 2017 to study the effect of different land configuration and establishment methods on yield attributes and yield of aerobic rice. The experimental site was geographically located at 9°54' N latitude and 78°54' E longitude with an altitude of 147 m above the mean sea level. The initial soil sample was collected from the experimental field and its physico chemical properties were analysed. The experimental field soil was sandy clay loam in texture with the pH of 7.25. The nutrient status was medium in available nitrogen and phosphorus and high in available potassium. The experiment was laid out in split plot design with three replications using rice variety ANNA (R) 4. Different land configurations *viz*., ridges and furrows (L_1), raised bed (L_2) and flat bed (L_3) as main plot and sup plot treatments consist of different establishment methods *viz*., direct seeding (E_1), transplanting of 14 (E_2) and 21 days old seedlings (E_3). The experimental field was ploughed twice with mould board plough followed by cultivator twice. Ridges and furrows were formed manually at 25 cm spacing and raised beds were formed with a top bed width of 100 cm and furrows of 15 cm deep and to a width of 30 cm. Flat beds were also formed by manually.

For direct seeding, seeds were soaked in water for 12 hrs and shade dried for 12 hrs and pre germinated seeds were directly sown with a spacing of 25 cm x 25 cm. For transplanting sturdy seedlings of 14 and 21 days old seedlings were transplanted by manually, it has inter row spacing of 25 cm and intra row spacing of 25 cm. After direct seeding, first irrigation was given and life irrigation was given on 3 DAS. Thereafter, the irrigation was given at once in five days interval. For raised bed system the irrigation was given up to the brim of the furrow. Finally irrigation was stopped 10 days prior to harvesting. The recommended dose of fertilizer 150:50:50 kg N, P_2O_5, K_2O per ha was applied for aerobic rice. The N was applied in the form of urea (46 % N) and applied at 20 % at 15 DAS, 30 % each at tillering and PI and remaining 20 per cent at flowering. Full dose of P_2O_5 was as applied as basal in the form of single super phosphate (16 % P_2O_5) and K_2O was applied as muriate of potash (60 % K_2O) at four equal splits viz., one at basal and another at active tillering, panicle initiation and heading stages. The yield parameters were recorded at harvest stage of the crop growth. The number of filled and ill filled grains per panicle was counted from five randomly selected panicles and the sterility percentage was worked out.

RESULTS AND DISCUSSION

Number of productive tillers per hill: There is significant influence on the number of productive tillers per hill under different land configuration and establishment methods (Table 1). Among the different land configurations, raised bed system recorded higher number of productive tillers m^{-2} (171 productive tillers m^{-2}) and followed by flat bed system. Whereas indifferent establishment methods, transplanting of 14 days old seedling recorded 157 productive tillers m^{-2} followed by transplanting of 21 days old seedlings. The minimum number of productive tillers was observed under direct seeding. The interaction between raised bed and transplanting of 14 days old seedling has registered 192 productive tillers m^{-2}. The maximum number of productive tiller in raised bed was attributed due to higher availability of soil moisture which positively influences the higher nutrient uptake of aerobic rice. These results were closely confirmity with the earlier findings of Aslam et al (2008).

Panicle length and panicle weight: Significant influence was noted in panicle length and weight due to different land configuration and establishment method in aerobic rice. Raised bed system recorded lengthier panicle (23.0 cm) and panicle weight (3.2 g) and followed by flat bed system (21.2 cm and 2.7 g panicle length and panicle weight, respectively) (Table 1). Establishment method of transplanting of 14 days old seedling was accounted higher panicle length (22.6 cm) and panicle weight (3.0 g), followed by transplanting of 21 days old seedlings. The significant interaction was noted in land configuration and establishment method of aerobic rice. The crop raised in beds with transplanting of 14 days old seedling was recorded higher panicle length and weight of 26.3 cm and 3.8 g respectively at 5 per cent probability level. The higher panicle length and weight was might be due to the better availability and utilization of nutrients in properly spaced and transplanted crop during panicle growth period (Awan et al 2011).

Number of filled and ill filled grains per panicle: The significant differences were observed in the number of filled

Table 1. Effect of different land configuration and establishment methods on number of productive tillers, panicle length and panicle weight of aerobic rice

Treatments	Productive tillers m^{-2}				Panicle length (cm)				Panicle weight (g)			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
E_1	90	146	125	120	18.4	20.4	19.3	19.4	2.1	2.5	2.5	2.3
E_2	118	192	160	157	19.4	26.3	22.2	22.6	2.2	3.8	3.1	3.0
E_3	107	176	144	142	18.6	22.3	22.0	21.0	2.1	3.4	2.6	2.7
Mean	105	171	143		18.8	23.0	21.2		2.1	3.2	2.7	
	L	E	L at E	E at L	L	E	L at E	E at L	L	E	L at E	E at L
CD (p=0.05)	32	33	35	36	1.51	1.28	2.34	2.22	0.35	0.31	0.37	0.37

and ill filled grains per panicle (Fig. 1). The perusal data on different land configurations, higher number of filled grains (95 grains per panicle) were noted under raised bed system followed by flat bed and ridges and furrows. Among the establishment methods, transplanting of 14 days old seedlings were registered higher number of filled grains per panicle (93 grains per panicle) followed by transplanting of 21 days old seedlings (92 grains per panicle). Whereas higher number of ill filled grains per panicle was accrued with ridges and furrows (22 grains) and it was followed by flat bed system. Raised bed system registered lower number of ill filled grains per panicle (11 grains per panicle). Data on establishment methods shows that minimum number of ill filled grains per panicle was noticed in transplanting of 14 days old seedlings; however it was on par with transplanting of 21 days old seedling. The interaction effect was found to be non-significant. Higher number of filled grains per panicle in raised bed and transplanting of 14 days old seedling was due higher soil moisture availability which increases nutrient availability possibly facilitated to supply the more food materials, moisture and light for the plants and ultimately developed more grains. These findings are in line agreement with the earlier findings Kumhar et al (2016).

Sterility percentage: Among the different land configuration significantly lower sterility percentage (12) was recorded in the raised bed and it as followed by flat bed system (14) (Fig. 1). With regards to different establishment methods, transplanting of 14 days old seedlings has registered lower sterility (14 per cent). The interaction effect was non-significant. The low sterility in raised bed planting system might be the basis of higher grains panicle^{-1}, which directly added the grain yield. Awan et al (2011) stated that maximum sterility percentage under direct seeding is because of more tertiary tillers production, which bear late flowering.

Test weight (1000 grains): Among the different land configurations, higher test weight was registered under raised bed system (24.7 g) and it was followed by flat bed system (Table 2). With regarding to different establishment methods, transplanting of 14 days old seedling has registered higher test weight of 24.4 g and it was on par with transplanting of 21 days old seedlings. The interaction effect was to be non-significant. It might be due to the production of less number of tillers per m^{-2}, which facilitated translocation of solutes throughout the grain developmental stages (Baloch et al 2007).

Grain yield and straw yield: Adoption of different land configurations coupled with different establishment methods positively influence the grain and straw yield of aerobic rice (Table 2). Among the different land configurations, raised bed system recorded higher grain yield of 4098 kg ha^{-1} followed by flat bed and by ridges and furrows. Higher yield under raised bed system are attributed to good crop conditions, more availability of soil moisture and nutrient availability which resulted higher panicle length, number of grain/panicle and 1000 grain weight resulted in higher grain yield. With respect to different establishment methods, transplanting of 14 days old seedlings recorded higher grain yield of 3719 kg ha^{-1} followed by transplanting of 21days old seedlings. The lowest grain yield was from direct seeding which may be due to lower number of grains per panicle and 1000 grain weight. These findings are in accordance with that of Awan et al (2005) who reported lower grain yield in direct seeding on flat soil than other planting methods of rice. The significant interaction effect was found between land configuration and

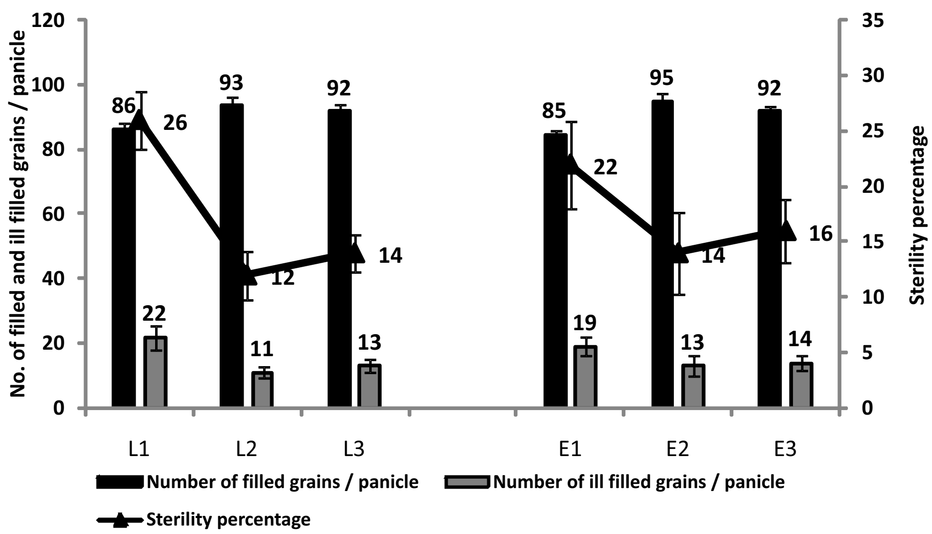

Fig. 1. Effect of different land configuration and establishment methods on number of filled grains, ill filled grains per panicle and sterility percentage of aerobic rice

Table 2. Effect of different land configuration and establishment methods on test weight , grain yield and straw yield of aerobic rice

Treatments	Test weight (g)				Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean	L_1	L_2	L_3	Mean
E_1	23.0	23.6	23.2	23.3	2100	3167	2765	2677	3302	4891	4428	4207
E_2	23.2	25.5	24.5	24.4	2576	4756	3825	3719	4081	6874	5743	5566
E_3	23.1	25.0	24.0	24.0	2459	4370	3282	3370	3874	6124	5021	5006
Mean	23.1	24.7	23.9		2378	4098	3291		3752	5963	5064	
	L	E	L at E	E at L	L	E	L at E	E at L	L	E	L at E	E at L
CD (p=0.05)	1.12	0.83	NS	NS	340	300	350	364	499	474	464	472

establishment methods, higher grain and straw yield of 4756 kg ha^{-1} and 6874 kg ha^{-1} was registered under raised bed system with transplanting of 14 days old seedlings, respectively. It was followed by transplanting of 21 days old seedlings under saturated soil condition. The lower grain and straw yield was recorded direct seeding in the ridges and furrows. Increment in grain yield in raised bed system is due to more soil moisture availability at the root zone particularly under subsurface level which favoured better crop growth, more nutrient uptake and higher translocation leading to production of larger leaf area index which was responsible for harvesting more solar energy. This coupled with higher stomatal conductance and transpiration rate resulted accumulation of more dry matter and yield components and ultimately the higher grain and straw yield. This is corroboration with the findings of Muralidaran and Solaimalai (2005) and Kaushik and Gautam (1991).

CONCLUSION

Direct seeding in aerobic rice did not exhibitany advantage over other establishment methods. From the study it could be concluded that cultivation of aerobic rice under raised beds with transplanting of 14 days old seedlings under saturated soil condition without puddling to be considered as best agronomic management practice compared to conventional method.

REFERENCES

Aslam M, Hussain S, Ramzan M and Akhter M 2008. Effect of different stand establishment techniques on rice yields and its attributes. *Journal of Animal Plant Sciences* **18:** 2-3.

Awan TH, Ali I, Anwar CM, SarwarGM, Ahmad C, Manzoor MZ and Yaqub M 2005. Economic effect of different plant establishment techniques on rice production. In Proc. *Int. Seminar on Rice Crop*, RRI, KSK, Lahore, Punjab – Pakistan. 2-3, October 2005. pp: 226-231.

Awan TH, Ali RI, Manzoor Z, Ahmad M and Akhtar M 2011. Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, KSK-133. *Journal of Animal Plant Sciences* **21**(2): 231–234.

Baloch MS, Awan IU, Jatoi SA, Hussain I and Khan. 2000. Evaluation of seeding densities in broadcast wet seeded rice. *Journal of Pure and Applied Sciences* **19**(1): 63–65.

Bouman BAM, Peng S, Castaneda AR and Visperas RM 2005. Yield and water use of irrigated tropical aerobic rice system. *Agricultural Water Management* **74**: 87-105.

Bouman BAM 2001. Water-efficient management strategies in rice production. *International Rice Research Notes* **26**(2): 17-22.

Bouman BAM, Peng S, Castaneda AR and Visperas RM 2004. Yield and water use of irrigated tropical aerobic rice systems. *Agricultural Water Management* **74**(2): 87-105.

Gomez KA, Gomez KA and Gomez AA 1984. Statistical procedures for agricultural research: John Wiley & Sons.

Kumhar BL, Chavan VA, Kanade VM, Dhopavkar RV, Ameta HK and Tilekar RN 2016. Effect of different rice establishment methods on growth, yield and different varieties during *kharif* season. *International Journal of Plant, Animal and environmental Sciences* **6**(2): 127-131.

Maclean JL, Dawe DC, Hardy B and Hettel GP 2002. Rice Almanac, 3rd edn. IRRI, Los Banos, Philippines.pp.253.

Peng S, Bouman BAM, Visperas RM, Castaneda AR, Nie L and Park H 2006. Comparison between aerobic and flooded rice in the tropics: Agronomic performance in an eight-season experiment. *Field Crops Research* **96:** 252-259.

Singh YP, Singh G, Singh SP, Kumar A, Sharma G, Singh MK, Mortin M and Johnson DE 2006. Effect of weed management and crop establishment methods on weed dynamics and grain yield of rice. *Indian Journal of Weed Sciences* **38**(1&2): 20-24.

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Bio-Efficacy of Sequential Application of Herbicides in Dual Purpose Wheat and Residue Estimation of Pre Emergence Herbicide

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Abstract: In field experiment nine combinations of pendimethalin pre emergence (PRE) alone and followed by (*fb*) post emergence (POE) application of pinoxaden + metsulfuron), sulfosulfuron + metsulfuron and clodinafop + metsulfuron at 2 weeks after cutting (WAC), alone application of pinoxaden + metsulfuron, sulfosulfuron + metsulfuron and clodinafop + metsulfuron at 2 WAC, weed free and weedy check were used to sudy the bio-efficacy of sequential application of herbicides in dual purpose wheat. Significantly less weed dry weight and higher weed control efficiency, effective tillers, grain yield and B-C ratio were recorded under sequential application of PRE*fb*POE herbicides and their mixtures as compared to alone application. No pendimethalin residue had leftover in wheat fodder, thus fodder could be safely used for livestock.

***Keywords*:** Dual purpose wheat, GC-MS, Herbicide mixture, Pendimethalin residue, Sequential application

The use of wheat as a forage and grain dual-purpose (DP) crop is aimed at reducing competition between area devoted to grain and forage crops and to prevent lodging in tall wheat. India is deficit in green fodder by about 35.6 per cent (Ministry of agriculture and farmers welfare 2015). Winter wheat can provide high quality forage at a time of the year when scarcity of fodder is very common. Weed infestation is one of the major biotic factors limiting wheat production and productivity and emerge with the emerging crop seedlings and if not controlled in early stages of crop growth, this may affect fodder quality and grain yield as weeds compete for nutrients, light, moisture and space with the crop plants. In North West Plain Zone of India, approximately 25-30 per cent reduction in yield of wheat is due to weed infestation (Mongia et al 2005). In early sown wheat, weeds are suppressed but after taking a cut from the wheat crop as forage in the late fall, new weeds germinate or the existing weeds find an opportunity to flourish in the absence of competition with the crop and thus negatively affect the yield and yield components of wheat. Sole dependence on post-applied herbicides for weed control in wheat has resulted in the evolution of multiple herbicide resistance (Kumar et al 2013). In such situations, herbicide efficacy can be increased by ready mixture, tank mixture or sequential application which widens the range of effective control of weed flora in wheat, save time and application cost (Sharma et al 2015). A number of herbicides have been recommended for weed management in grain crop of wheat. Thus, it is required to evaluate these herbicides in dual purpose wheat by applying them before and after cutting of crop for fodder. As different weed management methods like manual, mechanical weeding and other cultural operations may not be economical, so herbicides are required to manage weeds in dual purpose wheat crop, but PRE herbicides may cause residual problem in fodder which can directly affect the health of livestock. Pendimethalin persistence in the soil is affected by cultivation, soil temperature and moisture conditions. Dimitro et al (2006) reported that pendimethalin is subjected to cause various physiological changes and endocrine effects in the animal studies. Therefore, herbicide residue estimation in wheat fodder, grain, straw and soil is essential to determine the duration of herbicide activity in soil, its effect on the crop and to analyze the quality of the fodder. Thus, the present study was undertaken in this direction.

MATERIAL AND METHODS

Field experiments on bio-efficacy of sequential application of herbicides in dual purpose wheat (*Triticum aestivum* L.) and residual effect of pre emergence herbicide in fodder was carried out at CCS HAU, Hisar (during the *rabi* seasons of 2015-16 and 2016-17. During crop season of 2015-16, the mean weekly maximum temperature ranged between 15.3 to 36.6°C and minimum between 3.5 to 18.8°C, while, their corresponding values in 2016-17 were 16.9 to 38.4°C and 3.2 to 17.3°C. During second year 2-3°C higher mean weekly temperature than first year at initial period of crop growth which had an adverse effect on yield of dual purpose wheat. The rainfall received in the growing season during 2015-16 and 2016-17, was 3.4 mm and 47.2 mm respectively. The soil of the experimental site was sandy loam with slightly alkaline soil reaction and normal electrical conductivity, low in organic carbon and available nitrogen and medium in available phosphorus and high in available potassium.

The wheat variety C-306 was sown with seed cum fertilizer drill on28th and 30th October during the season 2015-16 and 2016-17 respectively with seed rate 100 kg ha^{-1}. The experiment was laid out in a RBD (randomized block design) with 3 replications and 9 treatments (Table 1). Application of PRE and POE herbicides in different treatments were done by using flat fan nozzle mounted on a knapsack sprayer with a spray discharge of 250 l ha^{-1} at 42 p.s.i. pressure. PRE herbicides was applied just after sowing of wheat and post emergence herbicides were applied 2 weeks after cutting (WAC) of wheat. Dry weight of weeds was recorded after drying the weeds in an oven at 70°C upto 72 hours. Weed control efficiency was calculated at 55 and 115 DAS with the help of formula:

$$\text{WCE (\%)} = \frac{\text{Dry matter of weeds in weedy check-}\\ \text{dry matter of weeds in treatment}}{\text{Dry matter of weeds in weedy check}} \times 100$$

Crop was harvested at 55 days after sowing (DAS) with 5 cm stubble height for green fodder and then weighed to have total green fodder yield. After maturity, above ground biomass of crop was harvested from each plot. Harvested crop was threshed with the help of the mini thresher and grain yield was recorded. Benefit-cost ratio was calculated to ascertain economic viability of the treatment.

All experimental data were analysed using software SPSS version 7.5. The data were subjected to analysis of variance and significant difference among treatments was tested by calculating Least Significant Difference (LSD) against 5 per cent level of significance. The data with zero value were subjected to square root transformation. Residues analysis of pendimethalin was carried out at agrochemicals residues testing laboratory, Department of Agronomy, CCS Haryana Agricultural University, Hisar using GC-MS/MS (Agilent 7890A series).

RESULTS AND DISCUSSION

Weed dry weight (g m^{-2}) and weed control efficiency (%): Major weeds in dual purpose wheat field were *Phalaris minor, Melilotus indica, Rumex dentatus*, *Convolvulous arvensis, Medicago denticulate*. Before cutting, among herbicidal treatments pendimethalin 1500 g ha^{-1} PRE, pendimethalin 1500 g ha^{-1} PRE *fb* pinoxaden + metsulfuron (50+4) 2 WAC (weeks after cutting), pendimethalin 1500 g ha^{-1} PRE *fb* sulfosulfuron + metsulfuron (30+2) 2 WAC and pendimethalin 1500 g ha^{-1} PRE *fb* clodinafop + metsulfuron (60+4) 2 WAC significantly reduced dry weight of weeds and were statistically at par with each other during both the years (Table 1). This might be due to efficacy of pedimethalin as a PRE herbicide application in controlling weeds. After cutting, significantly less weed dry weight and highest weed control efficiency were under sequential application of pendimethalin 1500 g ha^{-1} PRE *fb* pinoxaden + metsulfuron (50+4) 2 WAC, pendimethalin 1500 g ha^{-1} PRE *fb* sulfosulfuron + metsulfuron (30+2) 2 WAC and pendimethalin 1500 g ha^{-1} PRE *fb* clodinafop + metsulfuron (60+4) 2 WAC, but weeds under alone application of post emergence pinoxaden + metsulfuron (50+4) 2 WAC, sulfosulfuron + metsulfuron (30+2) 2 WAC, clodinafop + metsulfuron (60+4) 2 WAC did not show effective mortality which might be due to occurrence of new flush of weeds because of application of irrigation and fertilizer in the field just after cutting of wheat for fodder and aging factor of weeds

Table 1. Effect of different herbicides on dry weight of weeds and weed control efficiency in dual purpose wheat (Average data of two years)

Treatments	Dose (g ha^{-1})	Time of application	Weed dry weight (g m^{-2})				WCE (%)	
			25 DAS	55 DAS	85 DAS	115 DAS	55 DAS	115 DAS
Pendimethalin	1500	PRE*	3.2	4.9	5.8	13.9	79.7	64.9
Pendimethalin *fb* pinoxaden + metsulfuron	1500 *fb* (50+4)	PRE *fb* 2 WAC	3.2	4.9	5.7	5.2	79.7	95.4
Pendimethalin *fb* sulfosulfuron+ metsulfuron	1500 *fb* (30+2)	PRE *fb* 2 WAC	3.3	4.7	5.5	5.1	82.0	95.8
Pendimethalin *fb* clodinafop + metsulfuron	1500 *fb* (60+4)	PRE *fb* 2 WAC	3.1	4.6	5.9	5.2	83.7	95.6
Pinoxaden + metsulfuron	50 + 4	2 WAC*	5.3	10.1	7.8	10.8	2.7	78.5
Sulfosulfuron+ metsulfuron	30 + 2	2 WAC	5.1	9.8	8.0	10.7	9.6	78.5
Clodinafop + metsulfuron	60 + 4	2 WAC	5.5	9.9	7.9	11.1	5.3	77.4
Weed free	-		1.0	1.0	1.0	1.0	100	100
Weedy check	-		5.5	11.2	12.5	23.3	0	0
LSD (p<0.05)			1.8	3.1	4.1	4.2	-	-

*PRE- Pre emergence; WAC- weeks after cutting

(Table 1). As the post emergence spray of herbicides were at two weeks after cutting, most of the weeds (remaining stubble of weeds after cutting) were hardy, thus delayed application of alone POE herbicidal mixture at 70 DAS was less effective against aged and hardy weeds. The results are in conformity with Das (2008). Similarly, sequential application of pendimethalin 1.5 kg ha^{-1} PRE followed by tank mix pinoxaden + metsulfuron 64 g ha^{-1} or mesosulfuron + iodosulfuron 14.4 g ha^{-1} or sulfosulfuron + metsulfuron(RM) 32 g ha^{-1} POE provided excellent control of *P. minor* as well as broadleaf weeds in wheat field (Anonymous 2015-16). Baghestani et al (2008) also reported that tank-mix or pre-mix use of different herbicide chemistries or sequential application of pre- and post-emergence herbicides at different times showed effective weed control.

Yield parameters and yield: Weed free treatment and sequential application of herbicides produced significantly higher number of effective tillers, no. of grains/spike, grain yield and B-C ratio than weedy check and alone pre and post emergence application of herbicides during both the years of study (Table 2). Sequential application of pendimethalin 1500 g ha^{-1} PRE *fb* pinoxaden + metsulfuron (50+4) 2 WAC, pendimethalin 1500 g ha^{-1} PRE *fb* sulfosulfuron+ metsulfuron (30+2) 2 WAC andpendimethalin 1500 g ha^{-1} PRE *fb* clodinafop + metsulfuron (60+4) 2 WAC recorded 32.18, 33.5 and 31.4 per cent, higher grain yield, respectively than weedy check. However, weed control treatments had no significant effect on fodder yield of dual purpose wheat at 55 DAS during both years of experimentation.

Residue of pendimethalin: Analysis of wheat fodder, grain and straw indicated that very less amount of herbicide residue were found in fodder (cut at 55 DAS), straw and grain at crop harvest during 2015-16 and 2016-17 crop seasons (Table 3). The detected residue of pendimethalin in wheat fodder, grain and straw were below the maximum residue limit (MRL) of 0.05 µg g^{-1} set by European Food Safety Authority (EFSA). In the soil sample taken after harvest of wheat crop, pendimethalin residue was below the limit of MRL during first year. During second year, residues were observed between 0.021-0.023 µg g^{-1}. This might be due to increase in 2-3 ^{0}C temperature during second year of study, which affects microbial activity in soil and results slightly

Table 2. Effect of different herbicides on yield attributes and yield of dual purpose wheat (Average data of two years)

Treatments	Dose (g ha^{-1})	Time of application	Fodder yield (t ha^{-1})	Effective tillers (No./m.r.l)	No. of grains spike^{-1}	Grain yield (q ha^{-1})	B-C ratio
Pendimethalin	1500	PRE*	3.71	71.7	53.3	2.14	1.67
Pendimethalin *fb* pinoxaden + metsulfuron	1500 *fb* (50+4)	PRE *fb* 2 WAC	3.73	77.6	55.4	2.81	1.99
Pendimethalin *fb* sulfosulfuron+ metsulfuron	1500 *fb* (30+2)	PRE *fb* 2 WAC	3.72	77.4	55.2	2.87	2.05
Pendimethalin *fb* clodinafop + metsulfuron	1500 *fb* (60+4)	PRE *fb* 2 WAC	3.72	76.8	54.8	2.78	1.99
Pinoxaden + metsulfuron	50 + 4	2 WAC*	3.61	72.7	53.2	2.51	1.89
Sulfosulfuron+ metsulfuron	30 + 2	2 WAC	3.62	73.3	53.1	2.60	1.96
Clodinafop + metsulfuron	60 + 4	2 WAC	3.62	72.9	53.3	2.52	1.92
Weed free	-		3.73	77.7	55.8	2.94	1.72
Weedy check	-		3.58	64.6	51.3	1.87	1.56
LSD (p<0.05)			NS	2.6	1.4	0.17	-

*PRE- Pre emergence; WAC- weeks after cutting

Table 3. Effect of pendimethalin residue (µg/g) on fodder, grain, straw and soil of dual purpose wheat

Treatments	Dose (g ha^{-1})	Time of application	Fodder	Grain	Straw	Soil
Pendimethalin residue (2015-16)						
Pendimethalin	1500	PRE	0.019 ± 0.001*	0.004 ± 0.002	0.003 ± 0.001	0.004 ± 0.001
Pendimethalin *fb* pinoxaden + metsulfuron	1500 *fb* (50+4)	PRE *fb* 2 WAC	0.017 ± 0.004	0.002 ± 0.001	0.004 ± 0.002	0.002 ± 0.002
Pendimethalin *fb* sulfosulfuron+ metsulfuron	1500 *fb* (30+2)	PRE *fb* 2 WAC	0.014 ± 0.002	0.006 ± 0.001	0.003 ± 0.002	0.003 ± 0.001
Pendimethalin *fb* clodinafop + metsulfuron	1500 *fb* (60+4)	PRE *fb* 2 WAC	0.013 ± 0.003	0.005 ± 0.001	0.006 ± 0.001	0.002 ± 0.002
Pendimethalin residue (2016-17)						
Pendimethalin	1500	PRE	0.017 ± 0.002	0.004 ± 0.001	0.003 ± 0.002	0.025 ± 0.002
Pendimethalin *fb* pinoxaden + metsulfuron	1500 *fb* (50+4)	PRE *fb* 2 WAC	0.016 ± 0.001	0.003 ± 0.002	0.005 ± 0.001	0.022 ± 0.002
Pendimethalin *fb* sulfosulfuron+ metsulfuron	1500 *fb* (30+2)	PRE *fb* 2 WAC	0.015 ± 0.003	0.004 ± 0.001	0.007 ± 0.001	0.023 ± 0.001
Pendimethalin *fb* clodinafop + metsulfuron	1500 *fb* (60+4)	PRE *fb* 2 WAC	0.014 ± 0.002	0.003 ± 0.002	0.004 ± 0.001	0.021 ± 0.002

* - Standard deviation, MRL - 0.05 µg g^{-1}, Limit of detection (LOD) - 0.001 µg, Limit of quantification (LOQ) - 0.003 µg, Maximum residue limit (MRL) of 0.05 µg g^{-1}

higher persistence of pendimethalin in soil. But, this increase in persistence was below the residual limit and that won't affect the next succeeding crop. Arora and Tomar (2008) also reported that pendimethalin (1.0 kg ha^{-1}) applied to different *rabi* crops persisted in soil up to 75 days after application and beyond that no residues were left in soil.

CONCLUSION

This study has shown that sequential application of pendimethalin 1500 g/ha PRE *fb* pinoxaden + metsulfuron (50+4) g ha^{-1} orsulfosulfuron + metsulfuron (30+2) g ha^{-1} orclodinafop + metsulfuron (60+4) g ha^{-1} 2 WAC were effective in controlling weeds with higher crop productivity and net returns without any herbicide residual effect on fodder. The detected residue of pendimethalin in wheat fodder was below the maximum residue limit thus fodder could be safely used by livestock.

REFERENCES

Anonymous 2015-16. *Annual report, CCS HAU,* Hisar. *pp*, 37-39

Arora A and Tomar SS 2008. Persistence of pendimethalin in soil applied to different crops. *Agricultural Science Digest* **28**(4): 295-297.

Baghestani MA, Zand E, Soufizadeh S, Beheshtian M, Haghighi A, Barjasteh A, Birgani DG and Deihimfard R 2008. Study on the efficacy of weed control in wheat (*Triticum aestivum* L.) with tank mixtures of grass herbicides with broad-leaved herbicides. *Crop Protection* **27**: 104-111.

Das TK 2008. W*eed science basics and applications* book. pp 438. Jain Brothers Publication. New Delhi

Dimitro BD, Gadeva PG and Benova DK 2006. Comparative genotoxicity of the herbicides Round up, Stomp and Reglone in plant and mammalian test systems. *Mutagenesis* **21**: 375–382.

Kumar V, Singh S, Chhokar RS, Malik RK, Brainard DC and Ladha JK 2013. Weed management strategies to reduce herbicide use in zero-till rice-wheat cropping systems of the Indo-Gangetic Plains. *Weed Technology* **27**(1): 241–254.

Mongia AD, Sharma RK, Kharub AS, Tripathi SC, Chhokar RS and Sheoran J 2005. Coordinated research on wheat production technology in India, *pp.* 40. Karnal, India: Research Bulletin No. 20, Directorate of Wheat Research.

Sharma N, Thakur N, Chopra P, Kumar S and Badiyala D 2015. Evaluation of metsulfuron-methyl and clodinafop alone and in combination with other herbicides against weeds in wheat (*Triticum aestivum* L.) *Research Crops* **16**(3): 447-455.

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Dependence of Winter Wheat Yielding Capacity on Mineral Nutrition in Irrigation Conditions of Southern Steppe of Ukraine

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Abstract: This article is dedicated to the research of dependence of growth and development of winter wheat varieties Khersonska Awnless and Odeska 267 on conditions of moisture provision and mineral nutrition status, impact of indicated factors yielding capacity and grain quality. Years of research significantly varied in rainfall amount during growing season. According to moisture supply, 2016 was dry, 2017 was average humid and 2018 was subhumid, which had an impact on grain yield. The lowest winter wheat productivity level was f in 2016. Under supplemental watering without fertilizers the yield of the Khersonska Awnless variety was 2.07 t ha^{-1}, and of Odeska 267 variety - 1.51 t ha^{-1}. Under provision of vegetative watering, the yielding capacity increased to 3.14 and 2.94 t ha^{-1}. Fertilizers also had significant impact on production processes of plants, accumulation of over ground biomass, and area of assimilating surface that resulted in the yield increase of winter wheat. On average, the most significant factors were fertilizers (43%), irrigation (32%) and variety of winter wheat (9%).

***Keywords*:** Soft winter wheat, Varieties, Calculated fertilizer dose, Yielding capacity, Irrigation, Photosynthetic potential

In order to receive high and sustainable crop yields, it is necessary to provide favourable conditions for their growth and development throughout the whole growing season considering biological peculiarities of a crop. Soil nutrient status is one of the factors that influence these indicators. It is regulated by application of various rates of fertilizers and is the main way to interfere circulation of elements in agriculture, to increase yield of agricultural crops and to maintain soil productivity. The Southern steppe of Ukraine is classified as the zone of risky agriculture. In years with various weather conditions, it is possible to obtain high yields of field crops that are grown precisely under irrigation conditions. That's why the quality of an irrigation water which is used from the natural surface water sources (Pichura et al 2017, 2018) is an needed condition of an irrigated melioration of agricultural lands, especially in the conditions of climate change, and permanent lack of moisture (Lisetskii et al 2017). Highly intensive agricultural crop varieties, fertilizers, and other important factors and components of agrotechnical means do not prove themselves completely under moisture deficit. Evaporation from fields exceeds humidity inflow from rainfall and it breaches water balance. Drought happens every 2-3 years in the steppe area causing large damage. Winter wheat takes the largest crop sowing area in steppe zone. It is high-yielding and adapted to dry conditions effectively using autumn-winter soil moisture reserves. Soil moisture is the main source of water supply through the root system. Depending on the moisture preservation conditions the moisture content (MMC-75%) can be full and minimum for obtaining high levels of winter wheat yielding capacity in the southern Ukrainian conditions. The main feature of moisture regime of the steppe zone soil is its nonpercolative moisturization and lack of rain falls under high summer temperatures and low humidity. Water supply in Kherson region is low, but the predecessor plays an important role in the water supply of winter wheat. The purpose of the research is to study the possibilities of reducing the number of winter wheat irrigation through the use of water-saving methods of irrigation, which will save on irrigation water. Under the research program it was planned to study the possibility of reducing the number of winter wheat waterings during growing season and the value of irrigation rate due to use of water-saving watering methods.

MATERIAL AND METHODS

Field research was carried out during 2015-2018 atthe Institute of Irrigated Agriculture of the Southern Region of the National Academy of Agrarian Sciences of Ukraine, located in the southern part of the steppe zone of Ukraine. The soils of experimental areas (46 43.80688610691692,32 41.65510497081584) are dark-chestnut, medium-loamy, with a height of humus horizon 25 cm and humus content 2.2 per cent at a deep level of groundwater occurrence. Water for irrigation was taken from the basin of Inhulets irrigation system. The field experiment was based on the four times repeated three-factor scheme, where factor A was the winter wheat varieties: Khersonska Awnless and Odeska 267; factor B was irrigation regimes: supplemental watering and supplemental & vegetative watering; and factor C was various mineral nutrition statuses: unfertilized, unfertilized with feeding with microfertilizers Krystallon (2 kg ha^{-1}) and Tenso (0.6 kg ha^{-1}). The dose of fertilizers was calculated for the yield level 7.0 t ha^{-1}, the same dose of fertilizers for feeding with microfertilizers Krystallon and Tenso. Researches on the influence of alternative fertilizers and irrigation regimes on the grain productivity of winter wheat were conducted in the crop rotation link with subsequent succession of crops spring barley with alfalfa seeding-alfalfa-alfalfa-winter wheat. The predecessor of winter wheat varieties was alfalfa of three-year growing period. Doses of mineral fertilizers were calculated on the basis of the recommendations for the programmed yielding capacity level, considering subtraction of nutrient elements by crop, the NPK content in soil and coefficients of their use from soil and fertilizers (Table 1).

The dose of mineral fertilizers was determined according to the content of nutrients in soil considering subtraction of nutrient elements by preceding crop. During the years of research, nitrogen fertilizers for the basic soil treatment were introduced in an amount from 45 kg of application rate to 138 kg ha^{-1}. On average, over the years of research the dose of fertilizers for the planned yielding capacity level 7.0 t ha^{-1} was $N_{138}P_0K_0$. The tank mixture of germicides Donat – 130 g ha^{-1}, Estron - 300 g ha^{-1} and fungicide - Impact 0.5 l ha^{-1}. Irrigation has an impact on the growth of pathogens. Fungicide was used to reduce the damage of plants by patogenic microflora. Macro and micronutrient application (Krystallon + Tenso) at a rate 2 kg ha^{-1} and 0.6 kg ha^{-1} was carried out during heading phase and milky ripeness respectively. Predecessor's irrigation regime consisted of the norms and terms of watering that were adapted to climatic conditions of year on the basis of recommended crop irrigation regimes in the southern Ukrainian steppe.

Soil and crop samples were selected from two non-adjoining repetitions. The soil content of nitrate nitrogen (Grandval-Lyazh GOST 26107), labile phosphorus – in 1 per cent carbon-amniotic extract (Machihin GOST 26205-91), exchange potassium - from the same extract on a flame photometer (GOST 26205-91) were determined. Soil moisture was determined by the thermostat weight method. During growing season, biometric measurements were taken in main phases of crop development on plant height, growth of crude and dry over ground mass of winter wheat, area of leaves, the sample size was 200 typical plants in four fold. The calculations of net productivity of photosynthesis, photosynthetic potential of sowing were performed. The area of leaves was determined by the method of carving (Nychyporovych 1961). The net productivity of photosynthesis was determined according standard method (Nychyporovych 1982, Pysarenko, Kokovikhin and Hrabovskyi 2011), using the Kidd-West-Briggs formula

$$F_{n.pr.} = \frac{B_2 - B_1}{\frac{L_1 + L_2}{2} \cdot T}, \quad \text{where}$$

$F_{n.pr.}$ – the net productivity of photosynthesis, g/m^2 per day;
B_1, B_2 – the dry weight for 1 m^2 at the beginning and end of the record period, g;
L_1, L_2 – leaf surface area for 1 m^2 at the beginning and end of the record period, m^2;
T – Number of days between the first and the second determination.

Agricultural technology in the research was commonly accepted for the zone considering the issues being studied. The main treatment after alfalfa harvesting included, disking, 25-27 cm ploughing. The seeds were sown in a depth 4-5 cm. During the years of research, the sowing was carried out in the last week of September with the sowing rate 5 million grains per hectare.

RESULTS AND DISCUSSION

The leaf surface varied depending on the mineral nutrition, vegetative phase of plant and irrigation regimes (Table 2).

From tillering phase to stem elongation, the surface area

Table 1. Content of nutrient elements in soil before winter wheat sowing during years of research, mg/100g of soil

Soil layer, cm	NO^{3-}			P_2O_5			K_2O		
	2015-2016	2016-2017	2017-2018	2015-2016	2016-2017	2017-2018	2015-2016	2016-2017	2017-2018
0-30	0.80	5.98	9.65	5.65	5.95	3.68	26.5	48.0	33.0
30-50	0.75	4.18	3.09	1.75	1.05	1.47	22.0	35.0	23.0
50-70	0.35	1.13	0.87	0.37	0.70	0.24	15.5	30.0	20.5
70-100	0.35	0.25	0.52	0.41	0.75	0.50	17.0	27.0	19.0

of leaves of unfertilized plants of both studied winter wheat varieties increased two times on average within the years of study. During growing of winter wheat using fertilizers, this indicator increased 2.5 – 2.8 times in comparison with the control version without fertilizers. In further growing season, the area of leaves increased two times the most in comparison with stem elongation phase upon treatment without fertilizers and supplemental and vegetative watering over the years of research. The leaf surface of winter wheat plants varied from 18.6 – 19.1 to 29.0 – 31.5 thous. m^2 ha^{-1} in non-fertilized ground under supplemental irrigation. The calculated dose of mineral fertilizer $N_{138}P_0K_0$ was used for the planned yield of winter wheat grain 7.0 t ha^{-1}. It allows to significantly reduce the dose of fertilizers upon condition that soil is sufficiently supplied with labile soil nutrients, and due to their high content in soil it allows to avoid application of fertilizers or their varieties. Thus, the phosphoric and potassium fertilizers were not applied in sowing, as the content of labile phosphorus and exchange potassium in soil exceeded its average number (Hospodarenko 2010).

At the same time, the mixed microfertilizer Krystallon and Tenso was used in feeding during heading and kernel milk line period. This was due to the fact that winter wheat was grown in irrigated crop rotation after three years of growing of alfalfa for feeding of animals and organic fertilizers were not applied in crop rotation. Under such circumstances, the application of micro elements does not always significantly increase the crop yielding capacity, but significantly improves the quality of grown products. The nitrate content during growing of winter wheat varieties was quite high during vegetation (Table 3).

Such a high NO_3 content in the unfertilized soil is due to the fact that winter wheat was grown on an alfalfa layer, which accumulates a significant amount of root residues with high content of biological nitrogen. This fact explains quite high content of labile nitrogen in soil during the growing season of winter wheat, even without application of nitrogen fertilizer for crop in all studied layers of soil. Under conditions of using of nitrogen fertilizer, the nitrate content in soil was increasing in accordance with the dose of its introduction (Table 3). The grain yielding capacity of winter wheat, was affected by the nutrient status, had the – (43%). The factor B (irrigation) took the second place – 32 per cent, the variety composition of winter wheat (factor A) took only 9%. In addition, the research shows close interaction between irrigation and fertilizers (interaction of factors BC) at the level 7%. The interaction of other factors was less significant and ranged from 1 to 3 per cent (Fig. 1).

One of the most unfavourable conditions for winter wheat is water disbalance of soil at the beginning of its sowing and during the autumn vegetation. During sowing, the moisture content in soil is often extremely low, and winter wheat cannot germinate timely. The winter wheat seeds accumulate moisture in the autumn-winter period the most. Therefore, the most moisture content in soil is observed in early spring. In the research, the irrigation rate varied depending on the amount of rainfall in the years of growing of winter wheat varieties (Table 4).

Supplemental watering rate for all years of research was 700 m^3/ha, and vegetative irrigation rate was 500 m^3/ha. The winter wheat grain yield is influenced by many factors of cultivation. First of all, these are agrotechnical measures, biological features of variety, terms of sowing, seed quality during sowing, moisture conditions, peculiarities of weather

Table 2. Influence of the researched factors on growth dynamics of area of leaves of winter wheat plants (average for 2016-2018), thous.m^2 ha^{-1}

Nutrient status (factor C)	Irrigation regime (factor B)	Vegetative phase			
		Tillering	Stem elongation	Heading	Milky ripeness
Khersonska awnless (factor A)					
Unfertilized	Supplemental watering	9.8	18.6	31.5	32.7
	Supplemental + vegetative watering	10.1	18.6	39.7	41.3
Calculated dose $N_{138}P_0K_0$	Supplemental watering	11.3	29.6	39.7	42.0
	Supplemental + vegetative watering	11.8	31.4	44.8	46.1
Odeska 267 (factor A)					
Without fertilizers	Supplemental watering	10.0	19.1	29.0	30.2
	Supplemental + vegetative watering	9.9	19.1	37.9	39.3
Estimated dose $N_{138}P_0K_0$	Supplemental watering	11.5	26.1	38.1	39.6
	Supplemental + vegetative watering	11.7	28.9	43.4	44.7
LSD_{05}		0.21	1.12	1.87	2.03

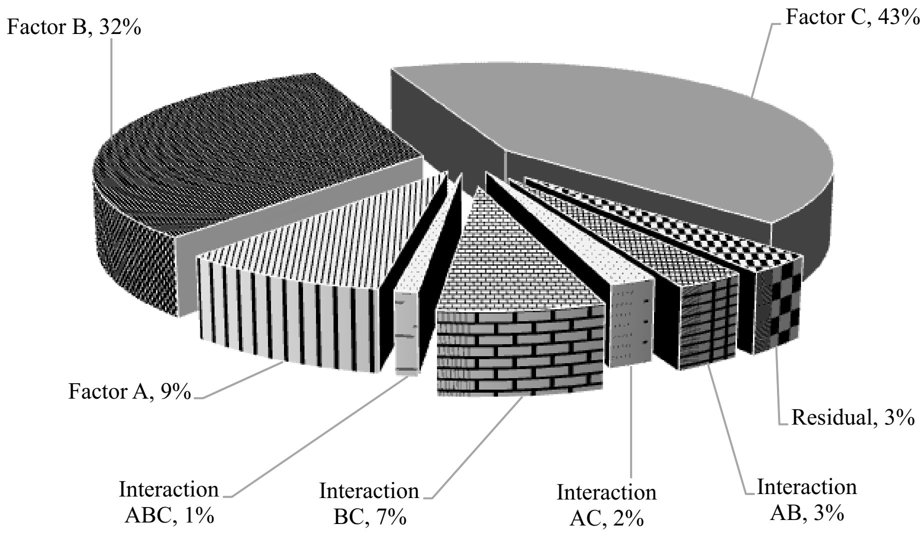

Fig. 1. Influence of researched factors on productivity of winter wheat (average for 2016 – 2018)

Table 3. Influence of mineral fertilizers and irrigation regime on nitrate content in soil during winter wheat vegetation (Average for 2016-2018)), mg 100 g^{-1} of soil

Nutrient status (factor C)	Researched soil layer, cm	Irrigation regime (factor B)							
		Supplemental watering				Supplemental + vegetative watering			
		Sowing-germination	Stem elongation	Beginning of heading	Complete grain ripeness	Sowing-germination	Stem elongation	Beginning of heading	Complete grain ripeness
Unfertilized	0-30	4.92	5.01	5.03	4.21	4.87	5.12	4.62	3.78
	0-50	2.78	2.86	3.14	2.60	2.76	2.81	2.49	2.32
	0-100	1.44	1.49	1.61	1.47	1.46	1.52	1.67	1.54
Calculated dose $N_{138}P_0K_0$	0-30	5.28	5.87	6.12	5.42	5.31	5.72	5.46	4.89
	0-50	3.02	3.81	3.88	3.47	2.99	3.74	3.38	3.12
	0-100	1.83	1.74	1.79	1.87	1.94	1.77	1.64	1.85
LSD_{05}	0-30	0.14-0.21	0.11-0.17	0.10-0.13	0.08-0.12	0.07-0.12	0.11-0.14	0.07-0.09	0.08-0.11
	0-50	0.09-0.15	0.08-0.12	0.09-0.14	0.06-0.10	0.07-0.09	0.10-0.15	0.10-0.12	0.07-0.09
	0-100	0.05-0.08	0.08-0.14	0.05-0.07	0.06-0.08	0.04-0.07	0.08-0.11	0.05-0.07	0.07-0.08

Table 4. Irrigation rate in winter wheat growing, m^3 ha^{-1}

Years of vegetation	Supplemental irrigation	Vegetative irrigation			Total irrigation rate, m^3/ha
		Number of irrigations	Watering depth	Irrigation rate	
2015-2016	700	3	500	1500	2200
2016-2017	700	1	500	500	1200
2017-2018	700	3	500	1500	2200
Average	700	2,3	500	1167	1867

Table 5. Yielding capacity of winter wheat varieties depending on fertilizers and irrigation regime (t ha^{-1})

Nutrient status (factor C)	Variety (factor A)	Irrigation regime (factor B)					
		2016		2017		2018	
		1*	2*	1	2	1	2
Unfertilized	Khersonska Awnless	2.07	3.14	4.35	5.15	3.42	4.07
	Odeska 267	1.51	2.94	4.28	4.95	3.4	3.91
Unfertilized + Krystallon + Tenso	Khersonska Awnless	2.13	3.19	4.43	5.30	3.68	4.13
	Odeska 267	1.68	3.02	4.44	5.18	3.74	3.99
Calculated dose $N_{138}P_0K_0$	Khersonska Awnless	4.02	5.25	6.56	7.34	4.42	6.61
	Odeska 267	3.63	4.78	6.12	6.93	4.32	6.39
Calculated dose $N_{138}P_0K_0$+ Krystallon + Tenso	Khersonska Awnless	3.87	5.23	6.52	7.53	4.73	6.72
	Odeska 267	3.79	5.12	6.18	7.09	4.68	6.45
LSD_{05}	Factor A	0.15		0.11		0.19	
	Factor B	0.09		0.19		0.17	
	Factor C	0.14		0.11		0.22	

1 – supplemental watering, 2 – supplemental + vegetative watering

and climate during year, use of protective means, etc. The introduction of mineral fertilizers in the calculated doses for productivity of winter wheat 7.0 t ha^{-1} increased the grain yielding capacity of the studied winter wheat varieties. It reached its maximum value under supplemental watering upon introduction of calculated dose of fertilizer $N_{138}P_0K_0$ for the yield level 7.0 t ha^{-1} and was 4.02 t ha^{-1} of the Khersonska awnless variety and 3.63 t ha^{-1} of the Odeska 267 variety. Top dressing with microelements in fertilized grounds also did not result in a significant increase of grain yielding capacity (Table 5). The top dressing with a complex mircofertilizer Krystallon@ 2 kg ha^{-1} mixed with Tenso (0.6 kg ha^{-1} during interphase heading period and the beginning of kernel milk line period) increased winter wheat yield of both studied varieties from 0.6 to 3.0 t ha^{-1}.

CONCLUSION

In order to receive grain yielding capacity at the level 7.0 t ha^{-1} and higher under low content of nitrogen and increased content of labile phosphorus potassium in soil, it is reasonable to add mineral fertilizers as the main soil treatment at the calculated rate $N_{138}P_0K_0$ along with top dressing with a mixture of complex fertilizers Krystallon and Tenso as calculated 2.0 and 0.6 kg ha^{-1} in the interphase period between the beginning of heading and kernel milk line period.

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REFERENCES

Babych VL 2005. Influence of mineral fertilizers on area of leaf surface, photosynthetic efficiency and photosynthetic potential of winter wheat. *Tavriia Scientific Bulletin* **37**: 72-77.

Hospodarenko HM 2010. Agrochemistry: Textbook. *NSC "IAE"*: 258-320.

Kudriashov IN 2001. Variety as a factor of stabilization of seed production of winter wheat. *Selection of winter wheat: Conference proceedings of scientific-practical conference "Scientific heritage of academician I.G. Kalinenko"*: 138-144.

Lisetskii FN, Stolba VF and Pichura VI 2017. Late-Holocene palaeoenvironments of Southern Crimea: Soils, soil-climate relationship and human impact. *Holocene* **27**(12): 1859-1875.

Moraru SA 1988. Winter wheat. *Kartia Moldovenske Publ.*: 400 p.

Netys IT 2003. Influence of predecessors, fertilizers and protection of plants on seed quality of winter wheat. *Tavriia Scientific Bulletin* **32**: 112-113.

Nychyporovych AA 1961. Photosynthetic activity of plants in sowing. *Academy of Science of USSR Publ*. 133 p.

Nychyporovych AA 1982. Physiology of photosynthesis and productivity of plants. *Physiology of photosynthesis* **3**: 7-33.

Peterburgskiy AV 1964. Feeding of plant roots. *Kolos Publ*. 43-48.

Pichura VI, Domaratsky YA, Yaremko YuI, Volochnyuk YG and Rybak VV 2017. Strategic ecological assessment of the state of the transboundary catchment basin of the Dnieper river under extensive agricultural. *Indian Journal of Ecology* **44**(3): 442-450.

Pichura VI, Malchykova DS, Ukrainskij PA, Shakhman IA and Bystriantseva AN 2018. Anthropogenic transformation of hydrological regime of the dnieper river. *Indian Journal of Ecology* **44**(3): 445-453.

Pysarenko PV, Kokovikhin SV, Hrabovskyi PV 2011. Influence of conditions and moisture supply and mineral nutrition status on dynamics of accumulation of wet and dry weights by winter wheat plants. *Irrigated Agriculture* **55**: 70-78.

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Generation of Variability in Chickpea (*Cicer arietinum* L.) through Mutagenesis

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Abstract: With the aim to create additional variability in a bold seeded *desi* chickpea variety HPG-17, seeds were treated with Ethyl Methane Sulphonate (EMS, 0.05, 0.10 and 0.15%), gamma rays (150 Gy, 200 Gy and 300 Gy) and their combination doses. The progeny plants from mutagen treated seed displayed wide range of variation in quantitative traits, however, no mutagen dose specific trend in increase or decrease of mean values of these traits was observed. All the mutagen treatments led to decrease in seed yield as well as harvest index, mutants showing early flowering, early maturity and more number of pods per plant were, however, observed in several treatments notably the 200 Gy (early flowering), 150 Gy + 0.15% EMS (early maturity) and 0.10% EMS (number of pods plant^{-1}). Maximum height and fruit bearing branches were observed at 0.05% EMS and 0.15% EMS, respectively. Only two treatments i.e. 300 Gy + 0.15% EMS and 200 Gy yielded mutants with increased 100-seed weight as compared to control. The study demonstrated that gamma rays, EMS and their combinations generated considerable variability in chickpea and that mutation breeding was an effective technique to generate additional variability in chickpea.

***Keywords*:** EMS, Gamma rays, Variability, Induced mutations, Chickpea

Genetic variation in chickpea (*Cicer arietinum* L.) is limited primarily due to its monophyletic descendance from its wild progenitor *Cicer reticulatum*. Wild relatives of chickpea possess additional variability that can be exploited for genetic enhancement of chickpea, however, exploitation of this variability is limited by cross-incompatibility barriers and linkage drags making this pool virtually unusable for the development of new chickpea germplasm. Mutagenesis is another mean for creation of genetic variability for exploitation in plant improvement programmes aimed at resistance to biotic and abiotic stresses or yield enhancement. Mutation breeding uses plant's own genetic resources mimicking the process of spontaneous mutations but at an enhanced rate compared to that of spontaneous mutations (10^{-5} – 10^{-8} in higher plants). Breeders exploit mutation breeding to modify well adapted plant varieties for one or two major traits that limit their productivity or quality (Kunter et al 2012). This approach has been exploited successfully to develop agronomically superior plant genotypes (Ahloowalia et al 2004, Serrat et al 2014) as well as in varieties (Anonymous 2018). The phenotypic variation following mutagenesis, particularly in self pollinated plants, is mainly due to increase in genetic components. Genetically, mutagens act either by replacing a base in the DNA or altering a base so that it specifically mispairs with another base or damages a base so that it can no longer pair with any base under normal conditions. Both physical and chemical mutagens are used to induce mutations in higher plants. Among the physical mutagens, gamma rays are preferred in higher plants due to their high penetrating capacity whereas among the chemical mutagens, ethyl methane sulphonate (EMS) is preferred as it induces high density irreversible mutations (Henikoff and Comai 2003). Use of physical and chemical mutagens together is also advocated as the combined treatments not only induce changes in DNA but may also affect fixation and recovery of potential mutants. Synergistic and antagonistic effects may, however, occur when various physical and chemical mutagens are used in combination and such affects may generate high variability than single agent. In the present study, an attempt was made to broaden the genetic base of a chickpea variety HPG-17 that is cultivated widely in Himachal Pradesh, through induced mutagenesis using gamma rays, EMS and their combined treatments.

MATERIAL AND METHODS

Seeds of a well-adapted *desi* chickpea variety (HPG-17) were treated with gamma-rays (150 Gy, 200 Gy, 300Gy), EMS (0.05%, 0.10% and 0.15%) and all possible combinations. For each treatment 150 seeds were taken. Gamma-irradiation was carried out in gamma chamber ^{60}Co gamma cell at Bhabha Atomic Research Centre (BARC), Mumbai. For EMS treatment, seeds were first pre-soaked in distilled water for 14 hours at room temperature and immersed in freshly prepared EMS solution followed by constant shaking for three hours. The treated seeds were washed for three hours to terminate the residual effect of the mutagenic chemical and immediate sowing was done. For combination treatments, irradiation was followed by chemical mutagen treatment. M_1 was raised and harvested in April 2014 to yield the M_2 generation. M_2 seeds were sown in October 2014 with 30 cm row to row distance and 10 cm plant to plant distance in plant to progeny rows along with control (HPG-17).

M_2 families were evaluated for various quantitative traits and observations were recorded on individual plants of M_2 progeny as well as control population. The data on various traits *viz*., days to flower initiation, days to 75 per cent maturity, plant height (cm), number of primary branches, number of pods, seed yield (g), harvest index (%) and 100 seed weight (g) per plant were subjected to statistical analysis.

Relative coefficient of variation was calculated as per formula given by Montalvan and Andro 2005 which is

$$\text{Relative coefficient of variation} = \frac{CV_t}{CV_{nt}}$$

where, CV_t= Coefficient of variation of treated population, CV_{nt} = Coefficient of variation of the non-treated population

Dose wise analysis based on individual plants in M_2 generation was carried out for the polygenic traits to get the mean performance of individual line as per the method of Sharma (1998).

RESULTS AND DISCUSSION

Days to flower initiation: Mutants were observed for all the traits under study. In northern region of India, medium to late flowering is considered a desirable trait as early flowers do not form pods due to frost injury. Additionally, very early flowering also compromises the vegetative growth of the plants. Considering late flowering as a desirable character, the 300 Gy + 0.05% EMS treatment was superior to others as well as control (3.60%) with 122.43 days to flower initiation (maximum mean) as compared to 118.17 days to flower initiation in control (Table 1). The mutants from treatment 200 Gy were earliest to flower with 114.25 days to flower initiation and -3.32 per cent superiority over control. Highest relative coefficient of variation was at 200Gy (1.69) and least at 300 Gy+0.10% EMS (0.04). Widest range in days to flowering was observed at 0.10% EMS (99-132) and least at 300 Gy+ 0.15% EMS.

Days to 75 per cent maturity: For days to 75 per cent maturity, highest mean and superiority over control (late maturity) was at 300 Gy + 0.10% EMS (185.98 and 0.13%) and minimum (early maturity) was at 150 Gy + 0.15% and 200 Gy+ 0.10% (164 and -0.01%) (Table 1). The mean value for control was 166.83 days. Maximum relative coefficient of variation was at 0.15% EMS (2.01) and minimum at 200 Gy + 0.05% EMS (0.66) while, maximum range was at 150 Gy + 0.05% EMS (165-192) and minimum at 300 Gy (188-192).

Plant height: Plants with maximum height were observed at 0.05% EMS (95.50 cm, and was superior over control) and those with minimum height and maximum inferiority over control were at 300 Gy + 0.15% EMS). The treatment 200 Gy + 0.15% EMS generated maximum variability (2.37) and plants with widest range of height (29-130 cm). The 0.15% EMS resulted in maximum number of fruit bearing branches (9.22) with maximum superiority (78.34%) over control (Table 1).

Number of branches: The 200 Gy +0.10% EMS generated maximum relative variability in number of branches (1.45) while 300 Gy + 0.10% EMS resulted in least relative variability (0.47) (Table 1). Range in number of primary branches varied from 4-15 at 0.15% EMS (maximum among all treatments).

Number of pods: The number of pods were maximum (130.30 pods plant^{-1}) at 0.10% EMS as compared to untreated control with 14.63% superiority (Table 1). In all other treatments, considerable reduction in this trait was observed. The 0.10% EMS gave widest range of mutants for number of pods (21-390) and 0.15% EMS generated maximum variability (2.33). The mutants generated with 300 Gy + 0.15% EMS had least number of pods per plant (22.81) and were inferior to control (-79.93%) with least variability (0.34) and narrow range (18-34).

Seed yield: All the treatments lead to considerable reduction in the seed yield. Minimum reduction in seed yield was at 0.10% EMS and maximum reduction at 300 Gy + 0.10% EMS as compared to control. Maximum variation was generated at 0.15% EMS (2.82) while, 0.10% EMS generated widest range of mutants for seed yield (Table 2).

Harvest index: All the treatments lead to reduction in harvest index as compared to the control (36.00). Mutants generated with 300Gy + 0.10% EMS were most inferior (-60.86%) for harvest index. Widest range and maximum variation was observed in population generated with 200 Gy + 0.10% EMS and 200Gy + 0.15% EMS, respectively (Table 2).

100 seed weight: The treatment 300Gy + 0.15% EMS lead to significant increase in 100 seed weight (30.01g) as compared to control (27.22 g) with 10.25% superiority (Table 2). Least superiority over control (-43.47%) was observed at 0.15% EMS with 15.36g mean 100 seed weight, however,

Table 1. Superiority over control, relative coefficient of variation (CV_t/CV_{nt}) and range for days to flower initiation, days to 75 per cent maturity, plant height and number of primary branches in M_2 generation of chickpea variety HPG-17

Dose	Days to flower initiation			Days to 75 per cent maturity			Plant height (cm)			Number of primary branches		
	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)
0.05% EMS	-2.57	1.56	100-128 (115.13)	0.01	0.77	160-173 (166.73)	20.38	1.08	50-115 (95.50)	51.45	0.76	5-12 (7.83)
0.10% EMS	2.59	1.60	99-132 (121.23)	0.07	1.32	159-188 (175.91)	13.29	0.89	52-115 (89.87)	36.56	0.77	2-13 (7.06)
0.15% EMS	-0.25	0.83	111-127 (117.88)	0.05	2.01	164-185 (172.90)	12.78	0.87	73-103 (89.47)	78.34	1.33	4-15 (9.22)
150 Gy	-1.73	0.93	99-130 (116.13)	0.01	0.99	160-180 (166.00)	-9.47	0.74	53-90 (71.82)	-21.86	0.74	2-8 (4.04)
200 Gy	-3.32	1.69	90-128 (114.25)	0.00	1.84	149-178 (164.04)	-13.20	0.71	69-108 (89.80)	2.71	0.84	2-10 (5.31)
300 Gy	2.19	0.88	108-136 (120.76)	0.13	0.92	188-192 (185.72)	-3.79	1.00	34-108 (76.32)	-27.47	0.87	1-10 (3.75)
150 Gy + 0.05% EMS	-2.34	0.85	110-125 (115.40)	0.05	1.85	165-192 (173.49)	-0.63	0.90	48-98 (78.83)	-7.35	0.95	1-10 (4.79)
150 Gy + 0.10% EMS	0.14	0.93	110-129 (118.34)	0.03	1.51	160-149 (169.00)	-3.20	1.02	31-100 (76.79)	-26.89	0.87	1-7 (3.78)
150 Gy + 0.15% EMS	-1.84	0.84	110-127 (115.99)	-0.01	1.63	164-190 (164.00)	-3.59	1.00	39-99 (76.48)	-11.61	0.74	2-9 (4.57)
200 Gy + 0.05% EMS	-2.81	0.90	100-127 (114.85)	0.03	0.66	157-179 (169.63)	8.04	0.65	44-130 (85.71)	-11.80	0.52	1-10 (4.56)
200 Gy + 0.10% EMS	0.00	1.33	110-125 (116.75)	-0.01	1.91	157-188 (164.00)	-18.58	1.74	20-84 (64.59)	-39.85	1.45	1-8 (3.11)
200 Gy + 0.15% EMS	1.45	1.17	110-125 (116.46)	0.04	1.28	165-180 (171.46)	-16.69	2.37	29-130 (66.09)	-34.62	1.33	1-8 (3.38)
300 Gy + 0.05% EMS	3.60	1.51	111-133 (122.43)	0.08	1.69	166-188 (177.43)	7.44	1.30	45-106 (85.23)	-15.47	1.13	2-9 (4.37)
300 Gy + 0.10% EMS	2.71	0.04	115-129 (121.37)	0.13	1.85	180-198 (185.98)	-34.64	0.74	35-77 (51.85)	-39.65	0.47	1-5 (3.12)
300 Gy + 0.15% EMS	3.44	0.38	117-129 (122.24)	0.02	0.82	161-188 (167.35)	-38.94	1.12	30-79 (48.44)	-47.58	0.78	1-7 (2.71)
Control	0.00	1.00	115-120 (118.17)	0.00	1.00	162-166 (166.83)	0.00	1.00	74-84 (79.33)	00.00	1.00	4-6 (5.17)

EMS: Ethyl Methane Sulphonate; **Gy**: Gray; **+**: Increase in value; **-**: Decrease in value

this treatment lead to generation of maximum variability (2.62). Widest range of variation for 100 seed weight was observed at 150Gy + 0.05% EMS (19.20- 54.18g) and least (15.45- 26.76 g), at 0.15% EMS.

Wide range of variation was observed in all the quantitative traits due to mutagenesis, however, no dose specific trend in increase or decrease in mean values was observed for all the treatments. The present results are in line with those of Kozgar et al. (2011) who also reported no trend in the variation of mean of different traits with different doses of EMS. In traits such as time to flowering, early maturity, plant height and number of branches per plant; wide range of mutants with high superiority over control were obtained while, in others like number of pods per plant, seed yield and harvest index, the mutagen treatments had negative impact leading to inferiority over untreated population. Similar results were reported by Siddiqui and Singh (2010), where majority of the mutagen treatments induced negative shift in mean seed yield as compared to control. In the present study, CV of the treatments fell in both the directions of the control. Such a positive and negative shift in the CV of the treated population as compared to the control was also observed by Patil et al (2018) in cotton and Arubalachandran and Mullainathan (2009) in *Vigna mungo* L. Hepper. Results contrary to these were reported by Siddiqui and Singh (2010) in Basmati rice and Khan and Goyal (2009) in moongbean where CV increased in all the treatments vis-a-vis control. In the present study, found no superiority over control for seed yield and harvest index. Begum and Dasgupta (2010) was observed also reported EMS to be more effective in producing variation as indicated by relative coefficient of variation as compared to the gamma-rays. Wani (2011)

Table 2. Superiority over control, relative coefficient of variation (CV_t/CV_{nt}) and range for number of pods per plant, seed yield per plant, harvest index and 100 seed weight in M_2 generation of chickpea variety HPG-17

Dose	Number of pods plant^{-1}			Seed yield plant^{-1} (g)			Harvest Index			100 seed weight		
	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)	Superiority over control	CV_t/CV_{nt}	Range (Mean)
0.05% EMS	-16.69	2.28	21-316 (94.70)	-47.14	2.50	4.00-67.01 (22.69)	-36.36	1.21	20.22-44.01 (22.91)	-18.22	1.32	11.50-33.01 (22.26)
0.10% EMS	14.63	1.83	21-390 (130.30)	-17.87	2.45	3.86-94.52 (35.30)	-36.39	1.74	28.13-47.29 (22.90)	-25.06	1.57	14.80-30.22 (20.40)
0.15% EMS	-5.14	2.33	30-240 (107.83)	-44.34	2.82	4.50-61.53 (23.90)	-46.92	2.39	27.22-41.20 (19.11)	-43.57	2.62	15.45-26.76 (15.36)
150 Gy	-74.23	1.49	10-104 (29.29)	-76.11	1.65	3.67-34.88 (10.21)	-49.39	1.49	4.29-44.20 (18.22)	-14.62	0.98	18.33-36.29 (23.24)
200 Gy	-53.73	2.22	12-152 (52.59)	-39.93	0.37	3.30-50.51 (25.80)	-28.11	0.99	6.59-45.55 (25.88)	1.80	1.09	20.00-43.8 (27.71)
300 Gy	-72.44	1.49	12-102 (31.33)	-75.05	1.79	3.30-33.51 (10.67)	-54.44	1.56	2.45-45.29 (16.40)	-12.09	0.85	14.49-39.88 (23.93)
150 Gy + 0.05% EMS	-74.76	1.31	12-75 (28.69)	-85.21	2.30	2.10-21.47 (6.29)	-37.50	1.76	2.32-45.66 (22.50)	-7.75	0.77	19.20-54.18 (25.11)
150 Gy + 0.10% EMS	-54.01	1.57	12-164 (52.28)	-63.67	2.42	3.48-70.21 (15.57)	-20.64	0.84	12.69-44.11 (28.57)	-4.22	0.59	19.11-34.19 (26.07)
150 Gy + 0.15% EMS	-65.45	1.78	6-140 (39.27)	-74.35	2.45	2.18-44.14 (10.97)	-23.89	1.39	4.31-48.11 (27.40)	-5.11	0.58	18.90-34.7 (25.83)
200 Gy + 0.05% EMS	-56.22	1.21	12-194 (49.76)	-66.64	1.74	1.88-60.84 (14.29)	-50.31	1.40	1.74-46.23 (17.89)	-1.65	0.55	17.58-38.62 (26.77)
200 Gy + 0.10% EMS	-68.90	2.13	16-104 (35.35)	-83.68	2.12	3.26-19.38 (6.95)	-29.86	2.35	1.12-47.85 (25.25)	-15.69	0.97	13.07-25.11 (22.95)
200 Gy + 0.15% EMS	-79.74	2.22	10-88 (23.03)	-42.78	2.50	3.14-84.80 (24.65)	-30.22	2.05	8.2-49.01 (25.12)	-4.67	1.84	16.79-45.12 (25.95)
300 Gy + 0.05% EMS	-74.57	1.65	12-90 (28.91)	-53.71	2.27	4.23-45.59 (19.86)	-23.08	0.97	10.27-48.02 (27.69)	-2.94	0.42	12.55-36.89 (26.42)
300 Gy + 0.10% EMS	-78.01	0.74	17-66 (25.00)	-89.04	0.52	3.20-8.74 (4.64)	-60.86	0.66	6.20-36.71 (14.09)	-18.88	0.72	16.10-36.91 (22.08)
300 Gy + 0.15% EMS	-79.93	0.34	18-34 (22.81)	-62.79	2.36	3.22-42.74 (15.95)	-18.53	0.87	12.39-45.36 (29.33)	10.25	0.78	11.22-39.76 (30.01)
Control	0.00	1.00	95-132 (113.67)	0.00	1.00	37.4-49.90 (43.08)	0.00	1.00	31.10-41.36 (36.00)	0.00	1.00	24.12-29.59 (27.22)

EMS: Ethyl Methane Sulphonate; **Gy**: Gray; **+**: Increase in value; **-**: Decrease in value

reported intermediate doses in combination to produce maximum variation in the mutagenized population of chickpea followed by EMS while, Sharma et al. (2018) found EMS to be more effective. These reports draw considerable support to the findings of the present investigation where EMS and combinations of EMS with gamma rays induced maximum variability in seed yield as indicated by coefficients of variation.

CONCLUSION

Wide ranges of chickpea mutants were obtained through mutagenesis. The desirable mutants i.e. with early/late flowering, early maturity, increased number of fruit bearing branches, increased number of pods, higher harvest index and higher seed yield will act as an indispensible gene pool for further crop improvement in chickpea. It can also be concluded that the gamma rays, EMS and combinations of these two mutagens generated considerable variability that can be exploited in chickpea breeding programmes.

REFERENCES

Ahloowalia BS, Maluszynski M and Nichterlein K 2004. Global impact of mutation-derived varieties. *Euphytica* **135**: 187–204.

Anonymous 2018. https://mvd.iaea.org/

Arulbalachandran D and Mullainathan L 2009. Changes on protein and methionine content of balck gram (*Vignamungo* L. Hepper) induced by gamma rays & EMS. *American–Eurasian Journal of Scientific Research* **4**(2): 68-72.

Begum T and Dasgupta T 2010. The comparison of the effects of physical and chemical mutagens in sesame (*Sesam umindicum* L.). *Genetics and Molecular Biology* **33**(4): 761-766.

Henikoff S and Comai L 2003. Single nucleotide mutations for plant functional genomics. *Annual Review of Plant Biology* **54**(1): 375-401.

Khan S and Goyal S 2009. Improvement of moongbean varieties through induced mutations. *African Journal of Plant Science* **3**(8): 174-180.

Kozgar MI, Goyal S and Khan S 2011. EMS induced mutational variability in *Vigna radiata* and *Vigna mungo. Research Journal of Botany* **6**(1): 31-37.

Kunter B, Bas M, Kantoglu Y and Burak M 2012. Mutation breeding of sweet cherry (*Prunus avium* L.) var. 0900 Ziraat, pp. 453-459. In: Shu QY, Forster BP and Nakagawa H (eds), *Plant Mutation Breeding and Biotechnology*. CAB International, Wallingford.

Montalvan R and Andro A 2005. Effect of gamma-radiation and sodium azide on quantitative characters in rice (*Oryza sativa* L.). *Genetics and Molecular Biology* **2**(1): 117-126.

Patil VS, Kalpande HV, Chinchane VN and Chavan SK 2018. Studies on genetic variability for yield and yield contributing traits through induced mutation in *desi* cotton (*Gossypium arboreum* L.). *International Journal of Current Microbiology and Applied Sciences* **6**: 1373-1382.

Serrat XE, Gauibourt R, Moysset L, Nogues S and Lalanne E 2014. EMS mutagenesis in mature seed-derived rice calli as a new method for rapidly obtaining TILLING mutant populations. *Plant Methods* **10**(5):1-14.

Sharma JR 1998. *Statistical and Biometrical Techniques in Plant Breeding*. New Age International (P) Limited, p 429.

Sharma KD, Katna G, Sharma N, Nag R, Sharma BK and Saha AJ 2018. Mutagenic effectiveness and efficiency of gamma rays, ethyl methane sulphonate and their combination treatments in chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences* **7**(11): 509-515.

Siddiqui SA and Singh S 2010. Induced genetic variability for yield and yield related traits in basmati rice. *World Journal of Agriculture Science* **6**(3): 331-337.

Wani AA 2011. Induced polygenic variability for quantitative traits in chickpea var. Pusa-372. *Comunicata Scientiae* **2(**2): 100-106.

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Rapid Assessment of Variability in Water Chestnut (*Trapa natans* var. *bispinosa* Roxb.) through Fruit and Stomatal Analysis

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Abstract: *Trapa natans* var. *bispinosa* Roxb, has immense potential in the water logged areas as alternative source of income, but is still under exploited. The study on its wide variability and its characterization is important for improvement and the present study analyses variability through fruit and stomatal morphology in 20 morphotypes collected from local ponds of central Uttar Pradesh and established in the experimental ponds at the Babasaheb Bhimrao Ambedkar University, Lucknow. A significant variation was observed in fruit morphology, yield and stomatal characters. Stomatal pore width showed highest PCV (35.44µm), GCV (35.07 µm), h^2 (%) (97.9) and GAM per cent (147.42), while stomatal density (μm^{-2}) showed highest genetic advance (26.01). However, close difference between GCV and PCV values indicated minimal influence of environment in the expression of the stomatal characters, thus may be governed genetically and these are positively correlated with some of fruit, peel, kernel characters. Thus, stomatal characters could be utilised as parameters for selection of superior water chestnut morphotypes for crop improvement in water chestnut.

Keywords: Characterization, Morphology, *Trapa natans* and variability

Water chestnut (*Trapa natans* var. *bispinosa* Roxb), having nutritional, medicinal and phytoremediative (Babu and Dwivedi 2012b) properties, belonging to the family Trapaceae is an important herb, grown in warm season for its fresh, edible and valuable fruits. Distributed ubiquitously in tropical, sub-tropical as well as temperate regions, it has previously been classified as one polymorphic group or as one genus having up to around 20 different species such as *Trapa maximouswiezii, T. acornis, T. quadrispinosa, T. bicornis, T. bispinosa, T. incisa, T. japonica, T. psedoincisa and T. Potanini* which may have different chromosome numbers (2n = 96 and 2n = 48) (Takano and Kadono 2005). Variability has been observed in respect of fruit shape and colour, shape and size of the leaves and other characteristics as well as in fruit weight, fruit growth, number of seeds/fruit, TSS and acidity by many workers on fruit crop (Majumdar 2004 in Mango, Shukla et al 2008 in Barhaland Babu et al 2011 in Water Chestnut). This crop has immense potential for cultivation in the water logged areas and is fast emerging as an alternative fruit crop, although it is still unexploited (Babu and Dwivedi 2012b). Development of high yielding varieties and improvement of fruit quality depends on genotypic worth of gene pool. Thus, systematic studies to document variability in this germplasm for its conservation become imperative although they are still lacking (Babu et al 2011) and character to be standardized for selection of the crop for further breeding programme.

Morphological characters may not adequately represent the genetic heterogeneity among accessions of a cultivar. Hence, characterization of inter-varietal heterogeneity based on morphological traits needs complementation with scanning electron microscopy. The prime advantage of morphological traits is that it is a simple, rapid and inexpensive assay techniques. However, they may be controlled by epistatic and pleiotropic genes and environmental influences may affect expression of these characteristics because of which they suffer from lack of decisiveness (Begum et al 2014, Kishor et al 2019). Stomatal initiation, on the other hand, is controlled by both environmental and genetic factors and their size and density are highly variable depending on the genetic background of the plants as well as on the growth conditions or the leaf ontogeny. Stomatal density has been shown to vary significantly within individuals, cultivars or ecotypes of a single species, as well as within a community. Within *Populus* genus, a wide inter-specific and inter-clonal variation in stomatal density, dimension and stomatal index has already been observed (Pellis et al 2004, Ferris et al 2002) as also in wheat (Shahinnia et al 2016). Thus, stomatal characters could be utilised as parameters for selection of superior water chestnut morphotypes cultivars, in addition to certain morphological traits, for crop improvement in water chestnut as experiment in the present study.

MATERIAL AND METHODS

Twenty germplasm of water chestnut from three districts (Lucknow, Gorakhapur and Deoria) of central Uttar Pradesh were collected during end of June to July, 2016 and established in ponds of $2{\times}1{\times}1m^3$ dimension at the Babasaheb Bhimrao Ambedkar University, Lucknow under standard management practices (Chattopadhyay2014)

Germplasm characterization through fruit morphology studies: The experiment was laid out in randomized block design. Data was analyzed using Windows-based computer software ICAR-SPAR. PCV, GCV, heritability in broad sense (h^2) and genetic advance were calculated as per procedure by Allard (1960). Number of fruits was counted manually. Length of fruit pedicel (cm) was recorded using measuring scale. Fruit, peel and kernel weight (g) were recorded and fruit length (mm), fruit width(mm), cheek diameter of fruits (mm), peel thickness (mm), kernel length (mm), kernel width (mm) and kernel cheek diameter (mm)were measured.

Stomatal anatomy studies through scanning electron microscopy (SEM): Variations in the anatomical characters of stomata were studied by scanning electron microscopy (SEM) (JSM-6490LV, JEOL, Japan) at USIC. Leaf samples were prepared as per procedure given by Fischer et al 2013 with slight modifications (Fig. 1) Stomatal density (μm^{-2}) was measured at 500X magnificence, while all stomatal dimensions were measured at 5000X magnificence.

RESULTS AND DISCUSSION

Morphological characterization: The morphological and stomatal traits showed significant variation in all morphotypes collected from different regions in Uttar Pradesh for the fruit, peel and karnel as well as stomatal characters under study. Various parameters recorded variations such as number of fruits, fruit pedicel, fruit weight, fruit volume, specific gravity, fruit length, fruit width, cheek diameter of fruits, peel thickness, peel weight, kernel weight, kernel volume, specific gravity of kernel, kernel length, kernel width, kernel cheek diameter, kernel: peel ratio and yield were showed the significantly critical difference among the various morphotypes (Table 1 and 2).

Stomatal characterization : Scanning electron microscopy studies of stomatal characters have revealed stomatal density ranging from 25-50 μm^{-2}, length from 11.48-1743 µm, width 4.68-7.52 µm, pore size (length 6.64-12.81 µm and width 1.40-3.83 µm) (Table 2)

Variability assessment: Variability estimates in terms of GCV, PCV, h^2, genetic advance and genetic advance as percent of mean show that the highest PCV (35.44), GCV (35.07), h^2 (97.9%) and genetic advance as percent of mean (147.42) were recorded from stomatal pore width. The results

Chopped leaf (2-4mm)
↓
Washed with distilled water (dH_2O)
↓
Fixed in Glutaraldehyde Karnovsky's fixative (2.5%) for 4 hours
↓
Washed in 0.1 M Phosphate buffer solution thrice at 4^0C for 15 minutes each
↓
Serial dehydration with acetone 30%, 50%, 70%, 90%, 95% and 100% for 30 minutes each
↓
Sample mounted on aluminium stubs with carbon tape and coated by using Sputter coater
↓
Observations recorded under the scanning electron microscope

Fig. 1. Procedure for preparation of leaf samples as per Fischer et al (2013) with modifications

are in agreement with those of Munshi and Behera (2000), Singh et al (2005) and Gupta et al (2009) in chilli. The narrow difference were recorded between PCV and GCV for kernel length, kernel cheek diameter, stomatal density, stomatal length, stomatal width, stomatal pore length and stomatal pore width which indicated that the phenotypic expression of characters is primarily due to the genotype, since environmental influence is negligible and expression of these characters could be controlled by some epistatic and pleiotropic gene effect useful for crop improvement through selection as in mango (Begum et al 2014, Kishor et al 2019) and banana (Kundu et al 2018). However, a wide variation between PCV and GCV were recorded for other fruit morphological parameters (Table 3) which was influenced by environmental effect and thus, cannot be considered reliable for crop improvement through selection (Ranpise and Desai 2003) of theses parameters. Although the genotypic coefficient of variation and phenotypic coefficient of variation are the measures of genetic variability, the amount of genetic gain can be estimated from genotypic coefficient of variation and phenotypic coefficient of variation along with heritability (Ogunniyan and Olakojo 2014). Estimates of GCV alone are not sufficient to quantify the amount of variation which is heritable and genotypic coefficient of variation effects, together with heritability estimates, furnish more reliable information. In the present study, heritability estimates as well as the GCV estimates were high for kernel length (65.6) and most of the stomatal characters *viz*. stomatal pore width (97.9), stomatal density (91.8), stomatal pore length (79.4), stomatal width (78.2), stomatal length (74.9) indicated their

Table 1. Variability in fruit morphological characters of water chestnut (* Average values recorded indicate two year pooled data).

Morphotypes	Average number of fruits	Fruit pedicel (cm)	Average fruit weight (g)	Fruit volume (ml)	Specific gravity g ml^{-1}	Fruit length (mm)	Fruit widths (mm)	Cheek diameter of fruits (mm)	Peel thickness (mm)	Peel weight (g)	Average yield (g plant^{-1})
Sel. -1	25.50	4.92	8.83	8.50	1.02	33.87	33.41	34.18	2.44	3.40	201.60
Sel. -2	14.33	4.43	6.97	6.90	1.04	32.23	36.31	36.62	1.81	2.80	101.44
Sel. -3	11.67	5.24	5.97	6.17	0.98	27.51	28.83	30.28	2.46	2.30	76.67
Sel. -4	14.33	4.74	6.87	6.47	1.03	29.39	27.68	28.53	2.44	2.90	97.67
Sel. -5	17.67	4.46	6.40	6.07	1.03	29.19	36.62	38.44	2.41	2.97	119.54
Sel. -6	17.83	4.32	7.40	6.87	1.12	33.84	31.87	33.38	2.12	2.77	139.77
Sel. -7	14.83	4.72	6.67	6.10	0.98	30.43	29.49	28.02	2.00	2.67	105.80
Sel. -8	16.67	4.54	5.87	5.77	1.01	30.97	28.30	30.77	1.82	1.78	103.67
Sel. -9	22.17	4.36	7.33	7.10	1.00	37.03	34.24	36.87	2.06	2.57	139.00
Sel. -10	19.50	4.18	5.87	5.33	0.99	29.47	27.65	29.03	2.18	2.23	129.04
Sel. -11	17.17	4.21	5.43	5.17	1.03	27.69	29.30	32.42	1.97	2.27	104.37
Sel. -12	25.50	4.47	7.53	6.97	1.17	28.82	28.63	32.71	2.09	2.13	255.07
Sel. -13	11.83	4.25	5.97	5.97	0.92	27.96	28.06	30.27	1.76	1.83	80.67
Sel. -14	15.17	4.10	6.73	6.70	1.00	32.33	29.39	31.09	2.26	2.47	113.40
Sel. -15	16.33	4.76	6.77	6.60	1.01	28.97	27.81	30.78	2.03	3.03	133.80
Sel. -16	12.67	4.46	6.53	6.43	1.01	32.60	31.35	31.68	1.98	2.40	82.60
Sel. -17	12.67	4.70	7.93	6.77	0.99	37.07	34.37	33.50	1.95	3.07	93.04
Sel. -18	21.50	5.16	6.47	5.83	1.03	33.78	32.27	33.83	2.03	2.13	145.22
Sel. -19	25.33	5.13	6.30	7.43	0.96	31.43	31.33	32.83	1.82	2.60	191.43
Sel. -20	24.83	5.17	8.90	8.93	1.00	37.45	35.70	37.04	2.03	3.23	246.60
CD (p= 0.05)	4.04	0.85	1.62	1.75	0.29	4.42	3.63	3.57	0.65	0.63	23.03

Table 2. Variability in kernel morphology and stomatal traits of water chestnut

Morphotypes	Kernel volume (ml)	Fresh kernel weight (g)	Specific gravity of kernel (g ml^{-1})	Kernel length (mm)	Kernel widths (mm)	Kernel cheek diameter (mm)	Kernel: peel ratio	Stomatal density (µm^{-2})	stomatal length (µm)	stomatal widths (µm)	Stomatal pore size (µm)	
											Length	Widths
Selection -1	5.17	5.60	1.01	27.53	28.38	30.18	2.04	25	13.73	7.36	9.12	2.48
Selection -2	4.27	4.17	0.95	26.61	27.14	27.60	1.70	38	13.88	6.04	9.91	3.44
Selection-3	3.53	3.67	1.01	26.38	28.04	29.06	1.61	47	12.95	4.68	8.68	1.40
Selection -4	3.93	3.97	0.96	25.13	24.84	26.75	1.54	31	15.24	6.56	8.68	2.20
Selection-5	4.17	3.93	0.94	26.49	26.83	28.75	1.46	29	17.00	6.28	12.81	3.44
Selection -6	4.57	4.63	0.99	30.92	27.71	29.91	2.38	39	16.00	6.68	12.78	5.16
Selection-7	4.33	4.03	1.99	26.98	27.69	29.45	1.85	46	12.55	6.85	6.94	1.84
Selection-8	4.33	4.13	0.97	25.06	24.15	27.47	2.62	44	11.53	6.4	8.08	3.72
Selection -9	4.90	4.77	0.97	26.89	26.69	28.20	2.14	40	14.88	6.76	8.42	3.04
Selection -10	3.43	3.40	0.92	29.92	28.64	28.68	1.75	39	14.28	5.29	8.54	1.92
Selection -11	3.33	3.17	1.00	28.59	27.35	28.19	1.51	38	14.44	4.76	10.78	1.76
Selection -12	4.64	4.93	0.95	27.77	26.22	27.46	2.31	35	15.44	6.76	11.27	1.60
Selection-13	4.43	4.13	0.92	24.17	25.29	26.02	2.24	48	11.80	5.44	8.24	2.72
Selection -14	4.33	4.24	0.98	27.27	27.17	28.07	1.85	50	13.33	8.05	8.22	3.44
Selection-15	3.47	3.53	0.96	26.00	27.79	28.53	1.40	42	15.73	5.48	10.61	2.56
Selection-16	3.87	3.73	0.94	26.24	28.13	28.83	1.75	42	13.20	6.52	8.59	3.64
Selection-17	4.90	4.87	0.95	24.43	25.69	26.52	1.85	44	13.40	6.56	9.36	6.56
Selection-18	4.47	4.33	0.96	24.80	25.20	26.81	2.24	44	14.16	7.52	10.28	3.83
Selection-19	3.70	3.33	0.96	26.67	27.80	28.97	1.43	42	17.43	5.53	13.52	1.84
Selection -20	5.17	5.67	1.00	28.15	28.09	30.19	1.84	46	11.48	5.92	6.64	2.36
CD (p=0.05)	1.00	1.12	0.18	2.36	2.69	2.25	0.74	2.06	1.35	0.64	1.36	2.79

suitability for reference during crop improvement in water chestnut (Table 3).

Higher heritability value indicates that these were inherited characters governed by major genes or additive gene effects and therefore, selection by these characters would be more effective for further crop improvement, which was also suggested by Sreelathakumary and Rajamory (2004). The highest genetic advance (26.01) was recorded for stomatal density, which, along with stomatal width (µm)correlated positively with the fruit weight, number of fruits, fruit pedicel, fruit volume, peel thickness, peel weight, fresh kernel weight, kernel volume, kernel width, kernel cheek diameter, kernel: peel ratio and yield. Stomatal traits such as density and size are considered key determinants of growth rate and water balance in plants (Dillen et al 2008) and influence the process of photosynthesis which is enhanced due to increased gaseous exchange through stomata. This subsequently affects photosynthate partitioning (Salisbury and Ross 2005), which is expressed in improved fruit size, weight, volume and yield. Thus, stomatal characters could be utilised as parameters for selection of superior water chestnut cultivars as also reported on cowpea (Varan et al 2017). There is a strong negative relationship between stomatal density and size in all plant (Hetherington and Woodward 2003, Doheny-Adams et al 2012). Larger stomata are usually distributed in low densities (Doheny-Adams et al 2012, Dillen et al 2008).

Heritability in broad sense includes both additive and non-additive gene effects. While, narrow sense heritability includes only additive components (Johri and Kumar 2007). Knowledge of heritability of a character is important as it indicates the possibility and extent to which improvement is possible through selection. Higher heritability does not always ensure an increased genetic advance. The character having high heritability with high genetic advance generally indicates that heritability is more due to the additive gene effect and advocated the use of high estimates of heritability along with high magnitude of genetic advance for genetic

Table 3. Estimates of genetic components for fruit, kernel morphology and stomatal traits of water chestnut

Characters	Means	Rang		PCV	GCV	h^2 (%)	GA	GAM%
		Maximum	Minimum					
No. of fruits	17.85	11.67	25.50	11.57	7.33	40.10	3.52	19.71
Fruits pedicel (cm)	4.61	4.10	5.24	9.72	6.39	43.20	0.82	17.78
Fruits weight (g)	6.83	5.43	8.83	10.02	3.54	12.50	0.37	5.41
Fruit volume (ml)	6.64	5.17	8.93	11.13	3.90	12.30	0.39	5.87
Fruit Specific gravity (g ml^{-1})	1.01	0.92	1.12	11.73	3.11	7.10	0.04	3.96
Fruit length (mm)	31.60	27.51	37.45	5.58	0.10	0.00	0.00	0.00
Fruit width (mm)	31.12	27.65	36.62	4.62	0.10	0.00	0.00	0.00
Fruits cheek diameter (mm)	32.61	28.02	38.44	5.38	3.20	35.30	2.63	8.06
Peel thickness (mm)	2.08	1.76	2.46	15.29	8.93	34.1	0.45	21.63
Peel weight (g)	2.57	1.78	3.40	9.72	1.23	01.6	0.02	0.77
Kernel weight (g)	4.21	3.17	5.67	11.55	4.68	16.4	0.32	7.60
Kernel Volume (ml)	4.24	3.33	5.17	9.36	0.74	0.6	0.02	0.47
Specific gravity of Kernel	0.96	0.92	1.99	8.20	3.27	15.9	0.06	6.25
Kernel length (mm)	26.79	24.17	30.92	5.95	4.82	65.6	4.44	16.57
Kernel widths (mm)	26.93	24.15	28.64	4.53	2.19	23.3	1.21	4.49
Kernel cheek diameter (mm)	28.28	26.52	30.19	4.54	3.27	51.9	2.82	9.97
Kernel: peel ratio	1.87	1.40	2.62	15.76	1.69	1.1	0.02	1.06
Stomatal density (μm^{-2})	40.43	25.00	50.00	16.51	15.82	91.8	26.01	64.33
Stomatal length (µm)	14.12	11.48	17.43	13.10	11.34	74.9	5.89	41.71
Stomatal widths (µm)	6.25	4.68	8.05	15.23	13.47	78.2	3.15	50.40
Stomatal pore length (µm)	9.55	6.64	13.52	21.55	19.20	79.4	6.94	72.67
Stomatal pore width (µm)	2.72	1.40	5.16	35.44	35.07	97.9	4.01	147.42
Yield g $plant^{-1}$	133.01	76.67	255.07	6.86	0.34	0.30	0.10	0.07

Table 4. GPS location, survey and collections site for water chestnut in the present study

Accessions	Local name	Sampling area	Latitude	Longitude
Sel-1	Singhree	Kewadi (Lucknow)	26°50' 21.41" N	80°55' 23.27" E.
Sel-2	DeshiLalla	Gosaiganj (Lucknow)	26°50'21.41"N	80°55'23.27"E.
Sel-3	Kadama Green	Gosaiganj (Lucknow)	26°50'21.41"N	80°55'23.27"E.
Sel-4	Saccharchini	Gosaiganj (Lucknow)	26°50'21.41"N	80°55'23.27"E.
Sel-5	Saccharchini	Sarojini Nagar (Lucknow)	26.81825^{0}N	80.92505^0 N
Sel-6	Kadama Green	Sarojini Nagar (Lucknow)	26.81825^{0}N	80.92505^0 N
Sel-7	Deshi	Mohanlalganj (Lucknow)	26.6676^{0}N	80.9867^{0}E
Sel-8	Saccharchini	BaksiKaTalab (Lucknow)	26.70135^{0}N	81.06145^{0}E
Sel-9	DeshiLalla	BaksiKaTalab (Lucknow)	26.70135^{0}N	81.06145^{0}E
Sel-10	Saccharchini	Kewadi (Lucknow)	26°50' 21.41" N	80°55' 23.27" E.
Sel-11	Light green	Kewadi (Lucknow)	26°50' 21.41" N	80°55' 23.27" E.
Sel-12	DeshiLalla	Khajni (Gorakhpur)	26° 45' 57.0384" N	83° 21' 53.7984"E.
Sel-13	Kadama Green	Khajni (Gorakhpur)	26° 45' 57.0384" N	83° 21' 53.7984"E.
Sel-14	Deshi Green	Bhatni (Deoria)	26^{0}23' 12.59"N	83^{0}56' 18.59"E
Sel-15	Singhree	Bhatni (Deoria)	26^{0}23' 12.59"N	83^{0}56' 18.59"E
Sel-16	DeshiLalla	Itonja (Lucknow)	27.0800^{0}N	80.9200^{0}E
Sel-17	Kadama Green	Itonja (Lucknow)	27.0800^{0}N	80.9200^{0}E
Sel-18	Kadma	Mohanlalganj (Lucknow)	26.6676^{0}N	80.9867^{0}E
Sel-19	Saccharchini	Mohanlalganj (Lucknow)	26.6676^{0}N	80.9867^{0}E
Sel-20	Singhdree	Sarojini Nagar (Lucknow)	26.81825^{0}N	80.92505^0 N

improvement in any trait through selection. Heritability estimates together with genetic advance are generally regarded to be more useful in predicting the gain through selection.

CONCLUSION

Water chestnut is an important crop keeping in view the nutritive as well as medicinal value of this hitherto underutilised crop besides its ecological benefit through bioremediation of water bodies. There is wide variation among the fruits available in the market although there are no standard varieties available across the country for this crop. The present study has concluded that statistically significant variation was observed among fruit, kernel morphology and stomatal characters, which indicates the potential to develop superior varieties and subsequently propagated them for enhancing the production of water chestnut. However, narrow difference between GCV, PCV and highest heritability and genetic advance was recorded for stomatal characters which indicated control of these characters at genetic level. Thus, stomatal characters may be considered for further crop improvement programme of water chestnut.

REFERENCES

Allard R W 1960. In: *Principles of Plant Breeding*. New York, NY, USA: John Wiley & Sons.

Babu M and Dwivedi DH 2012a. Bioaccumulation and distribution of Pb, Cu, and Fe in water chestnut (*Trapa natans* var. *bispinosa* Roxb.) in the Lucknow Region. *The Bioscan* **7**(4): 691-693.

Babu M and Dwivedi DH 2012b. Evaluation of biochemical attributes in water chestnut (*Trapa natans* var. *bispinosa* Roxb.) collected from Lucknow region. *The Asian Journal of Horticulture* **7**(2): 442-444.

Babu M, Dwivedi DH, Yogita and Ram BR 2011. Studies on physic chemical traits on local water chestnut (*Trapa natans* var. *bispinosa* Rox.) germplasm under central Uttrar Pradesh India. *Plant Archives* **11**(2): 949-951.

Begum H, Reddy MT, Malathi S, Reddy BP, Narshimulu G, Nagaraju J and Siddiq EA 2014. Morphological and microsatellite analysis of intra-varietal heterogeneity in 'Beneshan' mango (*Mangifera indica* L.). *International Journal of Agricultural and Food Research* **3**(2): 16-33.

Chattopadhyay TK 2014. *A Textbook on Pomology*. Vol. II.ISBN-13Kalyani Publishers, Calcutta, India.

Dillen SY, Marron N, Koch B and Ceulemans R 2008. Genetic variation of stomatal traits and carbon isotope discrimination in two hybrid poplar families (*Populus deltoides* 'S9-2' x P. nigra 'Ghoy' and P. deltoides 'S9-2' x P. trichocarpa 'V24') *Annuals of Botany* **102**: 399–407.

Doheny-Adams T, Hunt L, Franks PJ, Beerling DJ, Gray JE 2012. Genetic manipulation of stomatal density influences stomatal size, plant growth and tolerance to restricted water supply across a growth carbon dioxide gradient. *Philosophical Transactions of The Royal Society B Biological Science* **367**: 547–555.

Ferris R, Long L, Bunn SM, Robinson KM, Bradshaw HD, Rae A and Taylor G 2002. Leaf stomatal and epidermal cell development: Identification of putative quantitative trait loci in relation to elevated carbon dioxide concentration in poplar. *Tree Physiology* **22**: 633- 640.

Fischer ER, Hansen BT, Nair V, Hoyt FH, Dorward DW 2013. Scanning Electron Microscopy. NIH Public Access. 02-04.

Gupta AM, Singh D and Kumar A 2009. Genetic variability, genetic advance and correlation studies in chilli (*Capsicum annuum*). *Indian Journal of Agricultural Science* **79**: 221-223.

Hetherington AM and Woodward FI 2003. The role of stomata in sensing and driving environmental Change. *Nature* **424**: 901–908.

Johri S and Kumar V 2007. Study on genetic variability, heritability and genetic advance for yield and its attributes in bell pepper (*Capsicum annuum* L.). *Vegetable Science* **34**: 103–105.

Kishor S, Dwivedi DH, Singh N, Maji S and Sharma MK 2019. Analysis of intra-varietal variability in mango (*Mangifera indica* L.) cv. Dashehari. *Annals of Plant and Soil Research* **21**(2): 193-199.

Majumdar BC 2004. *Minor fruit crops of India tropical and subtropical*. Daya Publishing House, New Delhi. 25-26.

Musnshi AD and Behera TK 2000. Genetic variability, heritability, and genetic advance for some traits in chilli (*Capsicum annuum* L.). *Vegetable Science* **27**:39-41.

Kundu P, Bauri FK and Maji S 2018. Morphological study of genetic variability of banana genotypes for crop improvement. *Indian Journal of Ecology* **45**(3): 615-622.

Ogunniyan DJ and Olakojo SA 20014. Genetic variation, heritability, genetic advance and agronomic character association of yellow elite inbred lines of maize (*Zea mays* L.). *Nigerian Journal of Genetics* **28**(2): 24-28.

Pellis A, Laureysens I and Ceulemans R 2004. Genetic variation of the bud and leaf phenology of seventeen poplar clones in a short rotation coppice culture. *Plant Biology* **6**: 38-46.

Ranpise SA and Desai UT 2003. Genotypic and phenotypic variability in acid lime (*C. Aurantifolia* Swingle). *Journal of Maharashtra Agricultural University* **28**(1): 21-23.

Salisbury FB and Ross CW 2005 .Plant physiolgy.3 Ed. CBS Publishers and Distributors. Delhi (India). The photosynthesis-Transpiration Compromise, pp 54-63.

Shahinnia F, Roy JL, Laborde B, Sznajder B, Kalambettu P, Mahjourimajd S, Tilbrook J and Fleury D 2016. Genetic association of stomatal traits and yield in wheat grown in low rainfall environments. *BMC Plant Biology* **16**: 150.

Shukla SK, Ali A, Pandey D and Pandey G 2008. Physico chemical characterization of barhal (*A. lakoocha*) genotypes collected from central Uttar Pradesh. Souvenir: National seminar on sustainable horticultural research in India; perspective, priories and preparedness. 14-15 April. pp. 20.

Singh MD, Laisharam JM and Bhagirath T 2005. Genetic variability in local chillies (*Capsicum annuum* L.) of Manipur. *Indian Journal of Horticulture* **62**(2): 203-205.

Sreelathakumary I and I Rajamory 2004. Variability, heritability and genetic advance in chili (*Capsicum annuum* L.). *Journal of Tropical Agriculture* **42**: 35–37.

Takano A and Kadono Y 2005. Allozymevariations and classification of *Trapa* (Trapaceae) in Japan. *Aquatic Botany* **83**: 108–118.

Varan R, Singh YV, Kumar V, Jain and Bisen P 2017. Heterosis studies in vegetable cow pea [*Vigna unguiculata* (L.) Walp.] for yield and quality traits. *Indian Journal of Ecology* **44**(4): 190-194.

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Rainfall Variation and Frequency Analysis of Tiruppur District for Crop Planning, Tamil Nadu, India

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Abstract: Twenty years (1997-2016) daily rainfall data for Tiruppur district was collected from the TWAD (Tamil Nadu Water Supply and Drainage Board) to analyse the nature of distribution and frequency of rainfall. Average annual rainfall and annual rainy days during 20 years were 551 mm and 37 days. Highest monthly rainfall 148.4mm was in October mostly during the Northeast monsoon and highest rainy days were in October (8.06 days). Rainfall in winter, summer, southwest and northeast monsoon seasons were 56.81, 115.19, 66.2 and 327.03mm, respectively. The average annual rainfall of 551 mm can be expected to occur once in 2.2 years with a probability of 40 per cent. Monthly dependable rainfall is expected to occur every year from October to November. Based on results, the soil and water conservation structures, crop planning and management can be designed.

***Keywords*:** Rainfall, Rainfall variability, Frequency analysis, Weibull distribution

In India, about 60 per cent of total net sown area comes under rain fed lands and uncertainty in production due to alterations in total rainfall, changes in its distribution, etc. affect the livelihoods of the large population dependent on agriculture in the country. Tiruppur district receives the rain under the influence of both southwest and northeast monsoons. Northeast monsoon primarily contributes for the rainfall in Tiruppur district. The rainfall frequency analysis of Tiruppur district can be reasonably estimated using conventional methods where data are as compare to the desired return periods. For the required arrangements of water resources the awareness of the frequencies of recurrence of the extreme rainfall events are very important. The probability distributions were used to understand the rainfall distribution. Considering all these importance and issues of rainfed farming, a study on rainfall distribution and frequency of Tiruppur district, Tamilnadu was conducted for proper design of soil and water conservation structures, crop planning and irrigation management.

MATERIAL AND METHODS

Tiruppur district is located between latitudes 10°14' N and 11°20' N and longitudes 77°27' E and 77°56' E. The total geographical area of the district is 5187 Km^2. Major Agriculture in this district is banana, tomato, brinjal, onion. Tiruppur district is drained by Noyyal and Amaravathi rivers, which comes under the Cauvery basin. Normal annual rainfall over the district varies from 600 to 1400 mm. The normal onset and withdrawal of southwest monsoon is from June to September and for northeast monsoon is from October to December. Tamilnadu Water and Drainage Board (TWAD), is the key responsible organization for all hydro meteorological data's of Tamilnadu provided rainfall data for a period of 20 years (1997 to 2016) and was analyzed for annual, monthly and weekly rainfall. The relationship between rainfall and rainy days were generated by plotting annual, monthly and weekly rainfall against rainy days.

Frequency analysis is used to forecast how frequently certain values of a variable phenomenon tends to occur and to access the dependability of the forecasting. Rainfall data was also analyzed using Markov chain model for identifying appropriate cropping systems in different regions (Virmani et al 1982, Khichar et al 2000, Viswakharma et al 2000, Dabral and Jhajharia 2000, Cosmo et al 2011) and eighty two parameter distribution functions were studied for sub humid conditions (Sharda and Das 2005). The probability of each event is calculated by Weibull's method (Chow 1964).

$$P = \frac{M}{N + 1} \quad \text{------} \quad (1)$$

Where, P - is the probability of each event in %, M – is the rank assigned for each event when the data are arranged in decreasing order, N – is the total number of events in the data series

The return periods (recurrence interval) were calculated by using the formula

$$\text{Return period,} \quad T = \frac{1}{P} = \frac{N + 1}{M} \quad \text{------} \quad (2)$$

RESULTS AND DISCUSSION

Annual rainfall and rainy days: The yearly rainfall for 20 years (1997 to 2016) indicated maximum and minimum rainfall in 2005 (845 mm) and 2012 (291.3 mm) with 49 and 19 rainy days. Average rainfall for the 20 years was 551 mm. The eleven years received (40%) rainfall above average were observed. During eleven years rainfall above average. The average annual rainy days were 37 and the maximum and minimum rainy days were 52 days (2015) and 19 (2012). No specific trend was observed, however the rainy days were above average during 11 years. Although a linear relationship was obtained between the amount of rainfall and rainy days, however the maximum rainfall does not occur in the corresponding rainy days that may be a reason for the heavy rain that happened on a single day during the monsoon season.

Monthly rainfall and rainy days: The maximum rainfall 148.4 mm in October during Northeast monsoon season. Minimum rainfall of 2.84 mm was received in January during winter season (Fig. 1). Maximum rainfall 327.03 mm occurred September to November during northeast monsoon and the minimum rainfall of 56.31 mm during December to February in winter season. Annual monthly and mean monthly rainfall was 551 and 47.10 mm. January, February, March, April, June, July, August received below the mean monthly rainfall. The 66.24, 327.03, 56.81, 115.19 mm rainfall was received during Southwest monsoons, Northeast monsoon, winter and summer, respectively (Fig. 2).

Weekly rainfall and rainy days: The variations in weekly rainfall showed reductions in rainfall up to 13th week. After that rainfall showed an increasing sign and gradually starts reducing from 45th week to 52nd week. Maximum weekly rainfall was in the 42nd week (44.96 mm) followed by 45th week (43.99 mm). Minimum rainfall was in the 7th week. More than 18 weeks (35%) received rainfall higher than the average weekly rainfall of 10.8 mm. The weekly rainy days moves up and down and reaches the maximum in 44th week and was categorized into 6 (Table 2). The 85 per cent of the weeks the rainfall is less than 20 mm (Fig. 3)

Relationship between rainfall and rainy days: It is generally believed that the total rainfall is the function of total number of rainy days. The correlation coefficient between the two reveals that there exist a linear relationship between the rainfall and rainy days. The rainfall was higher than the average in 1998 whereas rainy days in the corresponding years were marginally below than the average. Monthly rainfall against monthly rainy days was plotted (Fig. 4) and the regression equation was established between the variables rainfall (Y) and rainy days (X), in which 90 per cent of the variables are following this relationship.

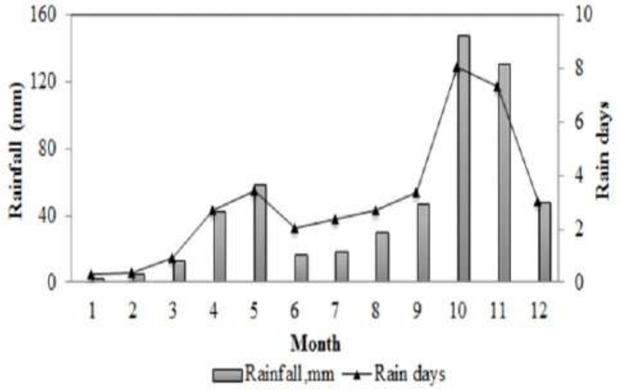

Fig. 1. Mean monthly rainfall & rainy days (1997-2016)

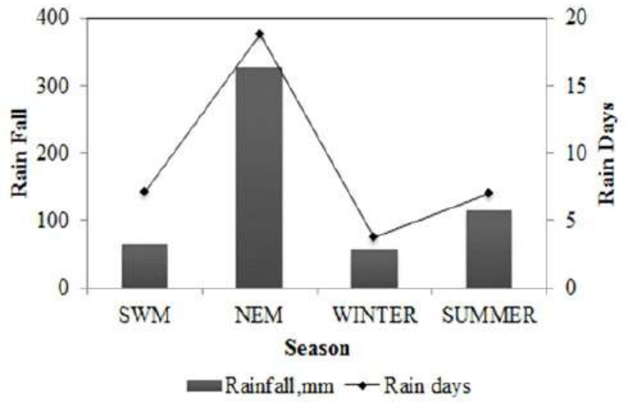

Fig. 2. Seasonal distribution of rainfall and rainy days (1997 - 2016)

Table 1. Annual rainfall and rainy days for the period of 1997-2016

Year	Annual rainfall	Annual rainy days	One day maximum rainfall
1997	623.13	49	35.09
1998	656.13	36	60.64
1999	660.4	41	44.98
2000	589.23	38	26.42
2001	468.7	36	29.00
2002	441.17	28	42.84
2003	398.18	30	39.46
2004	514.33	42	34.15
2005	844.99	49	75.00
2006	492.91	38	36.22
2007	636.98	39	75.94
2008	617.85	42	56.11
2009	530.01	34	71.90
2010	638.3	41	46.85
2011	629.39	37	38.64
2012	291.3	19	18.62
2013	336.87	27	34.60
2014	603.75	40	39.43
2015	734.55	52	37.75
2016	311.65	21	56.72

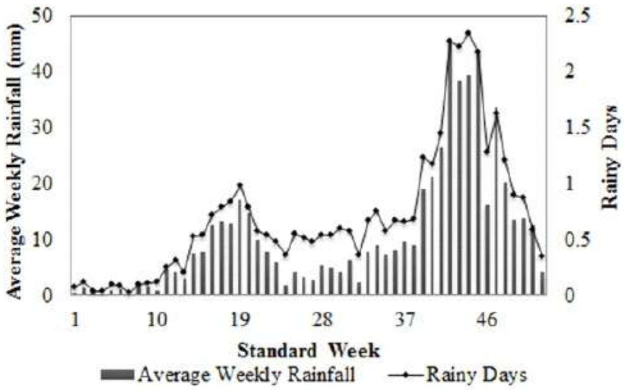

Fig .3. Mean weekly rainfall and rainy days (1997-2016)

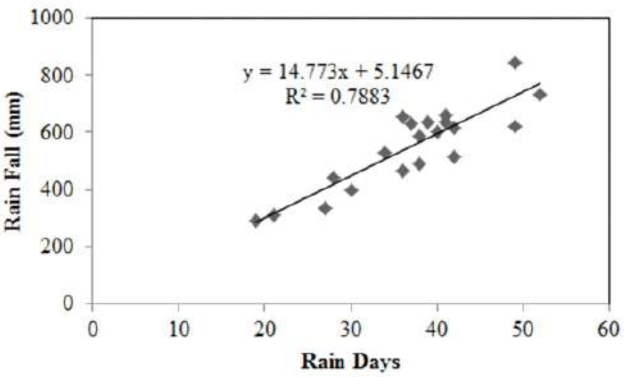

Fig. 4. Relationship between rainfall and rainy days (1997-2016)

Table 2. Number of Weeks under different amount of rainfall (mm)

Year	>=0	>=20	>=40	>=60	>=80	>=100
1997	45	1	1	1	1	3
1998	48	1	0	1	0	2
1999	47	1	1	0	0	3
2000	47	1	1	0	0	3
2001	47	1	1	1	0	2
2002	49	1	0	0	0	2
2003	48	1	1	0	0	2
2004	47	1	1	1	0	2
2005	46	1	1	0	0	4
2006	47	1	1	1	0	2
2007	47	1	1	1	0	2
2008	46	1	1	1	0	3
2009	48	1	1	0	0	2
2010	47	1	1	0	0	3
2011	47	1	1	0	0	3
2012	50	0	1	0	0	1
2013	49	1	0	0	0	2
2014	46	1	1	1	0	3
2015	45	1	1	1	0	4
2016	49	1	0	0	0	2
Total	945	19	16	9	1	50
Mean	47.25	0.95	0.8	0.45	0.05	2.5

Table 3. Monthly Rainfall Probability (P) and Return Period (T)

Rank	T	P	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	21.0	4.70	0	7.40	4.10	91.7	103.25	19.85	60.7	34.7	15.06	177.3	235.97	101.7
2	10.5	9.50	0	0	10.2	156.7	146.15	38.41	5.95	21.4	92.43	68.9	219.6	93.3
3	7.00	14.20	0	5	10.8	112.7	15.7	29.21	12.84	18.29	7.75	222.3	238.2	9.44
4	5.25	19.04	0	0	0	4.10	116.15	3.56	20.08	90.32	104.37	316.34	34.95	26.45
5	4.20	23.80	0	0	0	10.9	53.93	17.21	31.59	25.78	68.31	130.8	323.5	60.2
6	3.50	28.57	0	0	0	66.04	48.04	52.12	25.06	31.97	48.45	152.9	52.88	176.77
7	3.00	33.33	0	0	0	79.45	27.27	7.07	7.75	10.43	43.33	274.18	152.03	28.10
8	2.62	38.09	11.09	15.51	98.41	3.93	31.02	7.39	38.13	64.79	38.74	223.88	57.87	44
9	2.33	42.85	12.19	34.09	0	32.27	26.2	9.36	8.63	81.51	125.04	31.35	99.3	58.34
10	2.10	47.61	0	0	14.9	11.32	89.14	6.57	20.37	30.75	52.61	62.48	225.15	25.95
11	1.90	52.38	0	0	0	20.27	42.5	23.07	42.9	56.16	48.20	34.5	183.3	159.09
12	1.75	57.14	0	0	21.7	35.45	46.45	19.28	21.18	17.4	51.83	161.16	210.43	59.34
13	1.61	61.90	0	0	0	32.1	100.6	12.8	27.4	11.2	70	164	84.3	9.67
14	1.50	66.66	15.26	0	20.4	24.33	47.17	14	6.22	17.41	62.4	125.25	189.7	0
15	1.40	71.42	0	0	0	53.71	32.85	22.63	20.7	8.43	46.6	121.45	110.3	33.4
16	1.31	76.19	0	0	30.27	19.3	34.2	19.58	4.83	16.02	32.51	201.98	50.96	28.5
17	1.23	80.95	0	0	43.45	28.73	26.45	0	0	24.54	0	139.24	84.76	24
18	1.17	85.71	0	28.65	0	31.1	32.21	0	0	26.18	38.96	110.26	49.2	30.76
19	1.10	90.47	0	0	0	0	122.4	0	0	0	0	127	30.6	33
20	1.05	95.23	0	0	0	0	0	0	0	0	0	0	0	0

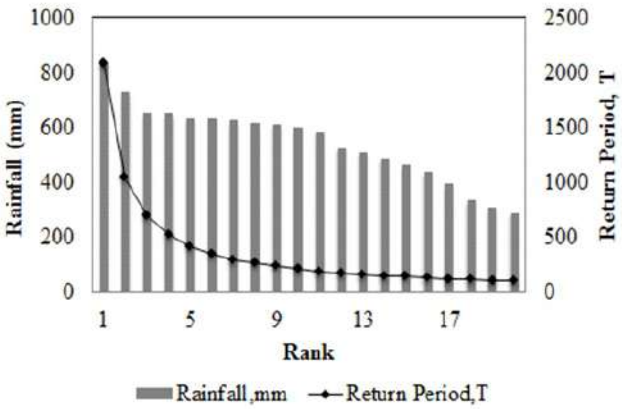

Fig. 5. Probability analysis of rainfall (1997-2016)

Rainfall frequency analysis: The annual rainfall of 551 mm can be expected to occur once in 2.2 years at a probability of 40 per cent (Fig. 5). The monthly dependable rainfall (with a probability >75 %) is expected in every year during May to December with higher accumulation during October to November (Table 3). Rainfall that is expected to occur in other recurrence intervals are considered to be undependable. The frequency analysis of minimum 500 mm rainfall can be expected to be equal or exceeded once in 1.2 years with a probability of 91 per cent.

CONCLUSION

This study was focused for analyzing the rainfall pattern of Tiruppur, One among the frequent drought affected district located in hot semi – arid region of Tamilnadu. Probability and return periods were measured for the frequency analysis, which will be useful for the proper planning and designing of surface and ground water conservation and recharging structures, as well as it guides for the better water management system to facilitate a proper planning of cropping patterns during the rainfall less periods.

REFERENCES

DES 2000. Agricultural statistics at a glance. *Agricultural statistics division, Directorate of Economics and statistics, Ministry of Agriculture, Government of India.*

Arti Devi and Parthasarathy Choudhury 2013. Extreme rainfall frequency analysis for meteorological sub – Division 4 of India using L – Moments. *International Journal of Environmental, Ecological, Geological and Geophysical Engineering* **7**(12): 664-669.

Gebre Hadgu, Kindie Tesfaye, Girma Mamo and Belay Kasssa 2013. Trend and variability of rainfall in Tigray, Northern Ethiopia: Analysis of meteorological data and farmer's perception. *Academia Journal of Agricultural Research* **1**(6): 88-100.

Cosmo S, Ngongondo Chong –Yu Xu, Lena M, Tallaksen, Berhan uAlemaw and Tobias Chirwa 2011. Regional frequency analysis of rainfall extremes in Southern Malawi using the index rainfall and L – moments approaches. *Journal of Stoch Environmental Research Risk Assess* **25**: 939-955.

Virmani SM, Sivakumar MVK and Reddy SJ 1982. Rainfall probability estimates for selected locations of semi-arid India. *Research bulletin No. 1, 2nd edition - enlarged, ICRISAT, Patancheru, Andra Pradesh: 19.*

Kichar ML, Niwas R and Pal S 2000. Markov chain model for use in analysis of SW monsoon rainfall of arid zone in Haryana. *Journal of Applied Hydrology* **XIII**(3/4): 60-65.

Vishwakarma SK, Ranade DH, Paradkar VK, Jain LK and Tomar AS 2000. Probability analysis of wet and dry spells for agricultural planning Chhindwara. *Indian Journal of Agricultural Science* **70**(10): 719-721.

Dabral PP and Jhajharia D 2000. Dry and Wet spell probability by Markov chain model and its application to crop planning in Doimukh (Izatnagar), Arunachal Pradesh. *Journal of Soil Water Conservation of India* **2**(1/2): 32-39.

Sharda VN and Das PK 2005. Modelling weekly rainfall data for crop planning in a sub – humid climate of India. *Agricultural Water Management* **76**: 120-138.

Islam S 2003. Banglapedia: National Encyclopedia of Bangladesh. *Asiatic Society of Bangladesh.*

Chow VT 1964. *Handbook of applied hydrology – A compendium of water resources technology,* Mc Grew Hill Book Company New York.

Sathyamoorthy NK, Ramaraj AP, Senthilraja K, Swaminathan C and Jagannathan R 2018. Exploring the rainfall scenario of periyarvaigai command area for crop planning. *Indian Journal of Ecology* **45**(1): 11-18.

Pratibha Kumari, Pravendra Kumar and Singh PV 2018. Rainfall-runoff modelling using artificial neural network and adaptive neuro-fuzzy inference system. *Indian Journal of Ecology* **45**(1): 281-285.

Gill KK, Rajan Aggarwal and Pallvi Goyal 2015. Rainfall probabilities for crop planning in Ludhiana by Markov Chain analysis. *Indian Journal of Ecology* **42**(1): 16-20.

Vijay Kumar Singh, Pravendra Kumar and Bhaskar Pratap Singh 2016. Rainfall-runoff modeling using artificial neural networks (ANNs) and multiple linear regression (MLR) Techniques. *Indian Journal of Ecology* **43**(2): 436-442.

Sathyamoorthy NK, Ramaraj AP, Dheebakaran G, Arthirani B, Senthilraja K and Jagannathan R 2017. Characterization of rainfall and length of growing period over north western zone of Tamil Nadu. *Indian Journal of Ecology* **44**(2): 232-238.

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Impact of Salinity on Primary Production in the Marshes

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Abstract: The comparison the high salinity area (HS) with the lowest (LS), indicate that there was no change in water temperature, dissolved oxygen and turbidity, and they were not significantly correlated with the primary production (chlorophyll-a). There was also no change in phosphorus and nitrate concentrations and were not significantly related with primary production. Its affected DIC and pH value significantly. Furthermore zooplankton biomass changed significantly due to salinity (but it has not related to primary productivity). Therefore the study concluded that salinity had a clear effect on the primary productivity, and the study suggested that salinity, due to climate change, could be the main key driver for primary productivity in the subtropics but still needs more deeply field studies in different subtropical regions.

Keywords: Salinity, Climate change, Primary production

Pelagic primary production is the flow of dissolved inorganic carbon into phytoplankton at that time, and its mean the amount of the primary energy which input to the aquatic ecosystem (Sea 2018) and represent global biomass carbon equivalent of phytoplankton less than 1 per cent of total self-feeding of biomass on the planet's surface (Bryant 2003), yet they account for 40-50 per cent of global carbon stabilization with more than 100 million tonnes of inorganic carbon determined by phytoplankton on a daily basis (Behrenfeld et al 2006). In general, most of the salt in the landscape is of oceanic composition (dominated by chloride and sodium) that accumulated from a different sources (e.g. such as groundwater, and rock weathering) - (Podmore 2009). In the periods of low-flow discharge, in the aquatic ecosystem g salts accumulates that results in high salinity which biota must either tolerate or avoid. In general, saline could affect wetland species communities (Nielsen et al 2003). Many freshwater-wetlands have highly hydrological variable, so the increase of evaporation may cause periods of total drying. Over low-water periods, several wetlands remain fresh and others be sufficiently saline to drive the assembly of wetland communities from fresh-water biota to haline tolerant biota.

Continued droughts foretell as an outcome of climate change (global warming and lower rainfall) that collaborated with human activities in changes of the natural hydrological regime will lead to shortage in water availability for environmental and anthropogenic utilize, and low-runoff may cause the despair of some wetland kinds. Recently, water evaporation increased significantly as a result of global warming leads to a rise of water salinity (Vineis, Chan and Khan 2011, Jakimavičius 2018); and that may directly affects trophic state of the ecosystem by affecting the number, types, distribution and phytoplankton community structures depend on the salinity avoid and tolerance (Little, Wood and Elliott 2017). Nutrients, temperature and light considered as the main factors which can affect the growth of functional groups of phytoplankton in an aquatic ecosystem (Cao et al 2018). Several studies were conducted on the effect of salinity on the plant physiology and chlorophyll concentration (Parida and Das 2005, Ali et al 2004,- Håkanson and Eklund, 2010, Rai and Rajashekhar 2014). Since phytoplankton is the main link that connects between the aquatic biogeochimaical processes and it is essential to understand the productivity of the aquatic ecosystem affected due to the environmental changes (Zhou et al 2016, Little et al 2017). There are rare studies about the effects of climate change and wetland salinize on primary productions in the subtropics wetlands, so this study were conducted on wetland pelagic primary production Since chlorophyll-a is the primary factor responsible for photosynthesis (Xu et al 2008), it a good indicator of photosynthesis activity in addition to planktonic biomass. Central marsh of Iraq was chosen to investigate this work, because it has two surface water continued regions, the first is a freshwater wetland feeding from the Euphrates River as a control, while the second region is a wetland with salt water because of water shortage as a treatment, so can compare between them.

MATERIAL AND METHODS

Twenty sampling sites (Fig. 1, Table 1) were chosen in two salinity different concentration at the same wetland area which located southern Iraq (Chibayish marshes), 10 sites (low salinity - LS) were in the fresh - brackish water pools (salinity=2.85 ± 0.294 ppt) while the other 10 sites (High

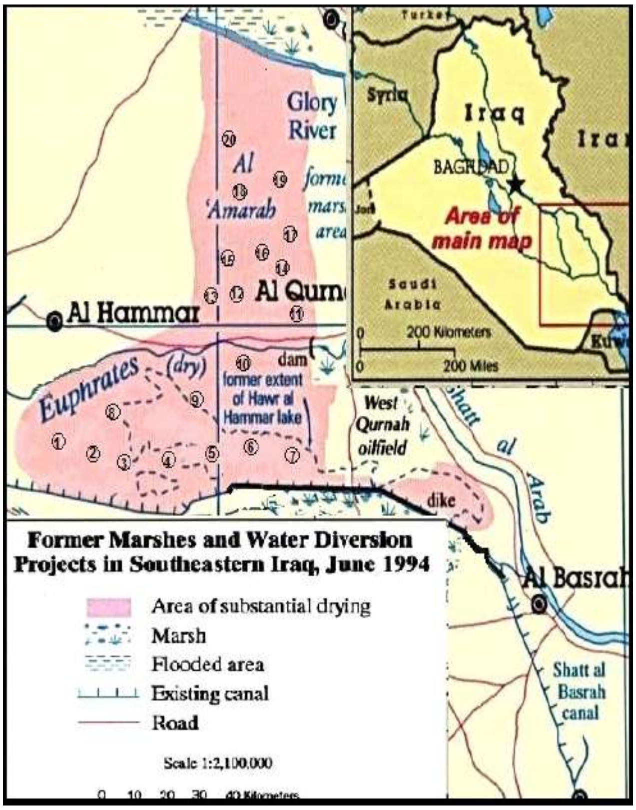

Fig. 1. The wetland study sites southern of Iraq (Chibayish marshes)

Table 1. Location of experimental sites in southern Iraq (Chibayish marshes)

Site (St.)	N	E
St.1	30°58'49.0"	46°65'01.4"
St.2	30°59'09.7"	46°58'04.9"
St.3	30°59'22.5"	47°00'03.5"
St.4	30°59'35.1"	47°01'52.3"
St.5	30°59'39.3"	47°03'50.9"
St.6	31°00'04.7"	47°06'14.2"
St.7	31°00'13.0"	47°08'17.8"
St.8	31°01'25.3"	46°59'38.8"
St.9	31°01'42.8"	47°01'19.7"
St.10	31°03'20.0"	47°03'33.2"
St.11	31°04'36.1"	47°05'02.4"
St.12	31°05'10.1"	47°03'03.8"
St.13	31°05'10.3"	47°00'25.6"
St.14	31°06'17.8"	47°03'33.5"
St.15	31°06'30.7"	46°59'36.2"
St.16	31°07'08.7"	47°01'25.0"
St.17	31°07'38.3"	47°02'59.1"
St.18	31°08'41.9"	47°00'11.0"
St.19	31°08'28.0"	47°02'45.4"
St.20	31°09'02.6"	46°58'57.7"

1st ten sites (St.1 – St.10) were low salinity (fresh – brackish; 2.85 ± 0.294ppt) while the other 10 sites (St.11 – St.20) were high salinity (08.55 ± 1.232ppt)

salinity =HS) were located in saline water pools (salinity = 8.55 ± 1.232ppt). Sub-surface water samples were collected by Van Dorn water sampler. In the field. salinity), water temperature), pH, dissolved oxygen) were measured by Multi 340i meter (WTW company/ made in Germany), turbidity was measured by turbidity meter (Portable turbidity meter tube. 430) and tranperency by Secchi disc. For nutrients, 40 ml of water samples was filtered through GF/F filters and stored in 50 ml falcon tubes in the freezer, soluble reactive phosphorus (PO_4) was analyzed with spectrophotometric-ammonium molybdate method (ISO 15681-1 Revision2, 2008), and nitrate (NO3) was analyzed according to ISO 13395 Revision, (1996). Dissolved inorganic carbon (DIC) were calculated s on total alkalinity (by titration), pH, water temperature and salinity (Strickland & Parsons, 1972). Chlorophyll-a were measured by filtering 100 ml of water through 0.45 µm GF/F-filters. Filters were directly covered in aluminum foil and stored at -20 °C. Chlorophyll was then extracted in 95% ethanol for 24 hrs in the dark and measured with a UV-Spectrometer (EMC Lab Germany). Zooplankton biomass samples were collected by vertical net-hauling using 20 µm mesh size 20 cm diameter net, and preserved with Lugol's solution and stored cold (6°C) until analysis and counting. Zooplankton were classified and measured using inverted microscopy. The volume of individuals was measured and converted to dry weight using length-weight regressions (Bottrell et al 1976). The carbon content was estimated as 50% of dry biomass (Salonen et al 1976).

Statistical analyses: For statistical analysis, IBM-SPSS statistics 24 was used to test treatment responses versus controls. Two-tailed t-test and repeated measures Pearson's correlation coefficient considered to test the correlation among the different variables. Treatment effects were consider statistical significant as *P* value < 0.05.

RESULTS AND DISCUSSION

The salinity ranged between 2.85 ppt in fresh – brackish water in the 1st part to saline water in the 2nd part (8.55 ppt).There were no different between LS and HS parts of water temperature, DO, turbidity and nutrients (Figure 2 c and d). There were significant changes in DIC, Chl-a and biomass of zooplankton (Table 2, Fig. 2b, e, and f). In Iraqi wetland, the water salinity have increased dramatically over time because of climate change, shortage in water resources, dams building and mismanagement. There are several factors that affect primary productivity, which includes top-down (non-living) factors (temperature, oxygen concentration, water, turbidity, pH, nutrients and salinity) and bottom-up (living factors such as zooplankton as main phytoplankton grazier). In present study, comparing the high salinity area (HS) with the lowest (LS), indicated that there was no change in water temperature, dissolved oxygen and turbidity and concentrations were not significantly correlated with the primary productivity (chlorophyll concentration. Also, there was no change in phosphorus and nitrate concentrations and there were not significantly related with primary production (Table 2).

Quynh et al (2016)indicated that DIC can be affected significantly by various environmental factors, including salinity (ions of sodium, potassium, calcium, and sulfur). The

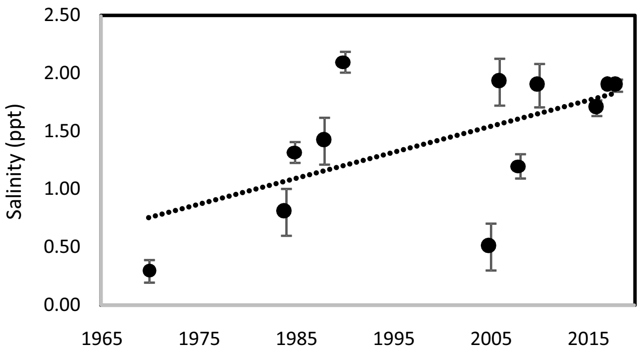

Fig. 3. The Mesopotamian marshes salinity average with time line (Mean± standard error) (Richardson and Hussain, 2006, Hussainand Grabe 2009,' Al-Haidareyet al 2010, Al-kenzawi et al 2010; Almaarofi 2015; and present study)

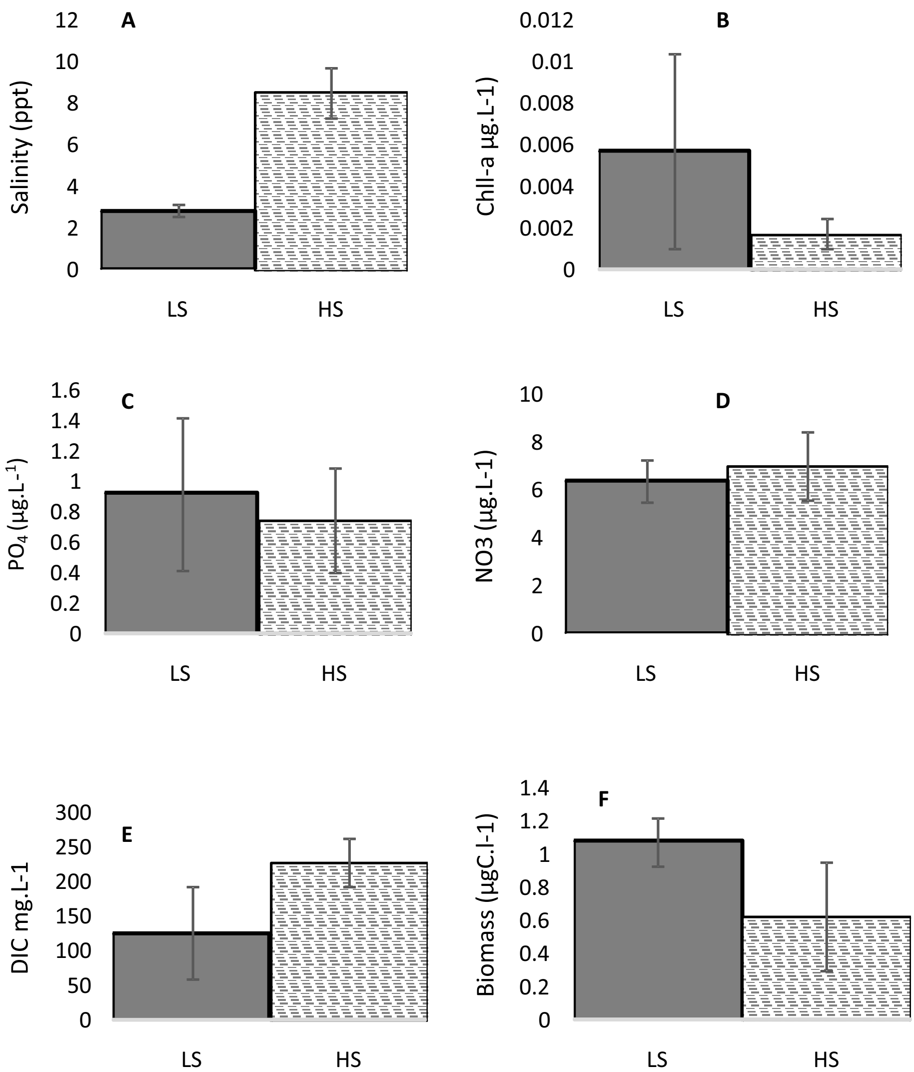

Fig. 2. The mean of salinity (a), Chl-a (b), PO_4 (c), NO_3 (d), DIC (e) and zooplankton biomass (f) with standard deviation bar in the low salinity and high salinity group sites

Table 2. Mean and regression correlation of different variables and salinity and Chl-a

Variables	LS(±SD)	HS (±SD)	$P_{T\text{-}Test}$	P-*Regression* Sal vs variables	P-*Regression* Chl-A vs variables	DF
Salinity (ppt)	2.85 ± 0.294	8.55 ± 1.23	< 0.001**	-	0.02*	19
WT (ºC)	13.03 ± 0.47	13.26 ± 0.65	0.376	0.709	0.541	19
pH	8.05 ± 0.34	8.3512 ± 0.24	0.035*	0.009*	0.063	19
DO (mg L^{-1})	2.70 ± 3.00	2.569 ± 0.25	0.889	< 0.001**	0.090	19
Turbidity (NTU)	16.306 ± 8.85	16.623 ± 5.62	0.925	0.979	0.194	19
PO4(P-µg L^{-1})	0.92 ± 0.50	0.747 ± 0.34	0.190	0.321	0.060	19
NO3(N-µg L^{-1})	6.40 ± 0.86	7.06 ± 1.43	0.114	0.145	0.052	19
DIC (µMol L^{-1})	127 ± 66	229 ± 35	< 0.001**	< 0.001**	0.081	19
Zooplankton biomass (µgC L^{-1})	1.07±0.15	0.63±0.33	< 0.001**	< 0.001**	0.084	19
Chl-a (µg L^{-1})	0.006 ± 0.005	0.002 ± 0.001	0.009*	0.020*	-	19

*Significant affects < 0.05, ** Significant affects < 0.001

value of DIC is also affected by the logarithmic concentration of hydrogen ions. This corresponds to the present study that the salinity affect DIC and pH value. Although studies indicate that DIC has an important role in primary productivity (as a source of carbon), the current study did not find that link.There was a significant change in zooplankton t biomass because it is very sensitive to changes in salinity (Tavsanoglu et al 2015). The zooplankton that affected by salinity, will decreasing grazier pressure on the pelagic producers, but in presentstudy, there is no direct effect of zooplankton on primary productivity.Salinity is a determining factor that could limited the composition and diversity of phytoplankton community structure (Barron, 2002;Nielsen et al 2003,Rai and Rajashekhar 2014). In present study, the salinity has direct effect on primary productivity by affecting physiological acts of phytoplankton (Parida and Das 2005) and similar findings were documneted by earlier workers(Håkanson and Eklund, 2010;Mostafa Heidari 2011,Rai & Rajashekhar 2014; –Al-Taee 2018).

CONCLUSIONS

In the present study, when we compared between high salinity region with the lowest salinity regions “under same climate conditions”, the dissolved oxygen, turbidity and nutrients were not changed significantly. Thus, they had not significant role in primary production. But the difference in salinity concentration affected dissolved inorganic carbon, pH values and zooplankton biomass. So they affected "in combination with salinity" primary production. Therefore, we concluded that salinity could be the main key driver for primary production in the marshes directly and indirectly.

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REFERENCES

Al-Haidarey MJS, Hassan FM, Al-Kubaisey ARA and Douabul AAZ 2010. The geoaccumulation index of some heavy metals in Al-Hawizeh Marsh, Iraq. *E-Journal of Chemistry* **7**(1): 973–4945.

Al-kenzawi MAH, Talib AH, Al-Haidary MJS and Karomi MF 2010. Environmental study of some water characteristics at Um-Naaj Marsh, South of Iraq. *Baghdad Science Journal* **8**(1): 531–538.

Al-Taee IA 2018. Salinity effect chlorophyll significantly. *Plant Archives* ***18***(1): 723–726.

Ali Y, Aslam Z, Ashraf MY and Tahir GR 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *International Journal of Environmental Science & Technology* **1**(3): 221–225.

Almaarofi SS 2015. Ecological *Assessment of Re-flooded Mesopotamian Marshes (Iraq)*. Ph.D. Dissertation, Waterloo University, Canada

Barron S, Weber C, Marino R, Davidson E and Tomasky G 2002. Effects of varying salinity on phytoplankton growth in a low-salinity coastal pond under two nutrient conditions. *Biological Bulletin* **203**: 260–261.

Bottrell HH, Duncan A, Gliwicz ZM, Grygierek E, Herzig A, Hillbricht-Ilkowska, A, … and Weglenska T 1976. A review of some problems in zooplankton production studies. *Norwegian Journal of Zoology* **24**: 419–456.

Cao J, Hou Z, Li Z, Chu Z, Yang P and Zheng B 2018. Succession of phytoplankton functional groups and their driving factors in a subtropical plateau lake. *Science of the Total Environment* **631-632**: 1127–1137.

Håkanson L and Eklund JM 2010. Relationships between chlorophyll, salinity, phosphorus, and nitrogen in lakes and marine areas. *Journal of Coastal Research* **263**: 412–423.

Hussain NA and Grabe SA 2009. A review of the water quality of the mesopotamian (Southern Iraq) Marshes Prior to the Massive Desiccation of the Early 1990s, **4**(2):98–120.

ISO 13395 Revision 2 1996. Determination of the sum of nitrate and nitrite in water by FIAstar 5000. https://www.iso.org/standard/21870.html

ISO 15681-1 Revision2 2008. Determination of ortho-phosphate in water by FIAstar 5000.https://www.sis.se/api/ document/preview/904242/

Jakimavičius D, Kriaučiuniene J and Sarauskiene D 2018. Impact of climate change on the curonian lagoon water balance components, salinity and water temperature in the 21^{st} century. *Oceanologia* **60**(3): 378–389.

Lau JA, Shaw RG, Reich PB, Shaw FH, Tiffin P and Tiffin P 2007. Strong ecological but weak evolutionary effects of elevated co_2

on a recombinant inbred population of arabidopsis Thaliana. *New Phytol* **175**(2):351-62.

Little S, Wood PJ and Elliott M 2017. Quantifying salinity-induced changes on estuarine benthic fauna: The potential implications of climate change. *Estuarine, Coastal and Shelf Science* **198**: 610–625.

Mostafa H 2011. Effects of salinity stress on growth, chlorophyll content and osmotic components of two Basil (*Ocimum Basilicum* L.) Genotypes. *African Journal of Biotechnology* **11**(2): 379–384.

Nielsen DLA, Brock MAB, Rees GNA and Baldwin DSA 2003. Effects of increasing salinity on freshwater ecosystems in Australia effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany* **51**(6): 655-665.

Olenina I, Hajdu S, Edler L, Wasmund N, Busch S, Göbel J, … Niemkiewicz E 2006. Biovolumes and size-classes of phytoplankton in The Baltic Sea. *Baltic Sea Environment Proceedings No.* **106**: 144. https://epic.awi.de/id/eprint/30141/1/bsep106.pdf

Oslen P and Blomqvist P 1981. Vaxtplanktokompedium. Uppsala: 1981 Uppsala.

Parida AK and Das AB 2005. Salt tolerance and salinity effects on plants: A review. *Ecotoxicology and Environmental Safety* **60**(3): 324–349.

Podmore C 2009. Urban Salinity-Causes and Impacts, 1–4. Retrieved from https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/309316/Urban-salinity-causes-and-impacts.pdf

Quynh TP, Binh TX, Thuy T, Nghia D and Cuong T 2016. Relationship of Dissolved Inorganic Carbon (DIC) concentrations with some environmental variables in the red river water in the period 2008-2015. *Journal of Vietnamese Environment* **8**(2): 102–106.

Rai SV and Rajashekhar M 2014. Effect of pH , Salinity and temperature on the growth of six species of marine phytoplankton. *Journal of Algal Biomass Utln* **5**(4): 55-59.

Richardson CJ and Hussain NA 2006. Restoring the garden of eden : An ecological assessment of the marshes of Iraq. *Bio Science* **56**(6): 477–489.

Received 18 May, 2019; Accepted 31 July, 2019

Salonen K, Sarvala J, Hakala I and Viljanen ML 1976. The relation of energy and organic carbon in aquatic invertebrates. *Limnology and Oceanography* **21**(5): 724–730.

Sea R 2018. A comparative study on pelagic primary productivity in the coastal areas marine science . *Research & Development* **8**(1): 1–8.

Strickland JD and Parsons TR 1972. A Practical Handbook of Seawater Analysis. Retrieved from https://epic.awi.de/id/eprint/39262/1/Strickland-Parsons_1972. pdf

Tavsanoglu UN, Maleki R and Akbulut N 2015. Effects of salinity on the zooplankton community structure in two maar lakes and one freshwater lake in the konya closed basin, Turkey. *Ekoloji* **24**(94): 25-32.

Thomsen HA (Ed) 1992. Plankton I Indre Danske Farvande. En Analyse af Forekomsten af Alger og Heterotrofe Protister (ekskl. ciliater) i Kattegat. *København: Miljøstyrelsen, Miljøministeriet*. 340p.

Tikkanen T and Willén T 1992. Växtplanktonflora. Statens naturvårdsverk, 1992.

Vesterinen J, Devlin SP, Syväranta J and Jones RI 2016. Accounting for littoral primary production by periphyton shifts a highly humic boreal lake towards net autotrophy. *Freshwater Biology* **61**(3): 265–276.

Vineis P, Chan Q and Khan A 2011. Climate change impacts on water salinity and health. *Journal of Epidemiology and Global Health* **1**(1): 5–10.

Wetzel RG and Likens GE 2000. Limnological Analysis, 3rd edn, Springer, New York, USA, p429.

Xu X, Xu H, Wang Y, Wang X, Qiu Y and Xu B 2008. The effect of salt stress on the chlorophyll level of the main sand-binding plants in the shelterbelt along the tarim desert highway. *Chinese Science Bulletin* **53**(2): 109–111.

Zhou W, Gao J, Liao J, Shi R, Li T, Guo Y and Long A 2016. Characteristics of Phytoplankton Biomass, Primary Production and Community Structure in The Modaomen Channel, Pearl River Estuary, With Special Reference to The Influence of Saltwater Intrusion During Neap and Spring Tides. *PLoS One* **11**(12). https://doi.org/10.1371/journal.pone.0167630

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Estimation of Reference Evapotranspiration using Cropwat- 8 Model In Semi-Arid Region

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Abstract: Accurate estimation of crop reference evapotranspiration (ETo) in semi arid region is essential for better irrigation management and irrigation scheduling of crops. The main objective of this study is to estimates the crop reference evapotranspiration (ET_0) using climatic parameters. The FAO Penman-Monteith method is regarded as a standard and reliable technique to estimate ET_0 and to evaluate other empirical methods. The ET_0 of Rangareddy district of Telangana state was estimated using the CROPWAT-8.0 model. CROPWAT-8 model indicated the total reference evapotranspiration estimated to be 1879.3 mm year^{-1}. The average annual ET_0 in Rangareddy region is 5.15 mm day^{-1}. The highest monthly ET_0 value of 8.09 mm day^{-1} was observed in May due to a higher temperature and sunshine hour. The lowest monthly ET_0 value of 3.26 mm day^{-1} was observed in December due to a lower temperature and sunshine hour.

***Keywords*:** Reference evapotranspiration, CROPWAT, Penman–montieth method

Water becomes increasingly scarce throughout the last three decades in many countries especially in India (IWMI). The rate of evapotranspiration from the reference surface is known as the reference evapotranspiration (ET_0) (Allen et al 1994).For better irrigation management and irrigation scheduling of crops, estimation of crop reference evapotranspiration (ET_0) is essential (Kumari and Srivastava 2018). The ET_0 is independent on crop type, development and cultural practices. The main components influencing ET_0 are climatic parameters including precipitation, maximum and minimum temperature, air humidity, wind speed and sunshine hour (Trivedi et al 2018). Estimated values of reference evapotranspiration (ET_0) are multiply with crop coefficients (K_c) to get actual crop evapotranspiration rate this can be used for many aspects of irrigation and water resources planning and management(Hargreaves 1994).

There are various methods are available to compute the $ET_{0.}$ The FAO Penman-Monteith method is regarded as a standard and reliable technique to estimate ET_0 and to evaluate other empirical methods (Arunadevi et al 2017, Patel et al 2017). It is impracticle to use this method on field level due to its complex behaviour (Gundekar et al 2008, Dumka et al 2018). Therefore, a lot of research has been attempted to assess a sort of reference evapotranspiration from meteorological information and convert this to the actual evapotranspiration (Hargreaves 1994). The CROPWAT model is one of the indirect techniques developed by the FAO Land and water development division, uses meteorological data like rainfall, temperature, relative humidity, sunlight, wind velocity for estimating reference evapotranspiration (ET_0) (Clarke et al 1998). The CROPWAT-8 model generated data is used for predicting net irrigation demand and irrigation scheduling of various crops of the region (Smith and Kivumbi 2002). The specific objective of this study is to estimate the ET_0 of Rangareddy district of Telangana state using climatic data for the period of 1997 to 2014 with CROPWAT-8 model.

MATERIAL AND METHODS

Study area: The study area was Rangareddy district lies between 16°19' and 18°20' Northern latitude and 77°30' and 79°30' Eastern longitude. It was bounded by Medak district on the North, Mahaboobnagar on the South and Nalgonda on the East and Gulbarga district of Karnataka on the West and Bidar district of Karnataka on the Northwest respectively (Fig. 1) with a total geographical area of 7.56 lakh ha. The mean annual rainfall of Rangareddy district is about 573 mm. The area receives most of the precipitation from the southwest monsoon (Purushotham et al 2011). In Rangareddy district the average air temperature was 26.0 ºC, whereas the maximum air temperature was45.9 ºC and the minimum air temperature was 23.5 ºC. The average relative humidity was between 70 and 80 per cent. The average wind speed was equal to10.3 km hr^{-1} while the annual precipitation ranges from 541-1053 mm.

Methodology: The methodology consisted of data collection, estimation of reference evapotranspiration. The weather data of the Rangareddy district was collected from

from regional meteorological station. The weather parameters e collected for the period 1997-2014 on a monthly basis were air temperature and humidity, wind speed, solar radiation and precipitation. These data were used for the calculation of reference evapotranspiration by CROPWAT 8.0 model (Penman-Monteith equation).

CROPWAT Model: The CROPWAT-8 is a computer program developed by the FAO Land and water development division(FAO 1992and uses the FAO (1992) Penman-Monteith formulation for estimating reference evapotranspiration (ET_0) (Clarke et al 1998). The CROPWAT-8 model generated data is used for predicting net irrigation demand and irrigation scheduling of various crops of the region. The procedure for the estimation of the crop water requirement (CWR) and water resource management needs this model depended on estimation of the potential evapotranspiration (ET_0) utilizing the Penman-Fortieth condition, and the crop parameters (Mehdi and Vienna 2015). The equation utilizes standard 17 years of climatological records of air temperature and humidity, wind speed, solar radiation and precipitation for the estimation of current ET_0. Not with standing atmosphere records, the equation requires the site area, for example, such as altitude above sea level (m) and latitude (degrees north or south). The monthly average value of maximum temperature, minimum temperature, precipitation, sunshine hour and the estimated air humidity were used as input to CROPWAT. The CROPWAT-8 model uses the Penman-Monteith equation for estimation of reference crop evapotranspiration (ET_0) as follows (FAO 1992):

$$ET_O = \frac{0.404\Delta\left(R_n - G\right) + \gamma \dfrac{900}{T+273} u_2\left(e_s - e_a\right)}{\Delta + \gamma\left(10.34 + u_2\right)} \quad \text{..............(1)}$$

Fig. 1. Location map of Rangareddy district, Telangana state

where, ET_0 is reference evapotranspiration (mm day^{-1}), Rn is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m-^{2}day^{-1}), T is mean daily air temperature at 2 m height (°C), u_2 is wind speed at 2 m height (m s-^{1}), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), e_s-e_a is saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve (kPa °C^{-1}) and γ is psychrometric constant (kPa °C^{-1}).

ET_0Calculation methodology using CROPWAT-8 model

ET_0/ Climate data input and output: The climate module was selected by clicking on the “Climate / ET_0” icon in the module bar located on the left of the main CROPWAT window. The data window opens with the default data type (monthly / decade / daily values); it was possible to quickly change to another data type by using the dropdown menu from the “New” button on the toolbar. The module was primary for data input, requiring information on the meteorological station together with climatic data.

ET_0/ Climate data saving: After checking the data for possible errors, climate/ ET_0 data was saved by selecting the “Save” button on the toolbar or the “File” > “Save” menu item. It was required to give an appropriate name to the data set

Table 1. Reference evapotranspiration of the Rangareddy district

Month	Min temperature (°C)	Max temperature (°C)	RH (%)	Wind speed (km day^{-1})	Sunshine hours	ET_O (mm day^{-1})
January	18	31	45	144	10.1	4.51
February	19	31	43	144	10.2	5.00
March	22	36	27	168	9.4	6.45
April	25	38	34	144	9.6	6.62
May	28	41	26	192	9.1	8.09
June	23	32	60	312	7.0	6.27
July	22	29	72	336	3.6	4.46
August	23	29	72	288	4.5	4.40
September	23	31	66	168	5.8	4.51
October	22	30	66	168	7.3	4.44
November	18	29	57	96	8.6	3.78
December	15	28	51	72	9.5	3.26
Average (mm-day^{-1})					5.15	

which can easily be recognized later. In this study, the name Rangareddy, referring to the climate station of plain region from which data has been taken, were used. The CROPWAT estimation window is shown in Fig. 2.

RESULTS AND DISCUSSION

The total reference evapotranspiration estimated to be 1879.3mm year^{-1}. The estimated ET_0 values varies from 3.26–8.09 mm day^{-1}. The average annual ET_0 in Rangareddy region is 5.15 mm day^{-1}. The highest monthly ET_0 value of 8.09 mm day^{-1} was observed in May due to a higher temperature and sunshine hour. The lowest monthly ET_0 value of 3.26 mm day^{-1} was observed in December due to a lower temperature and sunshine hour. The highest monthly ET_0 value of 8.09 mm day^{-1} was observed in May due to a higher temperature and sunshine hour followed by 6.62 mm day^{-1} and 6.45 mm day^{-1} in April and March respectively (Fig. 3). Similarly, the lowest monthly ET_0 value of 3.26 mm day^{-1} was observed in December due to a lower temperature and sunshine hour followed by 3.78 and 4.4 mm day^{-1} in the month of November and August respectively.

The Figure 4 graphically represents monthly ET_0 with combined effect of climatic parameters, such as max and min

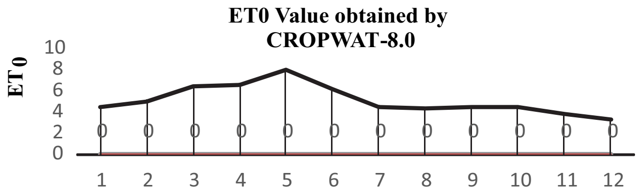

Fig. 3. ET_0 value obtained by using CROPWAT-8.0

Monthly ETo Penman-Monteith - C:\ProgramData\CROPWAT\data\climate\ET0.PEM

Country: INDIA   Station: HYDERABAD
Altitude: 542 m.   Latitude: 17.37 °N   Longitude: 78.48 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	18.0	31.0	45	144	10.1	20.0	4.51
February	19.0	31.0	43	144	10.2	22.0	5.00
March	22.0	36.0	27	168	9.4	22.8	6.45
April	25.0	38.0	34	144	9.6	24.2	6.62
May	28.0	41.0	26	192	9.1	23.5	8.09
June	23.0	32.0	60	312	7.0	20.2	6.27
July	22.0	29.0	72	336	3.6	15.1	4.46
August	22.0	29.0	72	288	4.5	16.3	4.40
September	23.0	31.0	66	168	5.8	17.7	4.51
October	22.0	30.0	66	168	7.3	18.4	4.44
November	18.0	29.0	57	96	8.6	18.4	3.78
December	15.0	28.0	51	72	9.5	18.6	3.26
Average	21.4	32.1	52	186	7.9	19.8	5.15

Fig. 2. CROPWAT-8.0 window

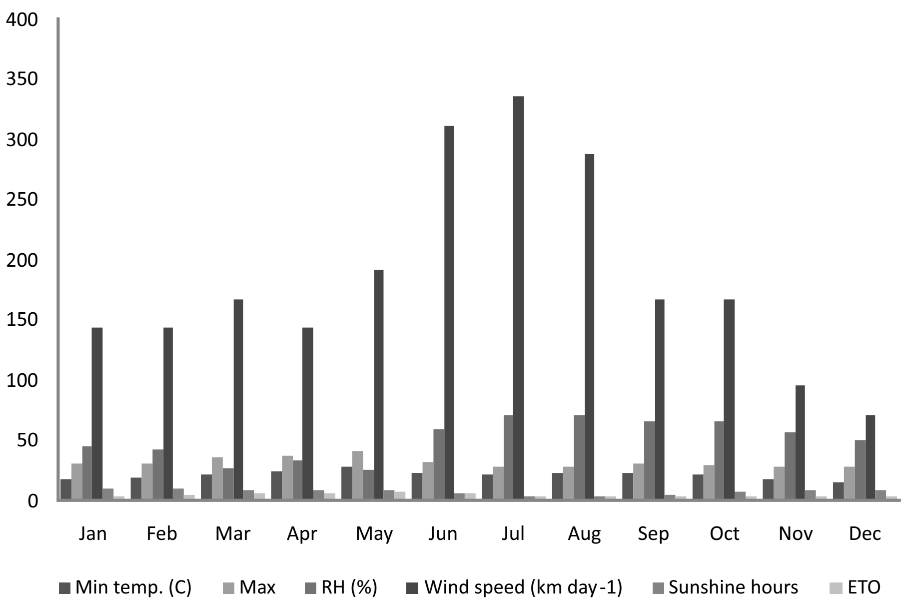

Fig. 4. All climate parameters have combined effect on ET_0

temperature, wind speed, relative humidity and sunshine hour.

CONCLUSION

The average annual ET_0 in Rangareddy region is estimated as 5.15 mm day^{-1}. The highest monthly ET_0 was 8.09 mm day^{-1} in May due to a higher temperature and sunshine hour. The lowest monthly ET_0 value of 3.26 mm day^{-1} was in December due to a lower temperature and sunshine hour. The research validates the usefulness of the CROPWAT-8 model for estimation of Reference crop Evapotranspiration (ET_0) with utilizing available climatic data. The CROPWAT-8 computer program is the best alternative to FAO Penman-Monteith method for estimation of Reference crop Evapotranspiration (ET_0). The estimated reference crop evapotranspiration (ET_0) values are used with crop coefficients for irrigation and water resources planning and management.

REFERENCES

Allen RG, Smith M, Perrier A and Pereira LS 1994. An update for the definition of reference evapotranspiration. *ICID bulletin* **43**(2): 1-34.

Arunadevi K, Ramachandran J, Vignesh S, Visuvanathakumar S and Anupriyanka S 2017. Comparison of reference evapotranspiration in semi-arid region. *International Journal of Agricultural Sciences* **9**(52): 4886–4888.

Clarke D, Smith M and El-Askari K 1998. Crop Wat for Windows Version 4.2.0013: User Guide.

Doria R, Madramootoo CA and Mehdi BB 2006. Estimation of future crop water requirements for 2020 and 2050, using CROPWAT. In *2006 IEEE EIC Climate Change Conference* 1-6.

Dumka BB, Kashyap PS and Saran B 2018. Modelling for reference evapotranspiration of Pantnagar using various training functions in artificial neural network. *Indian Journal of Ecology* **45**(1): 19-24.

Gundekar HG, Khodke UM, Sarkar S and Rai RK 2008. Evaluation of pan coefficient for reference crop evapotranspiration for semi-arid region. *Irrigation Science* **26**(2): 169-175.

Hargreaves GH 1994. Defining and using reference evapotranspiration. *Journal of Irrigation and Drainage Engineering* **120**(6): 1132-1139.

Kumari N and Srivastava A 2018. Harmonization and comparative evaluation of evapotranspiration estimates in data scarce conditions. *Indian Journal of Ecology* **45**(2): 305-310.

Patel A, Sharda R, Patel S and Meena P 2017. Reference evapotranspiration estimation using cropwat model at ludhiana district (Punjab). *International Journal of Science, Environment and Technology* **6**(1): 620-629.

Purushotham D, Rao AN, Prakash MR, Ahmed S and Babu GA 2011. Environmental impact on groundwater of Maheshwaram watershed, Ranga Reddy district, Andhra Pradesh. *Journal of the Geological Society of India* **77**(6): 539-548.

Smith M, Kivumbi D and Heng LK 2002. Use of the FAO CROPWAT model in deficit irrigation studies. In *Deficit Irrigation Practices*.17–27.

Surendran U, Sushanth CM, Mammen and Joseph EJ 2015. Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: A case study in Palakkad District of Humid Tropical Kerala, India. *Aquatic Procedia* **4:** 1211-1219.

Trivedi A, Pyasi SK and Galkate RV 2018. Estimation of EVAPOTRANSPIRATION using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh**.** *International Journal of Current Microbiology and Applied Sciences* **7**(5): 1248–1259

Vakulabharanam V 2004. Agricultural growth and irrigation in Telangana: A review of evidence. *Economic and Political Weekly*, 1421-1426.

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Public Perception on Climate Change and Its Impacts on Various Aspects: A Case Study of Great Himalayan National Park (India)

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Abstract: The present study aimed to access the local people's perception of climate change, impact of climate change on the plant diversity, livelihood of the local communities in Sainj and Tirthan valley of Great Himalayan National Park (GHNP), India. A total of 241 households were selected randomly for interview by means of structured questionnaire. Most of respondents of both valleys have perceived that climate change is occurring. Major changes were observed were change in temperature (97.5%, 99%), snowfall pattern (100%, 98.3%), rainfall pattern (96.7%, 97.5%) in Sainj and Tirthan valleys, respectively. The respondents of both valleys have reported hampered agriculture production due to changing climate that lead majority of people to change their land use strategies from agriculture to horticulture and from traditional crops to cash crops. Decrease in plant species like *Cedrus deodara* (59.5%), *Pinus wallichiana* (43.8%), *Abies pindrow* (20.66%), *Picea smithiana* (16.53%), Apple (7.44%), *Taxus baccata* (4.96%), *Morchella esculenta* (14.87%) have been observed by local people and the main reasons behind the reduction of these species were over exploitation, deforestation, forest fires and climatic variability according to the inhabitant of the study area. The results of present study provide a robust tool in identifying the impacts of climate change on biodiversity and the livelihood of the local communities and has wider application in designing the appropriate management strategies for mitigating the impacts of climate change on natural resources.
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***Keywords*:** Climate change, GHNP, Perception, Biodiversity, Adaptation

Global climate change is one of the serious threat effecting biodiversity and human health worldwide (Houet et al 2010, Barimah et al 2015, Negi et al 2017 and Pichura et al 2019). Several scientific studies have reported the impact of climate change on different mountainous ecosystems especially the Himalayas (IPCC 2007, Singh et al 2010). This in turn poses a serious threat to the indigenous people that are directly or indirectly dependent on the ecosystem services and functioning of these prestine ecosystems (Houet et al 2010, Singh et al 2010, Chaudhary and Bawa 2011, Schilling et al 2012 and Negi et al 2017). Further, it has also been reported that the rise in temperature will be more in mountainous areas than other ecosystems and there will also be a shift in the monsoon precipitation regimes due to climate change (Regmi et al 2009, Shrestha and Aryal 2011). These changes will pose an additional threat to the livelihood of several people in mountainous region as agriculture is extremely dependent on seasonal rain in these areas (Maikhuri et al 2001). Among these mountainous ecosystems, Great Himalayan National Park (GHNP), an ecologically fragile and bio diverse region harbouring many of the endemic and medicinally important plant species in Indian subcontinent (Nandy et al 2015) is also vulnerable to the recently happening climate change. The UNESCO's has designated it as one of the important World Heritage Site as well as integral part of Himalayan biodiversity hotspot. GHNP is an ecologically important zone for evaluating the impacts of climate change as it comprises an elevation gradient ranging riverine forests (1500m) up to the alpine vegetation (6000m). In addition, as the indigenous community's livelihood depends mainly upon agriculture, livestock, horticulture and minor forest products, these in turn are closely interdependent on GHNP resources (Nagia and Kumar 2001, Nandy et al 2015). Thus, any impact of climate variability such as, change in temperature or precipitation regimes will affect the local people's livelihood in a plethora of ways. Therefore understanding that how much the local communities of GHNP are aware about the ongoing climate change and its ill impacts on the natural resources assumes utmost research priority. This in turn will pave way to devise scientific management strategies to mitigate the climate change (Becker et al 2012, Manandhar et al 2013, Lebel 2013, Negi et al 2017). In this context that the present study aimed to address indigenous people's perceptions to climate change and how climate variability is impacting the livelihood of indigenous communities and the land use/land cover of the study region?

MATERIAL AND METHODS

Study area: The study was carried in the Sainj and Tirthan valley (Fig. 1) of Eco-development zone of GHNP (31° 38' 28" to N 31°51'58" and 77° 20' 11" E to 77° 45' 52" E). GHNP is located in Kullu district of Himachal Pradesh which represents an important conservation area of western Himalaya. GHNP is biodiversity hotspot harbouring many endemic species of plants and animals (Ramesh et al 1998, Vinod and Sathyakumar 1999). GHNP is among Global 200 critical ecosystems list of The World Wide Fund for Nature (https://www.greathimalayannationalpark. org/about-us/park-introduction/). The Great Himalayan National Park Conservation Area comprises of Sainj Wildlife Sanctuary, Tirthan Wildlife Sanctuary, Eco-development zone and core area of Great Himalayan National Park. Park and Eco development zone have huge variation in altitude that allows a large number of species i.e. floral as well as faunal species to sustain in this area. GHNP faces diverse seasons: winter, spring, summer/rainy, autumn. It receives a maximum annual rainfall of about 1298 mm. The temperature varies from -10°C to 40°C in months of January to June respectively.

Development of questionnaire: Literature was reviewed to develop questionnaire on public perception on climate change. Questions in the questionnaire were binary type, with three options, open ended and some were also descriptive in nature in order to gain more and more information from the respondents.

Data collection: Both qualitative and quantitative methods were used for collection of data in May-June of 2017 and 2018. In order to gather information on local people's perception, knowledge and experience a combination of participatory methods were used which includes structured interviews (n=241) and focussed group discussions (FGD) in Sainj and Tirthan valley of GHNP. In-depth interviews were used to collect information related to climate change as well as its impact on different aspects of community resources. Each interview took about 30 to 45 minute time. There were different sections in questionnaire like demographic characteristics, general awareness about climate change, awareness of climate change impacts on livelihood as well as plant diversity and traditional adaptive measures. Interviews were conducted based on random sampling in the study area among the respondents possessing different occupations like farmers, employee, students, and businessmen. Demographic profile is given in (Table 1).

Data analysis; Data was analysed with the help of Statistical Package for Social Sciences (SPSS) version 20. Characteristics of population i.e. demographic variables and responses of participants were presented in the form of frequency tables. Cross tabulation and chi-square tests were used to test the statistical significance of the relationship between different demographic variables and public perception about climate change.

Ethical approval: The present study was approved by Committee for Advanced Studies and Research (CASR-SESD), Central University of Gujarat. Permission was also granted from Forest Department, Kullu to do sampling in buffer zone of GHNP and from local people including Pradhan of respective Gram Panchayats before interview or filling questionnaires.

Table 1. Demographic statistics of study area

Variable	Sainj Valley		Tirthan Valley	
Gender	Frequency	%	Frequency	%
Male	70	57.38	84	70.6
Female	52	42.62	35	29.4
Marital status				
Married	114	93.4	96	80.7
Unmarried	8	6.6	23	19.3
Age group				
14-24	12	9.8	25	21.0
25-34	28	23.0	29	24.4
35-44	16	13.1	30	25.2
45-54	18	14.8	21	17.6
55-64	24	19.7	8	6.7
>65	24	19.7	6	5.0
Age(Mean$\pm$SD)	46.48$\pm$17.6		37.54$\pm$14.2	
Education level				
Illiterate	37	30.3	22	18.5
Primary	25	20.5	16	13.4
Secondary	33	27	26	21.8
Higher secondary	26	21.3	53	44.5
Higher education	1	0.8	1	0.8
Technical	0	0	1	0.8
Occupation				
Agriculture	42	34.4	56	47.1
Agriculture and livestock rearing	61	50.0	20	16.8
Student	5	4.1	18	15.1
Employee	2	1.6	1	0.8
Agri+Livestock+Employee*	10	8.2	9	7.6
Agriculture and home stay	1	0.8	1	0.8
Others	1	0.8	14	11.8

*Agri+Livestock+Employee referred here include the employees of various sectors i.e. teacher, forest guards, security guard, BTCA NGO member, electrician, etc. that are having agriculture and livestock too

RESULTS AND DISCUSSION

Knowledge about Climate Change

Perception on climate change in general: The about 85 (69.7%) of respondents in the Sainj valley and 95 (79.8%) in the Tirthan valley were aware of the ongoing climate change in the region. In both valleys, although people stated that they

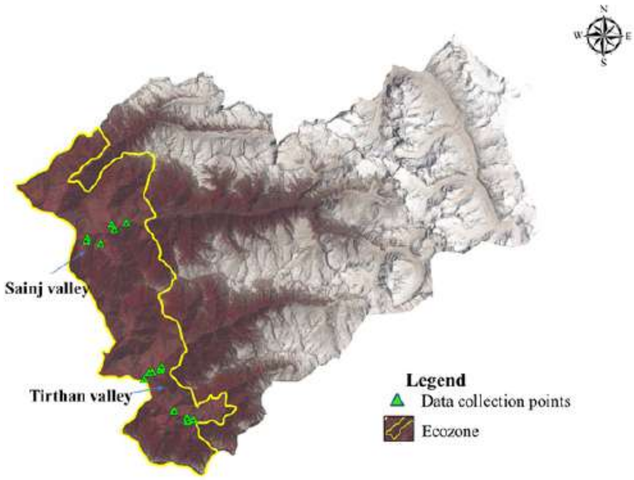

Fig. 1. Data collection points in Ecozone of GHNP

are aware of climate change but most of the respondents (75.4% in Sainj & 70.6% in Tirthan) were unable to describe the climate change. Most of respondents describe it "as change in rainfall and temperature pattern and warming of environment" and some respondents even describe it as "change in climatic conditions due to human activities and pollution". About 85 (69.7%) respondent in Sainj valley and 91(76.6%) in Tirthan valley stated that climate change is occurring (Table 2).

Most of the respondents stated that climate change is occurring and there is significant difference in perception on the basis of type of work where the respondents are engaged (X^2= 65.99, p=0.001) followed by education level (X^2= 33.72, p=0.004) and gender (X^2= 12.84, p=0.005). This may be attributed owing to difference in their occupation and experience of the changes at different time being observed by them. Those who are engaged in agriculture may observe the changes more than the other respondents. The farmers can face various consequences of climate change directly on their crops such as phonological changes, crop yield, pest attacks on crops due to change in climatic variables. In GHNP, the significant difference in perception about climate change occurrence on the basis of gender prevails that may be due to the fact that most of male respondents are engaged in agriculture practices. The respondents who have completed higher secondary education level are more aware of climate change and its occurrence. There is no significant difference in perception on the basis of age group of the respondents (Table 3).

Response on cause of climate change: Most of respondents in both valleys believe deforestation as the main cause of climate change followed by overpopulation, industrialization and urbanization as presented in Figure 2. This result is in agreement with several other research studies that have reported deforestation as the major contributing factor behind climate change (Singh 2011, Ahsan and Brandt 2015, Sen et al 2015).

Perception on indicators of climate change: In both valleys people observed change in snowfall pattern as major indicator of climate change followed by temperature, rainfall pattern whereas drought was the least observed indicator in both valleys (Fig. 3). Maximum respondents have perceived change in snowfall pattern or decrease in snowfall in GHNP. The results of present work were supported by the studies on western Himalaya and Bhutan (Shekhar et al 2010, Tewari et al 2017, Suberi et al 2018). The study conducted by Sen et al 2015 have also reported decrease in snowfall in the Kullu valley (Sen et al 2015), whereas study by Vishvakarma et al (2003) reported a 7 cm decrease in rainfall, 12 cm decrease in snowfall and increased mean temperature in Kullu valley.

Table 2. Statistics of perception on occurrence of climate change

Is climate change occurring?	Sainj valley		Tirthan valley	
Response	Frequency	%	Frequency	%
Occurring	85	69.7	91	76.5
Probably occurring	34	27.9	21	17.6
Probably not occurring	1	0.8	2	1.7
Don't Know	2	1.6	5	4.2

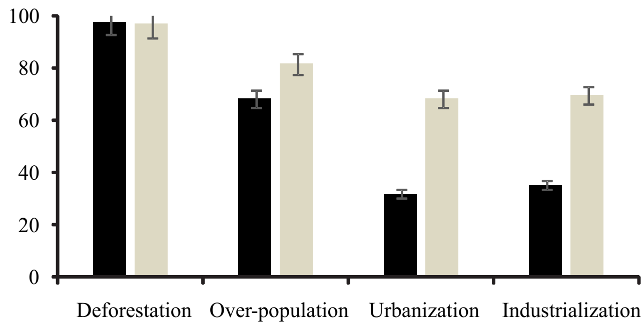

Fig. 2. Response on causes of climate change

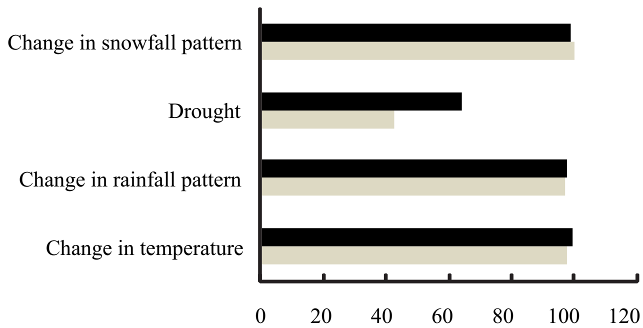

Fig. 3. Perception on indicators of climate change

Residents of GHNP have also reported an increase in drought that is well supported by report of the FAO (FAO 2018) in which prolonged droughts has been reported over many countries like Somalia, Southern Africa, Dry corridor of Central America and India during the period of 2011-2016.

People's perception on climate variability in GHNP: Regarding the effect of climate change on GHNP area, about 75.4 per cent and 94.1 per cent respondents from Sainj and Tirthan area confirmed that climate change is affecting GHNP (Table 4). The difference in observation of respondents from different valley may be due to their education, personal experience based on exposure time to natural environment that may be due to type of work the respondents are engaged as people who are engaged in agriculture or horticulture can observe more changes than any office employee. Significant relation was found in occupation of respondents and there perception of climate change (Table 3).

Perception about environmental effects in GHNP due to climate change: The decrease in snowfall, irregular rainfall,

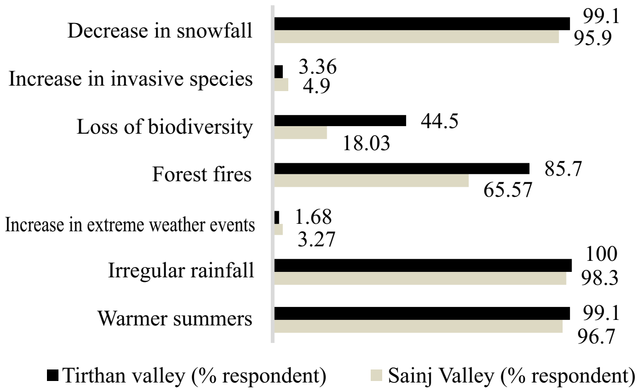

Fig. 4. Environmental effects of climate change on GHNP

Table 3. Association between demographic variables of both valleys and perception about occurrence of climate change

Variables	Is climate change occurring?					
Gender	Occurring	Probably occurring	Probably not occurring	Don't Know	Total	Statistics
Male	122	27	0	4	153	$X^2 = 12.836$ p = 0.005
Female	54	28	3	3	88	
Age-group						
14-24	30	7	0	0	37	$X^2 = 195.007$ p = 0.258
25-34	47	10	0	0	57	
35-44	33	8	2	3	46	
45-54	24	12	1	2	39	
55-64	20	12	0	0	32	
≥65	22	6	0	2	30	
Education						
Illiterate	32	22	1	4	59	$X^2=33.722$ p = 0.004
Primary	23	14	2	2	41	
Secondary	49	9	0	1	59	
Higher secondary	69	10	0	0	79	
Higher education	2	0	0	0	2	
Technical	1	0	0	0	1	
Occupation						
Agriculture	76	20	0	2	98	$X^2= 65.992$ p < 0.001
Agriculture and livestock rearing	47	28	2	4	81	
Student	18	5	0	0	23	
Employee	3	0	0	0	3	
Agri+Livestock+Employee*	18	1	0	0	19	
Agriculture and home stay	2	0	0	1	3	
Others	12	1	1	0	14	

*Agri+Livestock+Employee referred here include the employees of various sectors i.e. teacher, forest guards, security guard, BTCA NGO member, electrician, etc. that are having agriculture and livestock too and warmer summers are the main effects of climate change followed by forest fires. Loss of biodiversity followed by increase in invasive species and increase in extreme weather events (Fig. 4) are also important effects of concern in protected area as these can cause deterioration of biodiversity. Tirthan valley people reported biodiversity loss more than Sainj valley and this may be due to the difference in exposure to different landscapes by people. Tirthan valley people reported decrease in number of wild animals and plants due to anthropogenic activities like poaching.

Majority of people have perceived that climate change is a consequence of rise in temperature in summer season and irregular rainfall patterns. Studies have reported increased temperature, variable rainfall regimes (Sen et al 2015) and increased frequency of extreme weather events such as droughts in South Asia (Singh et al 2008; Lasco et al 2016). Khan and Arya (2017) also reported frequent droughts, increase in invasive species, increasing temperature and irregular rainfall in Almora, Kumaun part of the Himalayan region which also supports observation of present study. Shrestha et al (1999) have reported increase in temperature of higher altitudes than in low lying areas. An increase of 0.16°C per decade in the north-western Indian Himalayan region have been reported by Bhutiyani et al (2007) during the past century. Respondents of both valleys have observed increased incidence of forest fires and invasive species in GHNP. As per the study conducted by Bhatta (2007), about 8195 hectares of forest area has been lost in state of Himachal Pradesh.

Perception on climate change occurrence time period in GHNP: Most of the respondents in Tirthan valley perceived climate change since a period of 5 years, while 10 years in case of Sainj valley (Fig. 5) and these respondents mostly belonged to young age group (18-25 years). The old aged people observed climate change from more than 25 years but they stated that since 5 years this change in climatic pattern is intensifying. And this may be the reason that younger age group were reporting the intensified change time period.

Perception about effects of climate change at household level: People observed that the climate change has hampered agriculture production mostly followed by loss of house/garden, loss of income, health problems, loss of domestic animals and lack of safe drinking water (Fig. 6).

Changes in flowering, bearing and fruit yield of many plants specially apple, decrease in apple yield (chilling period affected and gap of 2-3 years in fruiting) due to decrease in snowfall, crop yield decreased, change in land use from traditional crops to cash crops, agriculture to horticulture. Cropping pattern and crop harvesting affected due to

Table 4. Perception on climate variability in GHNP

Is climate change affecting GHNP?	Sainj valley		Tirthan valley	
Responses	Frequency	%	Frequency	%
Yes	92	75.4	112	94.1
Don't Know	5	4.1	2	1.7
Undecided	25	20.5	5	4.2
Total	122	100	119	100

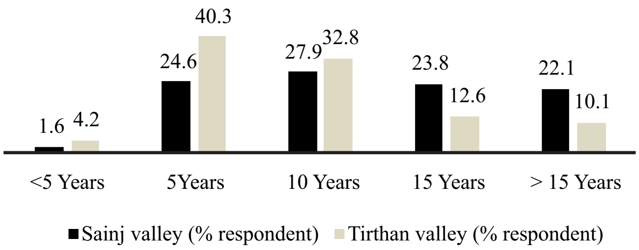

Fig. 5. People's perception on time period of climate change occurrence in GHNP

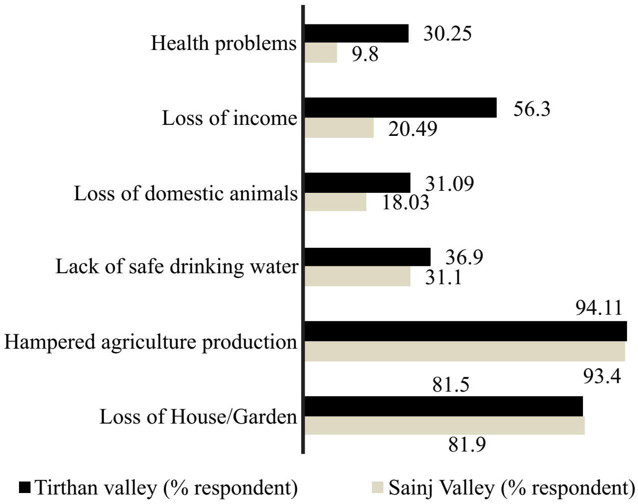

Fig. 6. Effects of climate change at household level

irregular rain, increase in invasive plants such as *Lantana camara*, *Solanum nigrum*, *Parthenium hysterophorus, Eucalyptus* etc., delayed sowing of crops (*Triticum aestivum*) and increase in pest which resulted in increase in number of sprays of pesticides. (These observations were not part of questionnaire but were general statements based on FGD). In the present study, major effect of climate change was reported on hampered agriculture production and increased incidents of pest attacks on plants in the GHNP area. Our study is well supported by several other studies that have reported a negative impact of rising temperature on major crop yields as well as increased pest attacks (Lasco et al 2016, FAO 2018). Further, an increase in the invasive species such as *Lantana* and *Parthenium*s pp. have been reported by Negi et al (2012).

Change in landuse/landcover (LULC) of GHNP: Maximum people of GHNP have observed change in landuse and land cover pattern of GHNP. About 90.2 per cent of the respondents have stated that there is change in LULC, 9 per cent respondent have not observed LULC change and 0.8 per cent people were ignorant about the change in Sainj valley, where as in case of Tirthan valley about 84.9 per cent of respondents observed change in LULC and 15.1 per cent of the respondents have not observed such change. In Sainj valley, the respondents observed major changes i.e. agriculture to horticulture (41.8%) followed by dense forests to sparse forests (6.6%), traditional crops to cash crops (4.1%), increase in roads and settlement area near roads (1.6%). About 11.5 per cent of the respondents were not able to describe the changes observed in the area. In Tirthan valley, the respondents observed change in LULC such as; agriculture to horticulture (26.1%) agriculture to barren land (5.9%), dense forests to sparse forests (6.7%), traditional crops to cash crops (2.5%). The main cause for shifting from agriculture to horticulture and traditional crops to cash crops was to get financial profit as well as the effect of climate variation. The difference in both valleys may be due to the fact that people of Tirthan valley rely more on alternate source of income such as tourist guide, home stays and business.

Changes observed in plant biodiversity by local inhabitants: About 65.1 per cent respondents from both valleys were of the opinion that some plant species are reducing their extent of occurrence in the GHNP area, 34.4 per cent respondents stated that plant species are not disappearing, while 0.4 per cent of the respondents stated that they don't have any idea about it. According to local people's observation these plants are reducing the area; *Cedrus deodara* (59.5%), *Pinus wallichiana* (43.8%), *Abies pindrow* (20.66%), *Picea smithiana* (16.53%), Apple (7.44%), *Taxus baccata* (4.96%), *Morchella esculenta* (14.87%), *Trillidium govanianum* (5.78%), *Quercus semecarpifolia* (2.48%) etc. (Singh et al 2010; Negi et al 2012). Main causes behind the reduction of these species were over exploitation, deforestation, forest fires and climatic variability according to the inhabitant of the study area. Studies by Chaturvedi et al (2011) and Gopalakrishnan et al (2011) have also reported the impact of climate change on forest ecosystems in India.

Perception about mitigation of climate change: In Sainj valley, about 18 per cent of the respondent stated that climate change can be mitigated, 36.1 per cent respondent said that climate change cannot be mitigated, and 45.9 per cent of the respondents were not aware about it. On the other hand in Tirthan valley 47.1 per cent respondent stated climate change can be mitigated, 26.1 per cent stated it cannot be mitigated and 26.9 per cent people were not aware about it. The difference in opinion of both valleys may be attributed to comparatively greater awareness among Tirthan valley people due to greater literacy in Tirthan in comparison to Sainj valley. Owing to their greater awareness, people of Tirthan valley believe in reducing the impact of climate change by measures such as afforestation and protecting natural resources. Similar results were observed in the study by Toan et al (2014).

Remedial measures suggested by local people to mitigate the impact of climate change: Majority of the respondents from Sainj valley stated that there should be community based programme (41%) in order to fight the effects at local scale, 8.2 per cent people stated that Government agencies should make some safety programmes and make people aware at village level, 6.6 per cent suggested that there should be NGOs for awareness and implementation at regional scale. Also in the Tirthan valley also, majority of respondents suggested that government should implement safety, awareness and community based programme (27.7%), 25.3 per cent suggested only community programmes, 12.6 per cent suggested only government programmes, 5.9 per cent suggested NGOs should be involved and 15.2 per cent people suggested different measures like there should be village level awareness, remove plastic waste in the area. On the basis of recorded data the main remedial measure would be education for the awareness of the local people and their active participation in programmes to mitigate the impact of climate change.

CONCLUSION

The large number of respondents perceived that climate change is occurring with warmer summers, decreased snowfall and irregular rainfall in GHNP. Moreover, the local knowledge and perception in this study is consistent with scientific observations. As expected, the respondents with educated background were having more understanding about climate change. Climate change has huge impact on the GHNP by affecting biodiversity, health of the indigenous people, as well as their means of livelihood especially agriculture and horticulture. Hopefully, the results of the present study will prove as a robust tool to understand the climate change and its consequences on the natural resources of GHNP. This study will be helpful in designing appropriate conservation strategies for GHNP in particular and other Indian Himalayan states in general.

REFERENCES

Ahsan D and Brandt US 2015. Climate change and coastal aquaculture farmers' risk perceptions: Experiences from Bangladesh and Denmark. *Journal of Environmental Planning and Management* **58**(9): 1649-1665.

Barimah PT, Kwadwo SO and David O 2015. Assessment of people's knowledge and perception of climate change: A case study of Asunafo North District, Ghana. *International Journal of Innovative Research in Science, Engineering and Technology* **4**(1): 18417-8424.

Becker A, Inoue S, Fischer M and Schwegler B 2012. Climate change impacts on international seaports: Knowledge, perceptions, and planning efforts among port administrators. *Climate Change* **110**: 5-29.

Berkes F and Jolly D 2002. Adapting to climate change: social ecological resilience in a Canadian western Arctic community. *Conservation Ecology* **5**(2): 18.

Bhagat S, Krishna RT, Gurung DB, Roshan MB and Bishal KS 2018. People's perception of climate change impacts and their adaptation practices in Khotokha valley, Wangdue, Bhutan. *Indian Journal of Traditional Knowledge* **17**(1): 97-105.

Bhatta A 2007. Himachal villagers resist pine monoculture, reclaim forests for fodder. *Down to Earth* **16**: 6.

Bhutiyani MR, Kale VS and Pawar NJ 2007. Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century.*Climatic Change* **85**: 159-177.

Brace C and Geoghegan H 2011. Human geographies of climate change: Landscape, temporality, and lay knowledge. *Progress in Human Geography* **35**: 284-302.

Brody SD, Zahran S, Vedlitz A and Grover H 2008. Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States. *Environment and Behaviour* **40**: 72-95.

Byg A and Salick J 2009. Local perspectives on a global phenomenon-climate change in eastern Tibetan villages. *Global Environmental Change* **19**: 156-166.

Chaturvedi RK, Ranjith G and Jayaraman M 2011. Impact of climate change on Indian forests: a dynamic vegetation modelling approach. *Mitigation and Adaptation Strategies for Global Change* **16**(2): 119-142.

Chaudhary P and Bawa KS 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters* **7**: 767-770.

Dang HL, Li E, Nuberg I and Bruwer J 2014. Understanding farmer's adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science & Policy* **41**: 11-22.

FAO report on "The state of food security and nutrition in the world 2018". 2018. http://www.fao.org/3/I9553EN/i9553en.pdf. Accessed 11 March 2019.

Ford JD, Vanderbilt W and Berrang-Ford L 2012. Authorship in IPCC AR5 and its implications for content: climate change and Indigenous populations in WGII. *Climate Change* **113**(2): 201-213.

Gopalakrishnan R, Jayaraman M, Govindasamy B and Ravindranath NH 2011. Climate change and Indian forests.*Current Science* **101**(3): 348-355.

Houet T, Loveland TR, Hubert-Moy L et al 2010. Exploring subtle land use and land cover changes: a framework for future landscape studies. *Landscape Ecology* **25**: 249-266.

https://www.greathimalayannationalpark.org/about-us/park-introduction/ Accessed on 10 April 2019.

IPCC 2007. Climate change 2007: The physical science basis, summary for policy makers. Contribution of working group I to the third assessment report of the IPCC, Geneva, Switzerland, 2007: IPCC secretariat.

Khan AH and Arya D 2017. People Perceptions of climate change and its impacts on phyto-diversity and livelihood of the inhabitants of Almora Kumaun Himalaya, Uttarakhand (India).*Indian Journal of Ecology* **44**(4): 735-740.

Lasco RD, Espaldon MLO and Habito CMD 2016. Smallholder farmers' perceptions of climate change and the roles of trees and agroforestry in climate risk adaptation: Evidence from Bohol, Philippines. *Agroforestry Systems* **90**: 521-540.

Maikhuri RK, Rao KS and Semwal RL 2001. Changing scenario of Himalayan agroecosystem: Loss of agrobiodiversity, an indicator of environmental change in Uttarakhand Himalaya, India. *The Environmentalist* **20**: 23-39.

Manandhar S, Pandey VP and Kazama F 2013. Climate change and adaptation: An integrated framework linking social and physical aspects in poorly-gauged regions. *Climatic Change* **120**: 727-739.

Nangia S and Kumar P 2001. Population and environment interface in the Great Himalayan National Park, pp. 18-24. **In:** Centre for the Study of Regional Development, Jawaharlal Nehru University, Paper submitted for session (S08) on Population and Environment of the *24th General Population Conference* of the IUSSP from August 2001, Salvador, Brazil.

Nandy S, Singh C, Das KK, Kingma NC and Kushwaha SPS 2015. Environmental vulnerability assessment of eco-development zone of Great Himalayan National Park, Himachal Pradesh, India. *Ecological Indicators* **57**: 182-195.

Negi GCS, Samal PK, Kuniyal JC, Kothyari BP, Sharma RK and Dhyani PP 2012. Impact of climate change on the western Himalayan mountain ecosystems: An overview. *Tropical Ecology* **53**(3): 345-356.

Negi VS, Maikhuri RK, Pharswan D, Thakur S and Dhyani PP 2017. Climate change impact in the Western Himalaya: People's perception and adaptive strategies. *Journal of Mountain Science* **14**(2): 403-16.

Pichura VI, Potravka LA, Vasylivna DN, Skrypchuk PM and Stratichuk NV 2019. Retrospective and forecast of heterochronal climatic fluctuations with in territory of dnieper basin. *Indian Journal of Ecology* **46**(2): 402-407.

Ramesh K, Satayakumar S and Rawat GS 1998. Recent trends in the pheasant population in Great Himalayan National Park, Western Himalaya. **In:** *National Seminar on Wildlife Research and Conservation*. Wildlife Institute of India, Dehradun.

Regmi BR, Thapa L, Suwal R, Sharma GB, Khadka S and Tamang BB 2009. Role of agro biodiversity in promoting community based adaptation in Nepal. *Journal of Forest and Livelihood* **8**: 111-119.

Schilling J, Freier KP, Hertige E and Scheffran J 2012. Climate change, vulnerability and adaptation in North Africa with focus on Morocco. *Agriculture, Ecosystems and Environment* **156**: 12-26.

Sen V, Rana RS, Chauhan RC and Aditya 2015. Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. *Indian Journal of Horticulture* **72**(1): 14-20.

Shekhar MS, Chand H, Kumar S, Srinivasan K andGanju A 2010. Climate-change studies in the western Himalaya. *Annals of Glaciology* **51**(54): 105-112.

Shrestha AB, Wake CP, Mayewski PA and Dibb JE 1999. Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. *Journal of Climate* **12**(9): 2775-2786.

Shrestha A and Aryal R 2011. Climate change in Nepal and its impact on Himalayan glaciers. *Regional Environmental Change* **11**(1): 65-77.

Singh J 2011. Effect of climate change on medicinal plants and local perception in Kullu district of Himachal Pradesh. **In:** *Proceedings Pre-Congress Workshop on Forests and Climate Change* 17th August, 2011, Himalayan Forest Research Institute, Shimla, India.

Singh P, Umesh KH and Kumar N 2008. Modelling and estimation of different components of stream flow for Gangotri Glacier basin, Himalayas. *Hydrological Sciences Journal* **53**: 309-322.

Singh SP, Singh V and Skutsch M 2010. Rapid warming in the Himalayas: Ecosystem responses and development options. *Climate & Development* **2**: 1-13.

Tewari VP, Verma RK and Gadow KV 2017. Climate change effects in the Western Himalayan ecosystems of India: Evidence and strategies. *Forest Ecosystems* **4**(13): 1-9.

Toan DTT, Kien VD, Giang KB, Minh HV and Wright P 2014. Perceptions of climate change and its impact on human health: An integrated quantitative and qualitative approach. *Global Health Action* **7**(1): 23025.

Vinod TR and Sathayakumar S 1999. Ecology and Conservation of Mountain Ungulates in Great Himalayan National Park, Western Himalaya. Final Report. Wildlife Institute of India, Dehradun. 92.

Vishvakarma SCR, Kuniyal JC and Rao KS 2003. Climate change and its impact on apple cropping in Kullu Valley, North-West Himalaya, India. **In:** 7^{th} *International Symposium on Temperate Zone Fruits in the Tropics and Subtropics*. 14-18 October, Nauni, Solan, Himachal Pradesh.

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Population Density and Damage of Invasive Giant African Snail *Achatina fulica* in Organic Farm in East Sikkim, India

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Abstract: Sikkim Himalayan traditional agriculture system is one of the 22 agrobiodiversity hotspots of India which is reeling under serious climate change impacts and invasive species. The invasive Giant African snail, *Achatina fulica* is one of the world's largest and most damaging land snail pests, which has appeared in the agricultural fields of Sikkim, an organically farming Himalayan state of India. Therefore, a study was undertaken in an organic farm at Pendam in East Sikkim to estimate the density of *Achatina fulica* and the extent of damage to agriculture crops. A total of 500 individuals (density of 0.33 individuals per m^2) of snail were recorded from the study area. The invasion of *Achatina fulica* in Pendam occurred during the year 2000-2001 which appears in the farms during end of May and continues till October coinciding with the growing of majority of crops. Economic losses estimated based on the comparison of income generated from agricultural products between pre- and post- snail invasion showed 56.82 per cent loss.

Keywords: Giant African snail, Invasive species, Sikkim, Economic loss, Traditional agriculture

Sikkim Himalayan Traditional Farming Systems (TFS) show a good example of small-scale home-garden agroforestry systems indigenously managed by farmers since ancient times for their socioecological, sociocultural and socioeconomic benefits (Sharma et al 2016). However, in the recent years, indigenous farmers have observed the serious impacts of climate change such as erratic rainfall pattern, emergence of diseases and pests in crops, shift of crop seasons and invasive species (Sharma and Rai 2012). One such example is the appearance of Giant African Snail *Achatina fulica* in the typical traditional agriculture farms which is one of the world's largest and most damaging land snail pests and considered as 100 most invasive species in the world (Lowe et al 2000). The snail is moisture dependent, being more active in high humidity conditions compared to drier areas (Raut and Barker 2002) and occurs in agricultural areas, gardens and also in urban areas (Thiengo et al 2007). The normal life span of the *A. fulica* is 3-5 years, but some may live as long as nine years (Roda et al 2016).The rapid invasion of *A. fulica* is attributed to its high reproductive capacity and the tendency for people to release the snails into the wild (Budha and Naggs 2008, Roda et al 2016).

The Giant African Snails are macrophytophagous and are reported to feed on at least 500 plant species (Capinera and White 2011). Four categories of plants are mostly damaged by the snail that includes garden flowers and ornamentals, vegetables (especially of cruciferae, cucurbitaceae and leguminosae families). *A. fulica*, especially young individuals, appears to prefer certain plants for food such as soft textured banana (*Musa*), bean (*Beta vulgaris*) and marigold (*Tagetes patula*) (Thakur 1998). Studies have shown that *A. fulica* causes serious damage to variety of horticultural and agricultural crops viz., mulberry (Shree and Kumar 2002), betel-vine, capsicum, areca, banana, tomato (Javaregowda 2004), bean, cabbage, cucumber, cauliflower, chillies (Reddy and Sreedharan 2006) and vegetable crops such as potato, spinach, radish and tomato (Sridhar et al 2013).

While the Giant African Snail has been an important pest of the agri-horticultural crops, no attempt has been made to study its population and damages in any parts of Sikkim as there was no serious report of its appearance in the region till recently. Hence, present study was undertaken to understand the population density of *A. fulica* and extent of damage to the agricultural crops, and its socio-economic impacts in Pendam, the snail affected agricultural area located in East District of Sikkim, India.

MATERIAL AND METHODS

Study area: This study was undertaken in the agricultural fields of Khanigaon (27°11.469`` N, 88°31.211``E) and Chiurebotay (27°12.036`` N, 88°31.391 ``E) villages in Pendam, East Sikkim sub-tropical belt. The area was selected based on the report of occurrence of the African Giant Snail in the villages by farmers. There are mainly two types of mixed farming system practiced in these villages: the forest-based agroforestry and the farmed based agroforestry (Sharma et al 2009). Sampling of the snail was undertaken in the farm-based agroforestry because majority of crops are cultivated in this system. A total of five sites spread along different elevations were identified for sampling based on the occurrence of snail and in consultation with the local communities (Table 1).

Sampling: Giant African snail was sampled using quadrat methods spread along the transect (Emberton et al 1996) with necessary modifications suitable to the hilly landscape during May 2016 through April 2017 but intensive sampling was done during July to October 2016. Two transects of around 300 m length were laid in each site keeping a minimum of 500 m distance between the transect. In each transect, quadrat of the size measuring 5 m x 5 m was established alternately maintaining 25 m distance between the two adjacent quadrats. Thus, a total of ten transects comprising 60 quadrats were placed for density estimation of the snail. Each quadrat was thoroughly searched by lifting leaf litter and the individuals detected were recorded. Additionally, life history stages such as juveniles, sub-adults and adults were also recorded during sampling.

Participatory rural appraisal and questionnaire survey: A participatory rural appraisal was conducted at Khanigaon in February 2017 involving local governance (*panchayat*) members and the indigenous communities. The views of the public were obtained on two important parameters namely, seasonal pattern for different crops and seasonal pattern of occurrence of snail. Additionally, a standard questionnaire was prepared and interviews were conducted by visiting 25 household in the study area. Interviewees were selected based on their knowledge on the snail and its occurrence, area of landholding and the extent of damage caused to the agricultural products. The perception of the individual was noted in an unbiased manner to record the seasonality of occurrence, control of pests and economic losses sustained by the local people.

Data analyses: The population densities of the various life-history stages of *A. fulica* in different study sites were computed “We used One-way ANOVA to test the variation in density of various life history stages of *A. fulica* in different study sites". It was given in the submitted version but omitted in the proof. The economic losses based on the comparison of income generation from agricultural products between pre- and post- snail invasion were estimated.

RESULTS AND DISCUSSION

Five hundred individuals of *A. Fulica* were recorded, out of which, 337 were juveniles, 141 sub-adults and 22 adults (Table 2). The highest number of individuals (167) was from the Khanigaon-II site followed by Chiurebotay-I, Chiuebotay-II, Khanigaon-III and the lowest number of individuals (35) were from the Khanigaon-I site. Based on pooled data, average population density of snail was 0.33 individual per m^2. The population density of *A. fulica* in Bihar, India ranged from 4.20 snails to 94.2 snails per 25 m^2 (Kumari et al 2015) and in Tamil Nadu, India from 1.86 to 3.81 per m^2 (Vanitha et al 2011). The density in the present study is lower than these areas which could be because the present study area was situated at much higher altitude than that of those locations in Bihar and Tamil Nadu. The snails are reported to occur more abundantly at hotter locations (low elevation areas) and the density of *A. fulica* decreases with the increase in elevation (Sarma et al 2015). Additionally, snail invasion in Sikkim is a recent phenomenon so that population is probably increasing every breeding season. The density was relatively low but the snail being a fast breeding invasive species can increase its population and can spread to other areas rapidly posing serious threat to agriculture.

Table 1. Details of the study sites located in the Pendam, East Sikkim

Name of sites	Co-ordinates	Elevation (m)	Aspects
Khanigaon-I	27°11.72``4N 88°31.059``E	889 m	South-West
Khanigaon-II	27°11.66``7N 88°31.048``E	866 m	South-East
Khanigaon-III	27°11.437``N 88°31.244``E	697 m	South-West
Chiurebotay-I	27°12.140``N 88°31.460``E	948 m	East-South
Chiurebotay-II	27°12.175``N 88°31.450``E	967 m	North-West

Out of various life-history stages of *A. fulica*, density of juvenile was highest (0.22 m^2) followed by sub-adults and the adults (Table 2). This may be because most of the field sampling was undertaken during August and September and the hatching of majority of eggs takes place during this season (Silva and Omena 2014). Overall density (i.e. all individuals irrespective of life history stages) showed statistically significant variation among sites (Table 2). There was statistically significant difference in density of juveniles and adults but no statistically significant difference in variation of density of sub-adults among different study sites. *A. fulica* appeared in agricultural field of Pendam village about 12-15 years ago somewhere around 2000-2001 (Fig. 1A). According to some of the respondents, this species was brought to the area by some religious people from an unknown place. The snail is considered as a chank shell *Turbinella pyrum*, an important cultural symbol of worship of the ethnic communities, and unwittingly taken from outside and subsequently released into the home gardens (Budha and Naggs 2008). Since then, it has been spreading at a rapid pace mainly due to its high reproductive rate causing havoc to the agricultural fields. The appearance of the snail in Sikkim could also be due to invasion from adjoining plains in response to warming climates as increase in temperature favours infestations of pests and invasive species (such as snails) leading to huge economic loss (Raut and Barker 2002, Singh et al 2013). *A. fulica* was prevalent in the agricultural field of the study area mostly during monsoon season. Out of the 25 respondents interviewed, 48 per cent mentioned that *A. fulica* appears during June and disappears by the end of August coinciding with the monsoon season (Fig. 1B). Moisture provides most favourable environment for snail's activity, growth and abundance (Kumari et al 2015). Rainfall increases sexual activity of the snail thus leading to the increase in their population density (Silva and Omena 2014).

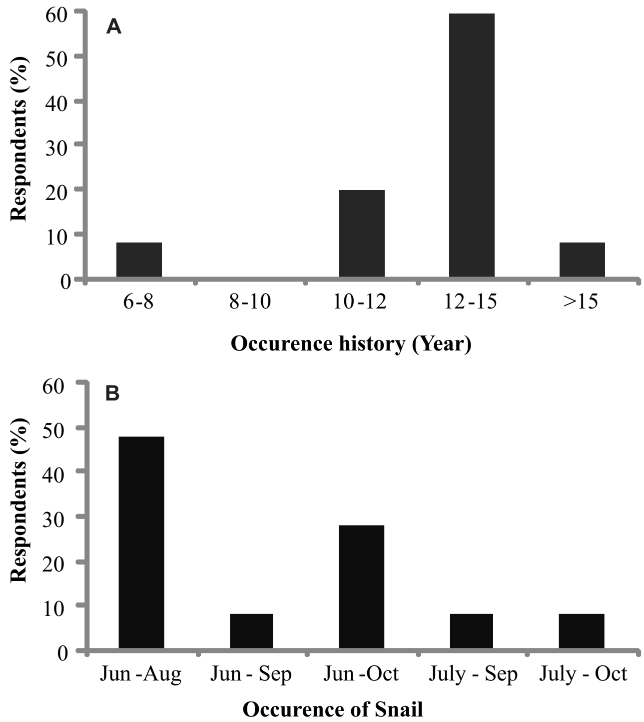

Fig. 1. History of appearance (A) and seasonality of occurrence (B) of *A. fulica* at Pendam, East Sikkim

Agroforestry is one of the most favoured agri-horticultural systems in Sikkim as it offers improve farm production and incomes to the farmers (Sharma et al 2007). The farmers of Pendam are involved in cultivation of around 20 crops ranging from cereals, pulses, vegetables to cash crops which are divided into major and minor crops. Harvest time from sowing is relatively long for all the crops except for some vegetable crops. Majority of the crops matures during June to October coinciding with the occurrence of different life history stages of *A. fulica* making them prone to damages by the snail.

The snail damaged nine different horticultural crops in the study area (Fig. 2A). Damages were more on vegetable crops such as cauliflower, potato, cabbage, pumpkin, cucumber, bottle gourd, tomato and cereals such as bean, maize and millet. Similar results were recorded by Budha and Naggs (2008) in Nepal. The snail was also reported to damage banana, cabbage, cucumber, cauliflower, tomato and chilies in Andhra Pradesh (Reddy and Sreedharan 2006). Forty-four percent of the respondents did not observe damage to the crops by *A. fulica* in Pendam. Some of the respondents believed that ginger (36%), rice (12%), maize (4%) and sugarcane (4%) are not frequently damaged by the snail (Fig. 2B). This result is contradictory because ginger (Venette and Larson 2004), rice and maize (Raut and Barker 2002) are considered as host plants for *A. fulica*. The snail prefers soft vegetable crops compared to hard, dry crops. Hence, availability of such soft vegetable crops in the study area would have prevented these few crops from damage by the snail indicating the need for further research. The most preferred local control measure adopted by farmers is the application of salt to kill the snail by dehydration. Similar practice of control measure has been adopted in Nepal (Budha and Naggs 2008). But with increasing rate of

Table 2. Distribution and density (numbers per m^2) of different life history stages of *A.fulica*

Site Name	Juveniles		Sub-Adults		Adults		Total	
	No.	Density	No.	Density	No.	Density	No.	Density
Khanigaon- I	20	0.07	12	0.04	3	0.01	35	0.12
Khanigaon- II	108	0.36	48	0.16	11	0.04	167	0.57
Khanigaon- III	79	0.26	20	0.07	0	0.00	99	0.33
Chiurebotay- I	61	0.20	38	0.13	6	0.02	105	0.35
Chiurebotay- II	69	0.23	23	0.08	2	0.01	94	0.31
Total	337	0.22	141	0.09	22	0.01	500	0.33
CD (p=0.05)	0.05		NS		0.04		0.04	

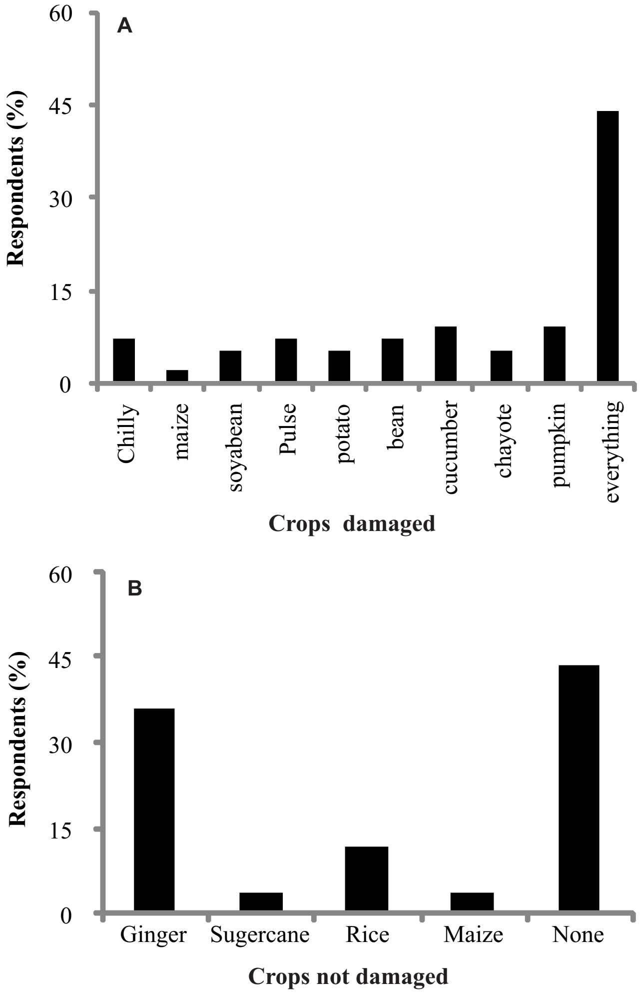

Fig. 2. Crops damaged (A) and not damaged (B) by *A. fulica* based on the perception of the farmers in the traditional agricultural lands at Pendam, East Sikkim

invasion, *A. Fulica* is causing huge damages to the agricultural and horticultural crops of Pendam, East Sikkim accounting an estimated economic loss of about US$3627.62 per annum with per household estimated loss of US$ 35 per week.

CONCLUSION

A. fulica is rapidly becoming a menace in the traditional agricultural farm of Sikkim causing much damage to the agricultural and horticultural crops. Five hundred individuals of snails with 0.33 individual per m^2 were recorded from the study area. The snails were most active during the monsoon season coinciding with the maturation of most of the crops grown in the area making them susceptible to damages by the snails. Such damages have accounted for huge economic losses to the farmers affecting their livelihoods. There is a possibility that the snail might make their way to other villages and may become serious threat to agrobiodiversity in the organically farming state of Sikkim in India.

REFERENCES

Budha PB and Naggs F 2008. The giant African land snail *Lissachatina fulica* (Bowdich) in Nepal. *The Malacologist* **50**: 19-21.

Capinera JL and White J 2011. Terrestrial snails affecting plants in Florida. *Department of Entomology, University of Florida, USA*.

Emberton KC, Pearce TA and Randalana R 1996. Quantitatively sampling land-snail species richness in Madagascan rainforests. *Malacologia-Philadelphia* **38**: 203-212.

Javaregowda 2006. Incidence of snail, *Achatina fulica* (Bowdich) in betel vine and its management. *Pest Management in Horticultural Ecosystem* **12**: 41-43.

Kumari P, Agarwal M and Kumar N 2015. Population dynamics of Giant African Snail, *Achatina fulica* bowdich (stylommatophora: achatinidae) and its correlation with weather parameters. *Bioscan* **10**: 1489-1492.

Lowe S, Browne M, Boudjelas S and De Poorter M 2000. *100 of the world's worst invasive alien species: a selection from the global invasive species database.*The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), New Zealand.

Raut SK and Barker G 2002. *Achatina fulica* bowdich and other achatinidae as pests in tropical agriculture. *Molluscs as crop pests*: 55-114.

Reddy KB and Sreedharan K 2006. Record of giant African snail, *Achatina fulica* Bowdich on coffee in Visakha agency areas, Andhra Pradesh. *Indian Coffee* **70**: 17-19.

Roda AG, Nachman S, Weihman Cong MY and Zimmerman F 2016. Reproductive ecology of the giant African snail in South Florida: implications for eradication programs. *PLoS one* **11**: e0165408.

Sarma RR, Munsi M and Ananthram AN 2015. Effect of climate change on invasion risk of giant African snail (*Achatina fulica* Ferussac, 1821: Achatinidae) in India. *PLoS One* **10**: e0143724.

Sharma G, Partap U, Sharma E and Awasthe RK 2016. Agrobiodiversity in the Sikkim Himalaya: Sociocultural significance, status, practices, and challenges*, ICIMOD Working Paper Kathmandu: ICIMOD*.

Sharma G and Rai LK 2012. Climate change and sustainability of agrodiversity in traditional farming of the Sikkim Himalaya, Climate Change in Sikkim Patterns, Impacts and Initiatives. *Information and Public Relations Department, Government of Sikkim, Gangtok*.

Sharma G, Sharma R and Sharma E 2009. Traditional knowledge systems in large cardamom farming: Biophysical and management diversity in Indian mountainous regions. *Indian Journal of Traditional Knowledge* **8**: 17-22.

Sharma R, Xu J and Sharma G 2007. Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. *Tropical Ecology* **48**: 189-200.

Shree MP and Kumar KR 2002. Effect of giant African snail- *Achatina fulica* Bowdich infestation on the nutritional quality of mulberry (*Morus* sp.) leaves. *Bulletin of Indian Academy of Sericulture* **6**: 50-56.

Silva EC and Omena EP 2014. Population dynamics and reproductive biology of *Achatina fulica* Bowdich, 1822 (Mollusca, Gastropoda) in Salvador-Bahia. *Biota Neotropica* **14**: e20140004.

Singh R, Jindal V and Dhaliwal GS 2013. Climate Change: Impact on insect pests and their management. *Indian Journal of Ecology* **40**(2): 178-186.

Sridhar V, Jayashankar M, Vinesh LS and Verghese A 2013. Severe occurrence of the giant African snail, *Achatina fulica* (Bowdich) (Stylommatophora: Achatinidae) in Kolar district, Karnataka. *Pest Management in Horticultural Ecosystem* **18**: 228-230.

Thakur S 1998. Studies on food preference and biology of giant African snail, *Achatina fulica* in Bihar. *Journal of Ecobiology* **10**: 103-109.

Thiengo SC, Faraco FA, Salgado NC, Cowie RH and Fernandez MA 2007. Rapid spread of an invasive snail in South America: the giant African snail, *Achatina fulica*, in Brasil. *Biological Invasions* **9**: 693-702.

Vanitha K, Karuppuchamy P and Sivasubramanian P 2011. Pests of vanilla and their natural enemies in Tamil Nadu, India. *International Journal of Biodiversity Conservation* **3**: 116-120.

Venette RC and Larson M 2004. *Mini risk assessment, Giant African snail, Achatina fulica* Bowdich *(Gastropoda: Achatinidae)*. Department of Entomology, University of Minnesota, St Paul, US.

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Effects of Feeding Floral Resource on Potential of *Bemisia tabaci* Parasitoids

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Abstract: The present study evaluate the role of sweet basil, *Ocimum ba silicum* L and geranium, *Pelargonium graveolens* L. as a tool to enhance the potential of *Bemisia tabaci* parasitoids (*Encarsia lutea* Masiand *Eretmocerus mundus* Mercet). Sweet basil significantly extended longevity of *E. lutea* and *E. mundus* females more than water treatment. The same result was obtained in *E. mundus* female fed on geranium flowers. The foraging behavior (searching rate and mutual interference values) of the tested parasitoids was affected according to supplemental food sources. *E. lutea* and *E. mundus* females fed on sweet basil exhibited the highest searching rate followed by geranium flowers and water, respectively. The lowest mutual interference was recorded when *E. lutea* and *E. mundus* females fed on sweet basil and geranium flowers, respectively. The feeding floral resource (sweet basil and geranium flowers) to *E. lutea* and *E. mundus* females increased their parasitism over unfed females. These results support the hypothesis that the potential of whitefly parasitoids can be increased by planting floral resources plants (geranium and sweet basil) adjacent to host plants of the pest.

Keywords: *Bemisia tabaci*, *Encarsia lutea* Masi, *Eretmocerus mundus* Mercet, Ocimum *ba silicum* L, Searching rate, Mutual interference

The sweet potato whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) is a key pest of vegetables and other horticultural crops. *Encarsia lutea* (Masi) and *Eretmocerus mundus* Mercet are the most abundant indigenous parasitoids of *B. tabaci* in the Mediterranean countries (Kirk et al 2000, Tellez et al 2003, Karut and Naranjo 2009). Both species exhibited high potential as bio control agents against *B. tabaci* (Gerling et al 2001, Tellez et al 2003, Urbaneja and Stansly 2004).Conservation biological control involves making better use of agent species that are already present in a region and can achieve that by habitat management to provide key ecological resources to natural enemies (Poveda et al 2008, Gurr and You 2016). Beneficial insectary planting is a form of conservation biological control that involves introducing flowering plants into agricultural and horticultural systems to increase nectar and pollen resources required by some natural enemies of insect pests. Several authors have reported that supply of a no prey food such as pollen and nectar is very important and beneficial for the use of natural enemies in agricultural systems (Rebek et al 2006, Abd El-Kareim et al 2007, Marouf 2011, Lu et al 2014). Hymenopteran parasitoids usually require a carbohydrate energy source during their adult stage, such as floral nectar, to increase longevity (Vattala et al 2006, Marouf 2011), fecundity and motivation to seek hosts (Winkler et al 2006). Conservation biological control is the least studied of all biological control approaches (Lu et al 2014). More research is still needed to identify which plants have the greatest potential as beneficial insectary plants (Lu et al 2014). The hymenopterous parasitoids exhibited different degrees of attractiveness in response to host plants (Abd El-Kareim et al 2007, 2011). The sweet basil (*Ocimum ba silicum* L.) and geranium (*Pelargonium graveolens* L.) are more preferred by *E. lutea* and *Eret. Mundus* (Marouf 2011). So, the present study aims to evaluate the effect of *P. graveolens* and *O. basilicum* flowers on the longevity, foraging behavior and efficiency of *E. lutea* and *E. mundus*.

MATERIAL AND METHODS

Sweet basil (*Ocimum ba silicum* L.) and geranium (*Pelargonium graveolens* L.) were purchased as seedlings from Faculty of Agriculture, Mansoura University and transplanted in 15 cm diameter plastic pots under laboratory conditions. Cowpea (*Vigna unguiculata* L.), was gown in 15 cm diameter plastic pots under laboratory conditions. The sweet potato whitefly, *Bemisia tabaci* was collected from *Latania camara* plants and were used to establish colonies in the laboratory (at 25 ± 2.2 °C and 69 ± 3.5% RH). For a source of *B. tabaci* homogenous in age, the adults were released into cages containing cowpea seedlings in a pot filled with soil for 48 h to lay eggs (Abd El-Kareim1998). *Encarsia lutea* Masi and *Eretmocerus mundus* Mercet were collected from the host, *B. tabaci* on *L. camara* leaves. Leaves heavily infested with *B. tabaci* were kept in glass tubes, until emergence of parasitoid adults. *E. mundus* adults were sexed under a stereoscopic microscope according to antennal color: dark for males, light for females (Rose and Zolnerowich 1997), whereas, *E. lutea* were sexed based on antennal color and modification: yellow and a strongly developed sensorial complex on F1-F3 for males (Polaszek et al 1999). Each newly-emerged wasp (males and females) from every species was placed in a separate glass tube. To assess the influence of geranium and sweet basil flowers on the longevity of the parasitoids, the flowers and newly emerged one pair (male and female) of each parasitoid were enclosed in a transparent cylindrical cage (30 cm high and 10 cm in diameter). The cages consisted of transparent plastic sheet with fine mesh on the top and foam on the bottom. The treatments consisted of geranium, sweet basil and water. Flowers were inserted into water-filled tubes with cotton plugs where parafilm was wrapped around the floral stem covering the wet cotton (Lee and Heimpel 2008).In water treatment, 25 ml vials with cotton were placed inside the cages. Flowers and water were replaced daily. Each treatment was repeated twenty five times for each parasitoid at 16L: 8D, at 26 ± 2.6 °Cand 68 ± 3.5 RH per cent. To assess the parasitoid longevity, wasps were checked daily, and sexed under the microscope according to Rose and Zolnerowich (1997) and Polaszek et al (1999) for *E. mundus* and *E. lutea*, respectively. The foraging behavior(searching rate and mutual interference) of the parasitoid females fed on forbs (sweet basil and geranium flowers) or no forbs (water only) was estimated on cowpea seedlings infested with *B. tabaci.* Newly emerged wasps of *E. mundus* and *E. lutea* parasitoid adults (males and females) from every species were maintained for mating (24 h) in a glass tube. Then, wasps were supplied with: sweet basil flowers, geranium flowers or water only for three days. The searching rates of the two parasitoids feed on different food sources were compared. Five densities consist of 1, 3, 5, 7 and 9 females of each parasitoid species, respectively, were examined by confining 50 suitable individuals (2^{nd} instars, for *E. lutea* and3^{rd} instars, for *E. mundus*) of *B. tabaci* (Urbaneja and Stansly 2004) on cowpea seedlings under glass chimney. The top of the chimney was covered with fine-mesh screen. The parasitoid females were left in the chimney for 48 hrs with their hosts. Each parasitoid density was replicated five times. After the removal of the parasitoid females, cowpea seedlings were kept under laboratory conditions (26 ± 2.5 °C, 69 ± 3.9 R.H. and a photoperiod of 16:8 h (L: D) until the parasitoid progenies reached their pupal stage. The parasitized hosts were counted and recorded. The search rate ($a_{t)}$, and mutual interference (m) values were calculated according to Varley et al (1973). No choice experiments were conducted in the laboratory to estimate the influence of the tested flowers (geranium and sweet basil) on the efficiency (parasitism %) of *E. lutea* and *E. mundus*. The flowers and newly emerged one pair (male and female) of each parasitoid were enclosed in a glass lamp chimney containing newly infested cowpea seedlings with 100-120 individuals of *B. tabaci* (2^{nd} and 3^{rd} instar nymph for *E. lutea* and *E. mundus*, respectively). The treatments consisted of geranium, sweet basil and water. In water treatment, 25 ml vial with a cotton wick was placed inside each glass lamp chimney. Each treatment was repeated ten times for each parasitoid at the previously mentioned laboratory conditions. At the beginning of adult emergence of the pest under attack, the percentages of parasitism were estimated.

RESULTS AND DISCUSSION

Longevity of parasitoids: The mean longevity of male and female of both *Encarsia lutea* and *Eretmocerus mundus* fed on different food resources (sweet basil, *Ocimum ba sillicum*L; geranium, *Pelargonium graveolens* and water) varied significantly. Sweet basil significantly extended longevity of *E. lutea* and *E. mundus* females (11.76 and 12.08 days) than water treatment (8.88 and 9.52, respectively). The same result in *E. mundus* female fed on geranium flowers have (12.24 days). To the adult male longevity, did not differ significantly among different response but in female longevity as more in sweet basil and geranium.

Foraging behavior of *B. tabaci* parasitoids: *E. mundus* and *E. lutea* females fed on sweet basil flowers exhibited the high searching rate (0.1742 and 0.1690) followed by geranium and water, respectively (Table 2, Fig. 1). The lowest mutual interference value was recorded for *E. mundus* (0.0463) and *E. lutea* (0.0517) females when fed on geranium and sweet basil, respectively.

Influence of tested flowers on *B. tabaci* parasitoid activity: Parasitism data (Table 3) indicated that sweet basil and geranium could be a potential plant for enhancing efficacy of the aphelinid parasitoids, *E. lutea* and *E. mundus*. Flowers increased parasitoid activity (parasitism percentage). There were significant differences in parasitism

Table 1. Mean longevity of *Encarsia lutea* (Masi) and *Eretmocerus mundus* (Mercet) adults fed on different food resources

Treatment	*Encarsialutea*		*Eretmocerus mundus*	
	Male	Female	Male	Female
Sweet basil	8.80 ± 1.98^{a}	11.76 ± 3.08^{a}	9.12 ± 2.60^{a}	12.08 ± 3.37^{a}
Geranium	8.32±1.77^{ab}	10.12 ± 2.24^{b}	8.44 ± 2.14^{a}	12.24 ± 4.11^{a}
Water (control)	7.72 ± 1.57^{b}	8.88 ± 1.74^{b}	8.28 ± 1.77^{a}	9.52 ± 2.12^{b}

All values with the same letter in column donot differ significantly (p=0.05)

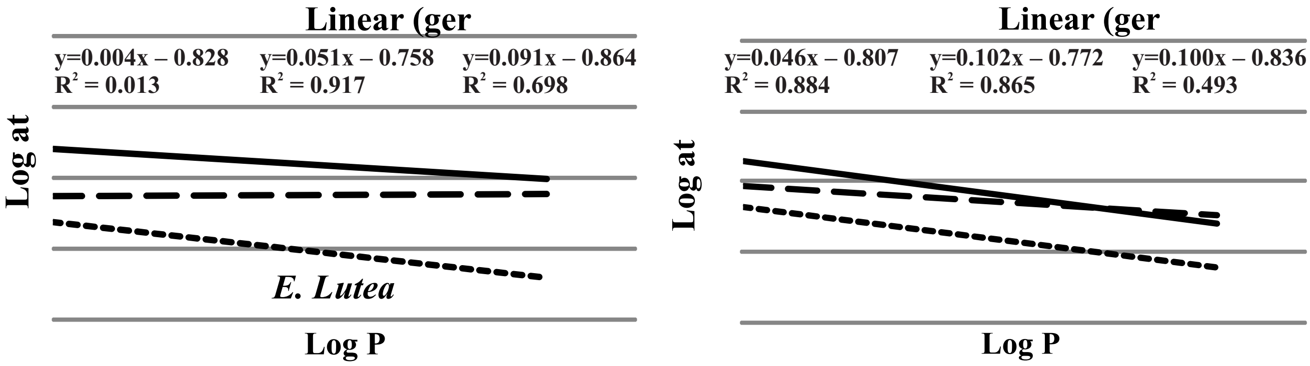

Fig. 1. The relation between parasitoid density (log P) and searching rate (log at) of *E. lutea* and *E. mundus* females under laboratory conditions

Table 2. Searching rate (a_t) and mutual interference (m) s of *Encarsia lutea* (Masi) and *Eretmocerus mundus* (Mercet) females fed on different food

Treatment	*Encarsialutea*		*Eretmocerus mundus*	
	a_t	m	a_t	M
Sweet basil	0.1690	0.0517	0.1742	0.1027
Geranium	0.1557	0.0639	0.1565	0.0463
Water (control)	0.1456	0.0912	0.1366	0.1009

Table 3. Parasitism percentage of *Encarsia. lutea* (Masi) and *Eretmocerus mundus* (Mercet) fed on different food resources

Treatment	*Encarsialutea*	*Eretmocerus mundus*
Sweet basil	85.9 ± 5.7 a	75.3 ± 7.9 a
Geranium	76.9 ± 9.9 b	81.5± 6.9 a
Water (control)	55.1 ± 5.5 c	60.9 ± 10.8 b

All values with the same letter in column donot differ significantly (p=0.05)

rate between the three feeding treatments. Parasitism rate caused by *E. lutea* was significantly higher in the sweet basil (85.9%) and geranium (76.9%) compared to the control (55.1%). The geranium (81.5%) and sweet basil (75.3%) enhanced parasitism rate caused by *E. mundus* compared with the control (60.9%).

The present study showed that flowers fed parasitoids lived longer than those provided with water only. However, the feeding treatments (sweet basil and geranium flowers) significantly increase the mean longevity of both *E. lutea* and *Eret. Mundus* adult females. Similar results were reported by Marouf (2011) in which *Aphidius* sp. adults fed on coriander or chamomile flowers resulted in the longest longevity of male and female, and was significantly higher than water treatment. Lee and Heimpel (2008) reported that both male and female of the braconid parasitoid, *Cotesia glomerata* (L.) showed longer life spanv when given buckwheat (*Fagopyrum esculentum* Moench) nectar daily than those given water. The Hymenopterans parasitoids usually require a carbohydrate energy source during their adult stage, such as floral nectar, to increase longevity (Malati and Hatami2005, Vattala et al 2006, Divya et al 2011, Ashraf et al 2017). The sweet basil and geranium flowers proved to be a good supplemental food sources for *E. lutea* and *E. mundus*. The searching rate of the tested parasitoids was affected according to supplemental food sources. However, the highest searching rate of *E. Lutea* and *E. mundus* adults was fed on sweet basil or geranium flowers. Earlier worker have also suggested that foraging behavior of the parasitoids were different with respect to supplemental food sources (Abd El-Kareim 2002, Abd El-Kareim et al 2007, Kehrli and Bacher 2008, Marouf 2011, Harvey et al 2012). Wäckers (2005) and Winkler et al (2006) observed that several parasitoids usually require a floral nectar source during their adult stage, to increase motivation to seek hosts. The present study also indicated that feeding floral resource (sweet basil and geranium flowers) to the females *E. lutea* and *E. mundus* significantly increased their parasitism over unfed females. The hymenopterous parasitoids activities were considerably higher in shrubs that were surrounded by flowering forbs than in shrubs that lacked flower (Ellis et al 2005, Bell et al 2006, Irvin et al 2006, Rebek et al 2006). Wäckers (2005) demonstrated that floral nectar is mainly composed of carbohydrates, amino acids, proteins, lipids, vitamins and secondary plant metabolites. Therefore, flowers increase parasitoid efficiency by improving their fitness (Al-Doghairi and Cranshaw 2004). According to Sivinski et al (2011) flowering plants in agricultural landscapes can provide ecological services, for adult parasitic Hymenoptera, So, these results support the hypothesis that the potential of whitefly parasitoids can be increased by planting floral resources plants (geranium and sweet basil) adjacent to host plants of the pest.

CONCLUSION

Flower nectar approved to an important factor for hymenopteran parasitoids during their adult stage, by improving their fitness. The sweet basil and geranium flowers proved to be a good supplemental food sources for *E. lutea* and *E. mundus*, it relates to parasitoid longevity and efficiency. So, useful information has been generated which may be exploited in mass rearing program of the wasps*, E. lutea* and *E. mundus*. Consequently, the potential of whitefly parasitoids can be increased by planting floral resources plants adjacent to host plants of the pest.

REFERENCES

Abd El-Kareim AI 1998. Searching rate and potential of some natural enemies as bio-agent against the cotton whitefly, *Bemisia tabaci* Genn. (Hom., Aleyrodidae). *Journal of Applied Entomology* **122**: 487-492.

Abd El-Kareim AI 2002. The potential of some natural enemies as bio-agents against certain diaspidid species. *Journal of Union of Arab Biologists Cairo. A, Zoology* **17**: 51-63.

Abd El-Kareim AI, El-Naggar ME and MaroufAmal E 2007. Is *Matricaria chamomilla* a beneficial insectary plant? *Journal of Agricultural Science - Mansoura University* **32**: 6777 - 6786.

Abd El-Kareim AI, El-Naggar ME and MaroufAmal E 2011. Survey of predaceous insects associated with four medicinal plants. *Journal of Plant Protection and Pathology, Mansoura University* **2**: 623-636.

Al-Doghairi MA and Cranshaw WS 2004. The effect of interplanting of necteriferous plants on the population density and parasitism of cabbage pests. *Southwestern Entomologist* **29**: 61-68.

Ashraf S, Abdin Z, Abbas SK, Khan RSA, Tahir M, Rasool S, Anwar M and Hussain F 2017. Effect of different diet concentrations on longevity and fecundity of parasitic wasp *Braconhebetor* (Say.) (Hymenoptera: Braconidae). *Pakistan Journal of Zoology* **49**: 761-767.

Bell VA, Brightwell RJ and Lester PJ 2006. Increasing vineyard floral resources may not enhance localised biological control of the leafroller *Epiphyas postvittana* (Lepidoptera: Tortricidae) by *Dolichogenidea* spp. (Hymenoptera: Braconidae) parasitoids. *Biocontrol Science and Technology* **16**: 1031-1042.

Divya S, Kalyanasundaram M and Karuppuchamy P 2011. Effect of adult nutrition on longevity and parasitisation efficiency of *Acerophagus papayae* Noyes and Schauff (Hymenoptera: Encyrtidae). *Biological Control* **25**: 316-319.

Ellis JA, Walter AD, Tooker JF, Ginzel MD, Reagel PF, Lacey ES, Bennett AB, Grossman EM and Hanks LM 2005. Conservation biological control in urban landscapes: Manipulating parasitoids of bagworm (Lepidoptera: Psychidae) with flowering forbs. *Biological Control* **34**: 99-107.

Gerling D, Alomar O and Arno J 2001. Biological control of Bemisia using predators and parasitoids. *Crop Protection* **20**: 779-799.

Gurr GM and You M 2016. Conservation biological control of pests in the molecular Era: New opportunities to address old constraints. *Frontiers in Plant Science*, www.frontiersin.org Volume **6** /Article 1255.

Harvey JA, Cloutier J, Visser B, Ellers J, Wäckers FL and Gols R 2012. The effect of different dietary sugars and honey on longevity and fecundity in two hyperparasitoid wasps. *Journal of Insect Physiology* **58**: 816-823.

Irvin NA, Scarratt SL, Wratten SD, Frampton CM, Chapman RB and Tylianakis JM 2006. The effects of floral under storeys on parasitism of leaf rollers (Lepidoptera: Tortricidae) on apples in New Zealand *Agricultural and Forest Entomology* **8**: 25-34.

Karut K and Naranjo SE 2009. Mortality factors affecting *Bemisia tabaci* populations on 477 cotton in Turkey. *Journal of Applied Entomology* **133**: 367-374.

Kehrli P and Bacher S 2008. Differential effects of flower-feeding in an insect host- parasitoid system. *Basic and Applied Ecology* **9**: 709-717.

Kirk AA, Lacey LA, Brown JK, Ciomperlik MA, Goolsby JA, Vacek DC, Wendel LE and Napompeth B 2000. Variation in the *Bemisiatabaci*s.l. species complex 480 (Hemiptera: Aleyrodidae) and its natural enemies leading to successful biological 481 control of *Bemisia* biotype B in the USA. *Bulletin of Entomological Research* **90**: 317-327.

Lee JC and Heimpel GE 2008. Effect of floral nectar, water, and feeding frequency on *Cotesia glomerata* longevity. *Biological Control* **53**: 289-294.

Lu ZX, Zhu PY, Gurr GM, Zheng XS, Read DMY, Heong KL, Yang YJ and Xu HX 2014. Mechanisms for flowering plants to benefit arthropod natural enemies of insect pests: Prospects for enhanced use in agriculture. *Insect Science* **21**: 1-12.

Malati AK and Hatami B 2005. Effect of honey, sugar and protein on longevity of *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) with and without host eggs. *Journal of Entomological Society of Iran* **25**: 1-12.

Marouf E Amal 2011. *Influence of some medicinal plants as a habitat management tool to enhance the role of certain natural enemies*. Ph.D. thesis Fac. Agric., Mansoura University, 164 p.

Polaszek A, Abd-Rabou S and Huang J 1999. The Egyptian species of Encarsia (Hymenoptera: Aphelinidae): A preliminary review. *Zoologische Mededelingen* **73**: 131-163.

Poveda K, Gomez MI and Martinez E 2008. Diversification practices: Their effect on pest regulation and production. *Revista Colombiana De Entomología* **34**: 131-144.

Rebek EJ, Sadof CS and Hanks LM 2006. Influence of floral resource plants on control of an armored scale pest by the parasitoid *Encarsia citrina* (Craw.) (Hymenoptera: Aphelinidae). *Biological Control* **37**: 320-328.

Rose M and Zolnerowich G 1997. The genus Eretmocerus (Hymenoptera: Aphelinidae): Parasites of whitefly (Homoptera: Aleyrodidae). *Tech. Broch., Calif. Dept. Food Agric*., 8 p.

Sivinski J, Wahl D, Holler T, Al Dobai S and Sivinski R 2011. Conserving natural enemies with flowering plants: Estimating floral attractiveness to parasitic Hymenoptera and attraction's relationship to flower and plant morphology. *Biological Control* **58**: 208-214.

Tellez MM, Lara L, Stansly PH and Urbaneja A 2003. *Eretmocerus mundus* (Hym: Aphelinidae), parasitoide autóctono de *Bemisia tabaci* (Hom.:Aleyrodidae): Primerosresultados de eficacia en judía. *Boletín De Sanidad Vegetal Plagas* **29**: 511-521.

Urbaneja A and Stansly PA 2004. Host suitability of different instars of the whitefly *Bemisia tabaci* biotype "Q" for *Eretmocerus mundus*. *Biological Control* **49**: 153-161.

Varley CG, Gradwell GR and Hassell MP 1973. Insect Population Ecology, an Analytical Approach. *Blackwells, Oxford*, **212** p.

Vattala HD, Wratten SD, Phillips CB and Wäckers FL 2006. The influence of flower morphology and nectar quality on the longevity of a parasitoid biological control agent, *Biological Control* **39:** 179-185.

Wäckers FL 2005. Suitability of (extra-) floral nectar, pollen, and honeydew as insect food sources, In *Plant-Provided Food for Carnivorous Insects*, ed. F.L. Wäckers, P.C.J. van Rijn, and J. Bruin, Cambridge University Press, Cambridge, p. 17-74.

Winkler K, Wäckers F, Bukovinszkine-Kiss G and Van Lenteren J 2006. Sugar resources are vital for *Diadegma semiclausum* fecundity under field conditions. *Basic and Applied Ecology* **7**: 133-140.

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Studies on Soil Nematodes in Al-Muthanna Province, Iraq

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Abstract: Fofty soil samples were collected from different regions of Al-Muthanna province. The examination carried out by sedimentation using of ethyl acetate. The rate of total positive samples with nematodes was 25.3 per cent. Four genera were identified in this study are *Aphelenchoides*, *Pratylenchus, Longidorus* and *Paratrichodorus*. The rate of positive samples was 7.4, 5.9, 4.4 and 4.4 per cent, respectively. *Toxocara* eggs were also detected under the microscope with rate of 2.9 per cent. The rate of parasitic existance vaired with the season as the highest rate of positive samples was in November (66.6%), while the lowest rate in March and April (8.3%). This can suggest the importance of the temperature and humidity in spreading of nematdes in the soil.

***Keywords*:** Identification, Investigation, Soil nematodes

Nematodes can habitate in different kinds of environments and 60 to 80 per cent of soil nematodes are beneficial worms (Neher 2010). These nematodes have long history in our planet which may be longer than that of human and other animals (Hodda 2007). They live in soil pores and use the pores or water channels for moving. Some human pathogenic nematodes were identified in the soil (Kagoshima et al 2019). The soil can play a crucial role in spreading of many pathogenic parasites to mammals. Based on that, the study of parasitic content in soil could explain an illustrative map of existence and types of parasites in the soil. The aim of this study is to diagnose the important nematodes genera in soil samples of Al-Muthanna province in western south of Iraq.

MATERIAL AND METHODS

Study area and sample collection: A point prevalence study was conducted to determine the prevalence of soil nematodes in Al- Muthanna province in western south of Iraq. Forty three samples of soil were collected by burrowing 10 cm in the soil then collecting the samples which after that put in 1 liter of water. These samples were collected near the plants and animal grazing. The sample was allowed to sediment for 1-2 hours, depending on the size of the container. It is recommended to use an open-topped, straight-sided container for sedimentation, as since this can make removing the supernatant easier and permit to thorough rinsing of the container (Ayres et al 1996). Ninety per cent of the supernatant was removed by using a suction pump or siphon. The sediment was carefully transferred to one or more centrifuge tubes, depending on the volume. The tubes were spun down at 3000 rpm for 5 minutes. The container was rinsed well with detergent solution, and then added to the sediment. Subsequent steps were done as the same steps as explained by Alsaadawi et al (2019). These steps started with removing the supernatant. All the sediments were transferred to one tube. After that the tube was re-centrifuged at 3000 rpm for 5 minutes. The pellet was suspended in acetoacetic buffer, pH 4.5 (an equal volume). Seven ml of formalin and 7 ml of ethyl acetate were added, and mixed the mixture using a vortex mixer or strongly by hand. The tubes were centrifuged at 3000 rpm for 15 min. the samples were separated to three layers as the following: the bottom layer which represents all the non-fatty, heavier debris, including helminthes and protozoa. Above this layer, the buffer, which should be clear in a form of circle. The top phase contains the fatty and other material and formed a thick dark plug. The volume of the pellet containing the parasites was recorded and then the rest of the supernatant was poured off using pasture pippets.

Determination of parasite concentration: The density and concentration of parasites were checked using Spectro-photometer machine. A 10-100 µl volume of precipitant solution was added into a 2 ml cuvette and then diluted in 1 ml of Milli Q water with absorbance change at OD600 nm. the concentration was estimated from an OD600 nm of 0.05-0.1 to be appropriate of microscopic examination. Finally, the sediment was quickly removed with a Pasteur pipette and transferred to a glass slide for microscopic examination after mixing with loguls iodine under 10× or 40× magnification.

Statistical analysis: All counted results were arranged then tabulated using Microsoft Excel program. These values were expressed as mean ± S.E.M. Statistical analysis was performed in Graph Pad Prism version 7.

RESULTS AND DISCUSSION

The total examined samples were 67 and the rate of positive results with nematodes was 25.3 per cent. Four genera were identified in this study based on the morphological features of the whole body (the adult worm) shape and these are: *Aphelenchoides*, *Pratylenchus, Longidorus* and *Paratrichodorus.* Different soil samples were collected and examined under the microscop. Aphelenchoides were the highest rates of the positive results, while the lowest rates were Toxocara. The rate of positive samples was 7.4, 5.9, 4.4 and 4.4 percent respectively (Fig. 1 & 2). *Toxocara*, the only genus that was identified based on the egg charecteristics with a rate of 2.9 per cent.

Highest rate of positive samples was in November (66.6%), while the lowest rate in March and April (8.3%) (Fig. 3). The results were analysed using one sample t test and

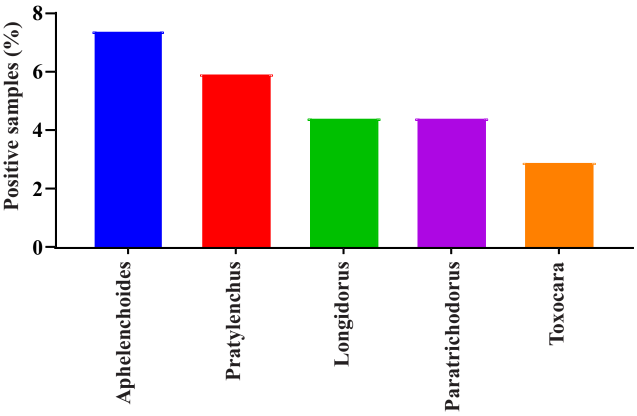

Fig. 1. Proportion of examined parasites

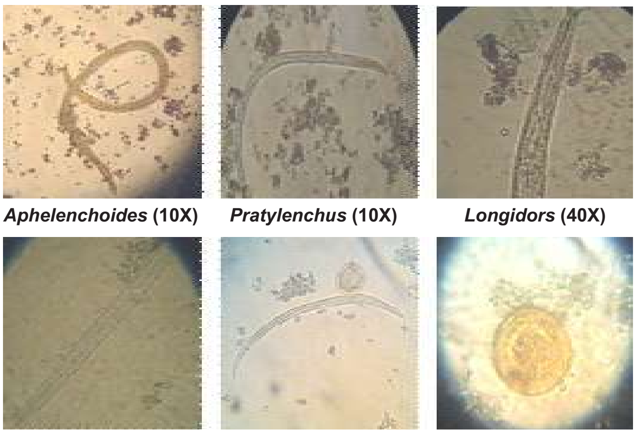

Fig. 2. Microscopic shapes of identified nematodes

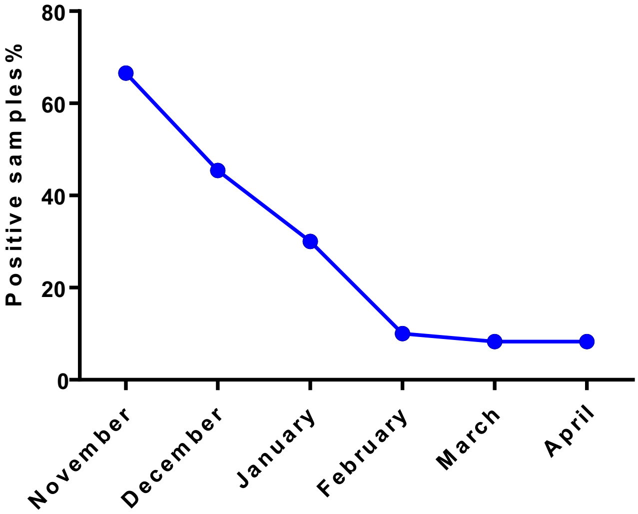

Fig. 3. Proportion of positive samples during different months

they were significantly different.

The samples were collected close to the surface only 10 cm from the top of soil as the presence of nematodes decreases in deeper places. The total nematodes rate was 25.3 per cent. In certain places, millions of different species of nematodes can live in very small area of soil (Lavelle and Spain, 2001). Four genera of plant nematodes were detected depending on the morphological characteristics. These are *Aphelenchoides*, *Pratylenchus, Longidorus* and *Paratrichodorus*. Several investigation studies explained that the nematodes are abundance in rhizosphere region in contact with plant's roots (Coleman and Wall 2015). In this study, a mammalian harmful parasite, Toxocara, was identified depending on the egg features. The adult stage of parasite is in mammals (Holland et al 2018).

The highest rate of nematodes abundance was in November (Fig. 3) which agrees with Alsaadawi et al (2018) who found that the parasitic contents increase in November in Iraq. This may relate to nature of the environment in November in south and middle of Iraq which is characterized by mild temperature and humidity. It is known that these factors play an important role in parasitic development and growth (Al Se´adawy 2013). The lowest rates of the investigation were in April which characterized by high temperature levels and absence of rain. This interprets why the parasitic levels were at the lowest abundance in April as expected.

REFERENCES

Al Se'adawy MAH 2013. Prevalence of subclinical coccidiosis associated with house reared chickens in Al-Muthanna province, Iraq. *Kufa Journal For Veterinary Medical Sciences* **4**(1): 128-133.

Alsaadawi MA 2019. Investigation of Bacterial and Parasitological

Contamination in Buffalo's Milk Cream (Arab Cream) in Alsamawa City, Iraq.

Alsaadawi MA, Alkhuzaie SS and AL-Sa'adawe MA 2019. Investigation about pathogenic parasites in Al-Muthana province/ Iraq water sources. *Multi Knowledge Electronic Comprehensive Journal for Education and Science Publications* **17**(1): 76-81.

Ayres RM and Mara DD 1996. *Analysis of Wastewater for use In Agriculture: A Laboratory Manual of Parasitological and Bacteriological Techniques*. Department of Civil Engineering University of Leeds Leeds, England. World Health Organization Geneva.

Coleman DC and Wall DH 2015. Soil fauna: Occurrence, biodiversity, and roles in ecosystem function. *Soil Microbiology, Ecology and Biochemistry* **17**(3): 111-149.

Freckman DW 1982. *Nematodes in Soil Ecosystems*. University of Texas Press, Austin, TX.

Griffiths BS 1994. Soil nutrient flow. In Soil Protozoa, ed. J Arbyshire, pp. 65-91. Wallingford, UK: CABI.

Hodda M 2007. Phylum Nematoda. *Zootaxa* **1668**(1): 265-93.

Ingham RE and Detling JK 1984. Plant-herbivore interactions in a North American mixed-grass prairie III. Soil nematode populations and root biomass on Cynomys ludovicianus colonies and adjacent uncolonized areas. *Oecologia* **63**(1): 307-313.

Ingham RE, Trofymow JA, Ingham ER and Coleman DC 1985. Interactions of bacteria, fungi, and their nematode grazers: effects on nutrient cycling and plant growth. *Ecological Monographs* **55**(1): 119-140.

Kagoshima H, Maslen R, Kito K, Imura S, Niki H and Convey P 2019. Integrated taxonomy combining morphological and molecular biological analyses of soil nematodes from maritime Antarctica. *Polar Biology* **42**(5): 877-887.

Lavelle P and Spain AV 2001. *Soil Ecology*. Kluwer Academic Publishers, Boston, MA.

Ma G, Holland CV, Wang T, Hofmann A, Fan CK, Maizels RM, Hotez PJ and Gasser RB 2018. *Human toxocariasis*. The Lancet Infectious Diseases. **18**(1): e14-e24.

Neher DA 2010. Ecology of plant and free-living nematodes in natural and agricultural soil. *Annual Review of Phytopathology* **48**: 12-17.

Peterson H and Luxton M 1982. A comparative analysis of soil fauna populations and their role in decomposition processes. *Oikos* **39**: 287–388.

Poinar GO 1983. *The Natural History of Nematodes*. Prentice-Hall, Englewood Cliffs, NJ.

Rocco JP and James C 2005. Use of the Chi-square Test to Determine Significance of Cumulative Antibiogram Data. *American Journal of Infectious Diseases* **1**(4): 162-167.

Wallace HR 1973. *Nematode Ecology and Plant Disease*. Edward Arnold, London, UK.

Wang KH, McSorley RT and Fasulo R 2006. Foliar and Root-knot Nematodes as Pests of Ornamental Plants. Bug Tutorials. Univeristy of Florida/IFAS. CD-ROM. SW-188.

Wharton DA 1986. *A Functional Biology of Nematodes*. Johns Hopkins University Press. Baltimore, MD.

Yeates GW, Bongers T, Goede RG, Freckman DW and Georgieva SS 1993. Feeding habits in soil nematode families and genera- an outline for soil ecologists. *Journal of Nematology* **25**: 315-331.

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Seasonal Variation of Physico-chemical Parameters of Chilika Lagoon, East Coast of India

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Abstract: Physico-chemical parameters of water of Chilika lagoon, Odisha such as salinity, temperature, dissolved oxygen, pH, water transparency, chloride, nitrate and phosphate content at nine sites were analysed during 2014 to 2015. The salinity level ranged between 2.1 and 29 ppt and temperature was more (31°C) at outer channel (Sipakuda), the mixing point with sea. pH varied from 8.0 to 8.8 and the water remained alkaline throughout the year in all the nine sites. Dissolved oxygen level was highest (8.9 mg l^{-1}) at Badakuda site during summer. During winter season, the water transparency was maximum (101 cm) at Badakuda site. Chloride content was highest (13.4 g l^{-1}) atouter channel (Sipakuda). Chloride, nitrate and phosphate contents of water fluctuated with season and sites.

Keywords: Chilika lagoon, Physico-chemical characteristics, pH, Salinity, Temperature

Chilika the largest coastal brackish water lagoon of Asia, is situated in costal Odisha between 19° 28' - 19° 54' N and 85° 05'- 85° 38' E. Chilika lagoon was designated as a wetland site under the Ramsar Convention in 1981and is one of the major and important wetlands in east-coast of India. Opening of new mouth in outer channel affected the water quality of the lagoon. The rivers Daya and Bhargavi are responsible for the major freshwater input into the lagoon, during monsoon and the post monsoon period. The water spread area of the lagoon varies between 906 to 1105 km^2 during the year. The pear shaped Chilika lagoon has a maximum length of 64.3 km and average width of 20 km (Fig. 1). Salinity plays a vital role in water quality of Chilika lagoon. However, Chilika lagoon is a dynamic ecosystem with reference to salinity due to unique assemblage of freshwater from the rivers and saline water from the Bay of Bengal. The quality of Chilika water changes with onset of different seasons and consequently the ecological characteristics also changes. Because of the unique hydrology of the lagoon, salinity and other physico-chemical gradients are not uniform and varying from site to site with seasons. Much work has been carried out on physico-chemical characteristics of Chilika lagoon (Panigrahi et al 2007, Panda et al 2015, Muduli et al 2017, Mukherjee et al 2018). The present study was undertaken to assess the quality of water samples with special reference to physico-chemical properties during 2014 to 2015.

MATERIAL AND METHODS

Site selection and sample collection: Nine sites (S1 to S9) under four different sectors, viz., Northern Sector, Central sector, Southern sector and Outer channel sector of Chilika lagoon were selected for water sample collection (Fig. 1). In Northern sector, water samples were collected from one site, Mangalajodi (S1); in Central Sector, from three sites, Barakul (S2), Nalaban (S3) and Kalijai (S4); in Southern Sector from three sites, Rambha (S5), Ghantasila (S6) and Badakuda (S7),and in Outer Channel Sector from two sites, Sipakuda (S8) and Arkhakuda (S9). Water samples were collected thrice from each site during 2014 to 2015, in the pre-monsoon (summer), monsoon (rainy) and post-monsoon (winter) period. Three replicate were collected for water quality analysis. The physico-chemical parameters, viz., dissolved oxygen (DO), salinity, temperature and pH of water samples of different sites were performed on the site by using Water Analysis kit (Globe Instrument 1570 G). Water transparency was recorded by using Secchi Disc. Water samples were brought to the laboratory for the analysis of chloride, nitrate and phosphate content of water following the standard methods (Von den Berg 1999). All the data presented in tables are mean of three samples with standard deviation.

RESULTS AND DISCUSSION

Salinity: In summer season, among the sites highest salinity was in Arkhakuda (S9) and lowest at Badakuda (S7). In rainy season, highest salinity was at S9 and lowest at Mangalajodi (S1). In winter season, among the sites, highest salinity (24 ppt) was at S9 and lowest at S1. At S1, S2 and S3 the salinity contents varied in rainy and winter due to the onset of rain and influx of fresh water in to the lagoon through the rivers and rivulets at S1, but in S2 and S3 there was no influx of fresh water from the rivers (Table 1). The water salinity during the summer was highest in S9 and S8 due to the inflow of sea water into the lagoon as these sites are situated near the mouth. Moreover, due to reduction in the water volume in the lagoon during summer salinity level of the water increased. Excess water evaporation in Chilika lagoon was increased during summer due to high temperature that led to higher water salinity (Panda and Mohanty 2008). In this study the highest salinity was observed at outer channel throughout the year. This may be due to the incursion of sea water in to the lagoon. In Northern sector, the salinity level was low because freshwater influx by rivers and water channel systems into the lagoon during rainy and winter seasons. Lower salinity level in Northern sector may be attributed to influx of river water in to the lagoon. Muduli et al (2017) also reported that the salinity concentration of water in Chilika lagoon was less in monsoon and winter period.

Temperature: In summer, highest water temperature (31.1^{0}C) was at Sipakuda (S8) and minimum at Nalaban (S3) and Kalijai (S4). In rainy season, highest temperature was at Sipakuda (S8) and minimum (24.5^{0}C) in two sites, Kalijai (S4) and Ghantasila (S6). In winter season, S1 exhibited maximum temperature (29^{0}C) while minimum temperature (23^{0}C) was at S6. In Northern sector, at S1 the temperature varied from 27.2 to 30.4^{0}C, maximum during summer and minimum during rainy. Similarly, in Central sector, highest water temperature was in summer and minimum in winter. At S2 the temperature fluctuated between 25 to 29.5^{0}C while at S3 and S4 it varied from 24 to 29^{0}C. In Southern sector, the highest temperature was during summer and minimum during winter. In outer channel also the maximum temperature was observed in summer and minimum in winter (Table 1). Seasonal variation of water temperature in different sites may be attributed to intensity of sun light (ambient temperature), depthless of water and vegetation cover.

Dissolved oxygen (DO): In summer, among the sites highest DO was recorded at S7 and lowest DO at S3. In rainy season, it varied between 2.3- 8.8 mg l^{-1} at S2 and S1. In winter, at S6 DO was highest and lowest at S2 (Table 2). Highest DO level (8.9 mg l^{-1}) at S7 may be attributed to the highest photosynthetic activity of the phytoplankton and macrophytes present in the lagoon. Panigrahi et al (2007) reported that the dissolved oxygen level was higher in northern sector due to massive vegetation and fresh water influx. In the present study, DO level was less at outer channel as compared to other sectors of the lagoon due to inflow of salt water. Nayak et al (2001) also reported low DO level in outer channel and attributed to influx of sea water in to the lagoon. Nayak and Behera (2004) reported higher DO values mostly in the sites where more phytoplankton were present and may be due to their photosynthetic activities. Jamila and Yousuf (2018) recorded highest DO level in spring season and lowest in summer in Dal Lake.

pH: In summer season, highest water pH (8.8) was observed at S6 and lowest pH (8.5) at both S3 and S4. In Rainy season, highest pH (8.5) was at three sites S1, S8 and S9. In winter season, the highest pH was at S2, S4, S8 and S9. In winter, lower pH was observed at S1 and S6. The pH of water at S1 as well as at outer channel (S8 and S9) remained

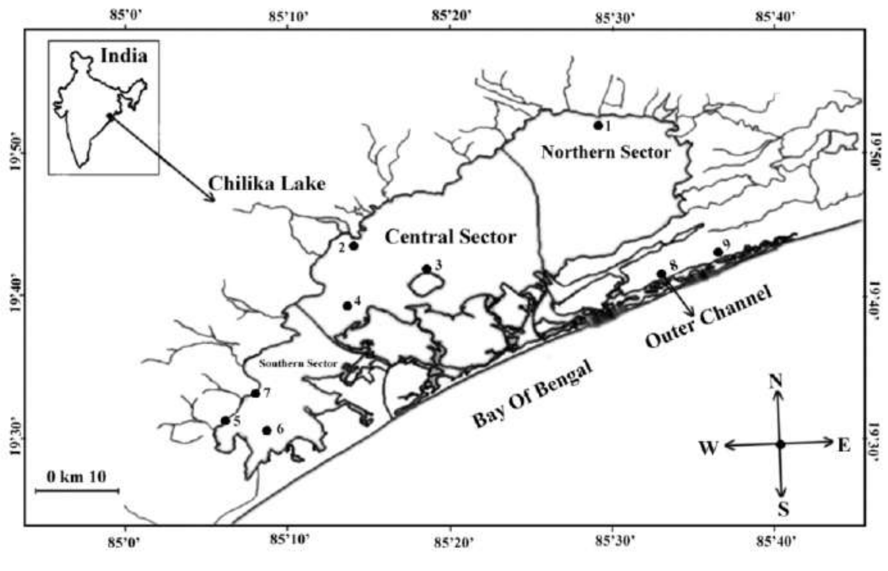

Fig. 1. Map of Chilika Lagoon showing different collection sites: 1. Mangalajodi (S1), 2. Barakul (S2) 3. Nalaban (S3), 4. Kalijai (S4), 5. Rambha (S5), 6. Ghantasila (S6), 7. Badakuda (S7), 8. Sipakuda (S8), 9. Arkhakuda (S9)

alkaline throughout the year (Table 2).The pH of the water was alkaline due to presence of salt in water brought by rivers (S1) and sea water (S8 and S9) in to the lagoon. Devi and Nagendran (2017) reported that alkaline pH could be contributed to high salinity level in the water.

Water transparency: In summer season, highest water transparency was observed at S5 and lowest at S1. During rainy season, among the sites, highest water transparency level (98 cm) was observed at S7 and lowest (50 cm) at S1. In winter season, S7 showed highest water transparency while S1 showed the lowest transparency (Table 3). The water transparency was more at S7 in Southern sector and less at S1 in Northern sector. S7 zone was more transparent may be due to less overland flow. In rainy season, water transparency was less due to presence of soil particles that were brought by rivers and water channels, particularly in northern sector that received silt loaded water through Daya and Bhargavi. During monsoon, the depth of the water column increased due to ingress of fresh water in to the lagoon (Panigrahi et al 2007). Mukherjee et al (2018) also reported that the water transparency was more in Southern sector and less in Northern sector of Chilika lagoon.

Chloride: During winter, the chloride content of the water was higher as compare to other seasons. Among the sites, the chloride was highest at S8 and lowest at S2 during winter (Table 3). In rainy season, the chloride level of the water was low at S2 and highest at S8. In summer season the chloride level was highest at S8 and lowest at S2. At outer Channel the chloride content was more as compare to other sector where salinity was more. This may be due to high evaporation rate and entering of sea water. High chloride content in outer channel, during summer, may be due to water evaporation and free influx of sea water through the mouth at outer channel (Patra et al 2010).The lowest value of chloride content in Central sector may be attributed to the mixing of fresh water into the lake by rivers and run off (Nayak et al 2001). Nayak et al (2010) have also reported more chloride content in outer channel, during summer. The chloride

Table 1. Salinity and temperature of water at different sites of Chilika lagoon, Odisha

Sites	Salinity (ppt)			Temperature (^{0}C)		
	Summer (PRM)	Rainy (MON)	Winter (POM)	Summer (PRM)	Rainy (MON)	Winter (POM)
Mangalajodi (S1)	14.1± 0.15	3.8 ± 0.12	2.1 ± 0.06	30.4 ± 0.40	27.2 ± 0.12	29.5 ± 0.06
Barakul (S2)	15.1 ± 0.10	8.5 ± 0.06	7.5 ± 0.06	29.5 ± 0.06	26.0 ± 0.36	25.0 ± 0.29
Nalaban (S3)	14.8 ± 0.06	7.9 ± 0.06	7.3 ± 0.06	29.0 ± 0.23	26.5 ± 0.05	24.0 ± 0.17
Kalijai (S4)	15.0 ± 0.05	7.5 ± 0.05	7.1 ± 0.05	29.0 ± 0.06	24.5 ± 0.10	24.0 ± 0.06
Rambha (S5)	14.1 ± 0.10	8.2 ± 0.02	8.0 ± 0.05	30.0 ± 0.20	25.0 ± 0.10	24.0 ± 0.05
Ghantasila (S6)	14.3 ± 0.05	9.4 ± 0.06	8.5 ± 0.10	30.0 ± 0.11	24.5 ± 0.15	23.0 ± 0.05
Badakuda (S7)	14.0 ± 0.06	7.5 ± 0.05	7.6 ± 0.05	29.5 ± 0.06	25.0 ± 0.32	24.0 ± 0.05
Sipakuda (S8)	28.5 ± 0.05	24.5 ± 0.10	23.0 ± 0.17	31.1 ± 0.1	31.0 ± 0.20	25.0 ± 0.10
Arkhakuda (S9)	29.0 ± 0.10	25.0 ± 0.10	24.0 ± 0.06	29.5 ± 0.26	29.0 ± 0.05	25.0 ± 0.26

PRM- Pre-monsoon, MON -Monsoon, POM- Post- monsoon
Values are mean ± standard deviations

Table 2. Dissolved oxygen (DO) and pH of water at different sites of Chilika lagoon, Odisha

Sites	Dissolved oxygen (mg l^{-1})			pH		
	Summer (PRM)	Rainy (MON)	Winter (POM)	Summer (PRM)	Rainy (MON)	Winter (POM)
Mangalajodi (S1)	5.8 ± 0.57	8.8 ± 0.57	8.1 ± 0.12	8.6 ± 0.57	8.5 ± 0.57	8.0 ± 0.11
Barakul (S2)	5.4 ± 0.05	2.3 ± 0.1	4.5 ± 0.06	8.6 ± 0.05	8.3 ± 0.06	8.5 ± 0.05
Nalaban (S3)	5.2 ± 0.05	3.1 ± 0.05	5.5 ± 0.05	8.6 ± 0.05	8.3 ± 0.06	8.5 ± 0.05
Kalijai (S4)	7.5 ± 0.05	4.0 ± 0.05	6.6 ± 0.06	8.5 ± 0.05	8.4 ± 0.05	8.5 ± 0.057
Rambha (S5)	7.2 ± 0.05	4.7 ± 0.06	7.5 ± 0.05	8.7 ± 0.06	8.3 ± 0.06	8.1±0.06
Ghantasila (S6)	7.8 ± 0.05	8.2 ± 0.1	8.2 ± 0.05	8.8 ± 0.057	8.4 ± 0.1	8.0 ±0.057
Badakuda (S7)	8.9 ± 0.06	5.6 ± 0.1	7.6 ± 0.05	8.6 ± 0.05	8.4 ± 0.1	8.3±0.05
Sipakuda (S8)	6.5 ± 0.15	4.1 ± 0.1	7.1 ±0.05	8.6 ± 0.057	8.5 ±0.05	8.5 ±0.2
Arkhakuda (S9)	8.5 ± 0.05	5.4 ±0.05	6.2 ±0.15	8.7 ±0.11	8.5 ±0.15	8.5 ±0.15

See Table 1 for treatment details

Table 3. Transparency and chloride concentration of water at different sites of Chilika lagoon, Odisha

Sites	Water transparency (cm)			Chloride (g l^{-1})		
	Summer (PRM)	Rainy (MON)	Winter (POM)	Summer (PRM)	Rainy (MON)	Winter (POM)
Mangalajodi (S1)	75 ± 0.57	50 ± 0.58	80± 1.15	3.3 ± 0.057	3.1 ± 0.11	3.4 ± 0.11
Barakul (S2)	80 ± 0.06	78± 0.06	88 ± 0.06	2.1 ±0.15	0.9±0.09	1.2±0.06
Nalaban (S3)	84 ± 0.05	81 ± 0.05	90 ± 0.05	4.3 ±0.06	2.3±0.2	3.7±0.1
Kalijai (S4)	88 ± 0.057	86 ± 0.05	90 ± 0.057	4 ±0.15	4.9 ±0.066	4.1±0.25
Rambha (S5)	98 ±0.57	96 ±0.40	90±0.57	4.5 ±0.057	5.7 ±0.1	6.3±0.058
Ghantasila (S6)	91 ±0.57	90±0.57	98 ±0.58	6.2±0.1	6.7±0.1	5.9±0.05
Badakuda (S7)	94 ±0.57	98 ±0.57	101±0.58	4.7±0.057	3.2±0.057	6.3±0.057
Sipakuda(S8)	89 ±0.57	80 ±0.57	91 ±0.57	10.2 ±0.057	8.2 ±0.1	13.4±0.057
Arkhakuda (S9)	83 ±0.57	82 ±0.34	86 ±0.57	8.9 ±0.057	3.2 ±0.057	4.3 ±0.11

See Table 1 for treatment details

Table 4. Nitrate and phosphate concentration of water at different sites of Chilika lagoon, Odisha

Sites	Nitrate (µmol l^{-1})			Phosphate (µmol l^{-1})		
	Summer (PRM)	Rainy (MON)	Winter (POM)	Summer (PRM)	Rainy (MON)	Winter (POM)
Mangalajodi (S1)	12.0 ± 0.11	21.0± 0.1	19± 0.11	0.5± 0.06	0.20± 0.006	0.30± 0.006
Barakul (S2)	70 ± 0.06	50 ± 0.32	78 ±0.1	0.8±0.015	1.10±0.06	1.0±0.1
Nalaban (S3)	72 ±0.17	56±0.25	81±0.06	0.9±0.01	0.53±0.006	0.90±0.005
Kalijai (S4)	85 ±0.057	55±0.4	67±0.15	1.1±0.1	0.59±0.006	0.52±0.006
Rambha (S5)	19.1 ±0.1	10.2 ±0.25	14.6±0.05	0.8±0.015	0.26±0.005	0.56±0.025
Ghantasila (S6)	20.2±0.05	13.1±0.15	18.2±0.15	0.9±0.26	0.43±0.25	0.53±0.02
Badakuda (S7)	13.5±0.11	10.4±0.05	11.5±0.2	0.5±0.04	0.16±0.02	0.36±0.025
Sipakuda(S8)	51.2 ±0.1	23.4 ±0.1	38.6 ±0.05	1.1±0.055	0.34±0.01	0.76±0.005
Arkhakuda (S9)	33.4 ±0.1	30.1 ±0.12	30.2±0.20	0.7±0.052	0.30±0.006	0.51±0.015

See Table 1 for treatment details

content of present study was much higher than the standard value 250 mg l^{-1} provided by (WHO 2003).

Nitrate: In summer, among the sites higher nitrate level was at S4 and lower at S1. In rainy season, highest nitrate concentration was at S3 and lowest at S5. During winter, the highest nitrate content was observed at S3 and lowest at S7 (Table 4). Nitrate concentration of the water varied throughout the year. In the present investigation, the highest nitrate content was in summer at S4 was possibly due to the increased temperature. Rise in temperature and rapidly mixing of surface and sub-surface source of water during summer might support to refill the nitrate mechanism. Panigrahi et al (2007) reported that in northern sector nitrate content was more due to presence of major rivers and agricultural drainage in the sector. The nitrate content of present study was much below the standard value 50 mg l^{-1} provided by (WHO 2007).

Phosphate: In summer, two sites (S4 and S8) exhibited maximum phosphate content (1.1 µmol l^{-1}). Minimum phosphate level was at S1and S7. In rainy season, maximum phosphate level was at S2 and minimum at S7. In winter, maximum phosphate level was observed at S2 and minimum at S1 (Table 4). Maximum phosphate content at S4 in Central sector may be due to the release of phosphate from sediment and organic loading in water (Patra et al 2010).

CONCLUSION

Chilika lagoon is influenced by nutrient enrichment due to arrival of fresh water by the river and inflow of sea water into the Lagoon. In the present day different human activities influenced the water quality of the Chilika Lagoon. Deviation in some of the physico-chemical parameters, in the present study, in Chilika lagoon, may be attributed to the change in climatic condition and exchange of water between the sea and lagoon. The physico-chemical parameters of Chilika lagoon are complicated due to the variation in salinity, temperature, dissolved oxygen, river inlets and massive growth vegetation.

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REFERENCES

Devi VV and Nagendran R 2017. Spatial assessment of water quality in Kondurupalem lagoon inlet, South East Coast of India. *Indian Journal of Ecology* **44**(4): 687-696.

Jamilal and Yousuf AR 2018. Seasonal variation in physico chemical charecteristics of Dal Lake, Kashmir. *Indian Journal of Ecology* **45**(1): 33-43.

Muduli PR, Barik SK, Mahapatro D, Samal RN, Rastogi G, Tripathy M, Bhatt, KS and Pattnaik AK 2017. The tropical cyclone 'Phailin' on the hydrology of Chilika Lagoon, India. *International Journal of Environmental Sciences and Natural Resources* **4**(2): 1-9.

Mukherjee M, Suresh VR and Manna RK 2018. Microplankton dynamics of a coastal lagoon, Chilika: Interactive effect of environmental parameters on microplankton groups. *Environmental Monitoring and Assessment* **190**(11): 689.

Nayak BK, Acharya BC, Panda C, Nayak BB and Acharya SK 2001. Variation of water quality in Chilika Lake, Orissa. *Indian Journal of Marine Science* **33**(2): 164-169.

Nayak L and Behera DP 2004. Seasonal variation of some physico chemical parameters of the Chilika lagoon (east coast of India) after opening the new mouth, near Sipakuda. *Indian Journal of Marine Science* **33**(2): 206-208.

Nayak S, Nahak G, Nayak GC and Sahu RK 2010. Physico-chemical parameters of Chilika Lake water after opening a new mouth to Bay of Bengal,Orissa, India. *Continental Journal Environmental Sciences* **4**: 57- 65.

Panda US and Mohanty PK 2008. Monitoring and modelling of Chilika environment using remote sensing data, pp. 617-638. In: M. Sengupta and R. Dalwani (eds), Proceedings *of Taal 2007: The 12th World LakeConference*, October 28– November 2, 2007, B.M. Birla Auditorium and Convention Centre, Jaipur, Rajasthan, India.

Panda US, Mahanty MM, Rao Ranga V, Patra S and Mishra P 2015. Hydrodynamics and water quality in Chilika Lagoon-A modelling approach.8th International Conference on Asian and Pacific coasts. *Procedia Engineering* **116**: 639-646.

Panigrahi S, Acharya B, Panigrahy R, Nayak B, Banerjee K and Sarkar S 2007. Anthropogenic impact on water quality of Chilika lagoon RAMSAR site: a statistical approach. *Wetland Ecology Management Series* **15**: 113–126.

Patra AP, Patra JK, Mahapatra NK, Das S and Swain GC 2010. Seasonal variation in physicochemical parameters of Chilika Lake after opening of new mouth near Gabakunda, Orissa, India. *World Journal of Fish and Marine Sciences* **2**(2): 109-117.

Von den Berg CMG 1999. Methods of sea water analysis, pp 320-319. In: K Grasshoff, K Kremlimg, and M Ehrhardt (eds). *Determination of trace element: Analysis by electrochemical methods*. Wiley-VCH, Weinheim.

World Health Organisation 2003. *Carbofuran in drinking-water.* Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization.

World Health Organisation 2007. *Nitrate and nitrite in drinking-water.* Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization.

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Impact of Wildfire on Biological Activity of Sandy Soil in The South of Russia

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Abstract: The authors considered the effect of a strong wildfire in deciduous and coniferous forests on the microbiological and enzyme activity as well as physical and chemical properties of sandy soil (Arenosol). Soil samples were taken from the top soil (0-10 cm) two weeks after wildfire in Ustdonetsk forestry (Rostov region, Russia). Three areas were selected for the research i.e. area check forest (without wildfire), area short-term wildfire, long-term wildfire. The areas were selected based on the condition of trees and amount of ash on the soil surface. Small amount of ash on the soil surface was indicative of weak fire intensity and large amount of ash was present in area with strong fire intensity. We have found that forest wildfire leads to the decrease in microbial biomass by 12-38 per cent when compared with the check area, decrease in nitrogen-fixing bacteria abundance by 22-52 per cent, decrease in enzyme activity by 11-50 per cent, change in pH level and increase in electrical conductivity.

Keywords: Wildfire, Sandy soil, Pyrogenic effect, Nitrogen-fixing bacteria, Microbial biomass, Enzyme activity

Wildfires have a devastating effect on the forest ecosystems as it cause degradation of vegetation, soil, microorganisms and soil invertebrates. In recent times, there has been a global trend towards the increase in frequency, intensity and duration of forest wildfires. Forest wildfires usually lead to the reduction of total nutrient stock in the burned area because of oxidation, volatilization, ash translocation, leaching and erosion. For example, volatilization and oxidation in case of low-intensity wildfire reduce nutrient stock in the forest litter, i.e. nitrogen is reduced by 54-75 per cent, phosphorus – by 37-50 per cent, potassium – by 43-66 per cent, calcium – by 31-34 per cent, magnesium – by 25-49 per cent, manganese – by 25-43 per cent, boron – by 35-54 per cent (Raison et al 1985). Soil fertility may increase after low-intensity wildfires, since fire transforms the nutrients bonded in plant residues and makes them accessible to microorganisms (Schoch and Binkley 1986). Generally, sandy soils contain less moisture and nutrients as compared with loam and clay loam soils and wildfire may significantly reduce soil moisture and nutrient content. Permeability of soil is reduced due to thermal fracture of the soil aggregates and accumulation of ash on the soil surface, thus enhancing its hydrophobic properties (Robichaud 2000). Wildfire leads to the changes in physical properties of sandy soil, as well as sand - clay ratio (Bogdanov 2012). Decrease in the content of organic matter and soil clay after a wildfire leads to the increase in soil density (Granged et al 2011). Sandy soils consist of 18 per cent clay and over 68 per cent sand in a layer of 0-100 cm. According to the World Reference Base for Soil Resources (WRB), the sandy soils under study belong to Arenosols (Braud et al 2005).

High temperatures during a wildfire and the associated changes in minerals and organics are more intensive in the top soil. However, over time, the pyrogenic agents settle or go to the adjoining unburned areas due to the wind. The indirect effect of wildfire on soil may exceed the direct one. In particular, with the burning of vegetation, the top soil may be subject to wind erosion or landslides (Certini 2015, Shakesby 2015). The objective of the studies was to study the effect of wildfire of different intensity on the biological activity of sandy soil. The importance of this study is to study the impact of wildfire on the biological properties of the soil, how to change the microbiological and enzymatic activity, and in the search for indicators for biodiagnostics of post-pyrogenic soils.

MATERIAL AND METHODS

Study area: The studies were conducted in Ustdonetsk forestry in Rostov region after strong wildfire in August 2017. Soil samples were taken from 6 areas. Location of these areas is shown in Figures 1a, b, 2. Trial area No. 1 is a check area, trial area No. 2 – holdover wildfire, trial area No. 3 – strong wildfire.

Study object is a raw sandy soil (arenosol). During the sampling, the post-pyrogenic sandy soil was dark brown with high content of ash (Fig. 4). Soil samples were taken from burned and non-burned areas. Top soil (0-10 cm) was sampled two weeks after wildfire in deciduous and coniferous forests (Fig. 3a,b), put in plastic bags and delivered to the laboratory for further analysis. The soil was dried and sieved through 1 mm sieve. Dehydrogenase activity was estimated using method described by Galstyan (1978), and its activity was expressed in mg of triphenylformazan 1g of soil in 24 hours released. Phosphatase activity was estimated following the procedure described by Ramirez-Martinez and McLaren (1966) its activity was expressed in mg of P_2O_5 1g of soil in 1 hour. Total microbial biomass was estimated using rehydration method with biocidal treatment and drying of soil at a medium high temperature (65-70°C, 24 h). Microbial biomass was determined based on increase in the content of water-soluble compounds in the dried soil as compared with check fresh soil. Abundance of nitrogen-fixing bacteria of the genus *Azotobacter* was estimated through the method of soil lumps fouling on nitrogen-free medium. The reaction of the medium (pH) of the soil was estimated using potentiometric method, the conductivity was estimated using conductometric method, organic carbon was determined by the Tyurin method in Nikitin modification (Kazeev et al 2016). The total carbon content was determined after the oxidation of 0.1 g dry soil in a mixture of $K_2Cr_2O_7$ and concentrated sulfuric acid, following the method of Schumacher et al (2002).

RESULTS AND DISCUSSION

Change in physical and chemical properties: After forest wildfires, in area with holdover wildfire, pH level changed from 7.1 to 7.3, in area with strong wildfire pH level changed from 7.1 to 7.5. Change in pH level may directly influence the

Fig. 1a. Ustdonetsk forestry before strong wildfire (2017)

Fig. 1b. Ustdonetsk forestry after strong wildfire (2019)

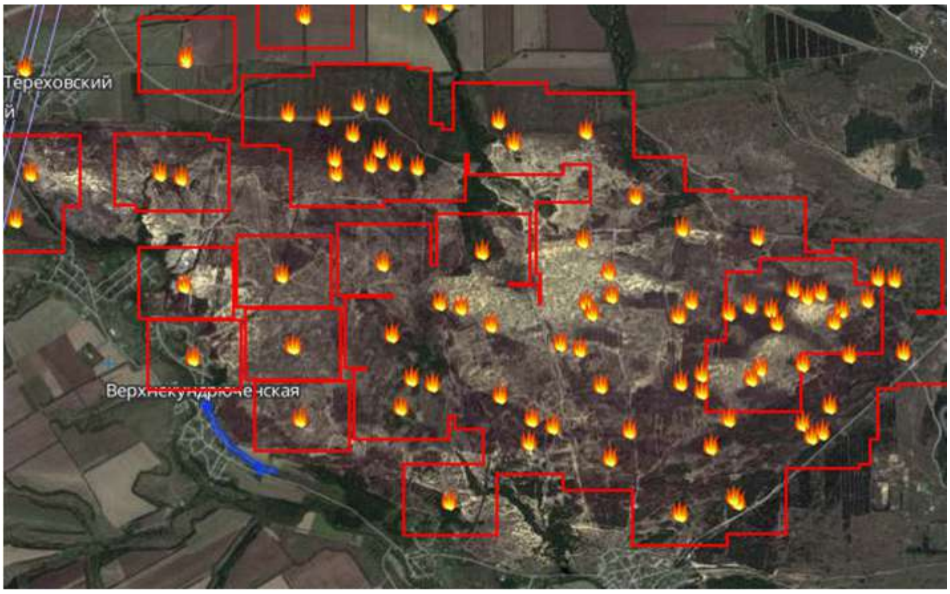

Fig. 2. Fire area

soil biota, chemical reactions in soil, solubility of organic matter (Killham et al 1994).There was insignificant increase in neutral reaction of soil medium. Electrical conductivity of sandy soil after holdover wildfire in coniferous forest, varied from 0.06 to 0.09 (dS m^{-1}), electrical conductivity after strong wildfire increased to 0.11 (dS m^{-1}). Electrical conductivity correlates to biological and chemical properties of soil that impact on soil texture, cation-exchange capacity, drainage conditions, content of organic matter. Low electrical conductivity may be indicative of small content of nutrient elements in soil (Grisso et al 2009). After wildfire in deciduous forest, in area with holdover wildfire, pH level changed from 7.1 to 7.3, in area with strong wildfire, pH level changed from 7.1 to 7.4. Electrical conductivity of soil also changed from 0.10 to 0.15 (dS m^{-1}) after holdover wildfire and from 0.10 to 0.17 (dS m^{-1}) after strong wildfire.

Change in organic matter: After wildfire, content of total organic carbon increases. After holdover wildfire in deciduous forest, content of organic carbon increased from 1.6 to 2.5 per cent, after strong wildfire, content of organic carbon increased to 2.9 per cent. In coniferous forest, after holdover wildfire, content of organic carbon increased from 0.8 to 1.5 per cent, after strong wildfire – from 0.8 to 2.6 per cent (Fig. 5).

Soil organic matter is a major energy source for soil microorganisms. Decrease in organic matter content may

Fig. 3a. Coniferous forest after wildfire

Fig. 3b. Deciduous forest after wildfire

Fig. 4. Soil samples

From left to right: control, short-term wildfire, long-term wildfire lead to the reduction of microbiological activity. The loss of organic matter might occur at temperatures below 100°C. Volatile components of organic matter get lost at a temperature of 200°C. At temperatures of 200-300°C, about 85 per cent of organic matter burn down. At temperatures above 300-450°C, about 99 per cent of organic matter burn down (Neary et al 2005, 2008).

Change in biological activity: Microbial communities are well adapted to broad range of existing temperature conditions. However, radical change in temperature during soil heating may lead to the death of microbial cells and change in microbiocenosis content (Pietikainen et al 2000). After holdover wildfire (deciduous forest), microbial biomass decreased by 32 per cent as compared with check forest, and by 48 per cent after strong wildfire. Microbial biomass after holdover wildfire in coniferous forest decreased by 36 per cent, after strong wildfire – by 52 per cent (Fig. 6). Abundance of nitrogen-fixing bacteria has also decreased. After holdover wildfire (deciduous forest), abundance of nitrogen-fixing bacteria of the genus *Azotobacter* reduced by 45 per cent, after strong wildfire, abundance of nitrogen-fixing bacteria reduced by 60 per cent.

Enzyme activity of soil is closely related to microbial biomass. Dehydrogenases, cellulose, phosphatases and invertase are among the main important enzymes in soils, which are partially responsible for the rate of chemical transformations and decomposition in soil. Activity of dehydrogenases and phosphatases before and after the wildfire was lower than the values of check in the area covered by wildfire. Activity of dehydrogenases in deciduous forest decreased by 30 per cent after holdover wildfire (Fig. 7). In case of strong wildfire, activity of dehydrogenases decreased by 44 per cent. Phosphatase activity decreased by 11 per cent after holdover wildfire and by 33 per cent after strong wildfire. Activity of dehydrogenases in coniferous forest decreased by 32 per cent from the value of check after holdover wildfire and by 48 per cent after strong wildfire. Phosphatase activity decreased by 22 per cent after holdover wildfire and by 39 per cent after strong wildfire (Fig.7). Irreversible inactivation of enzymes was particularly strong on surface soil.

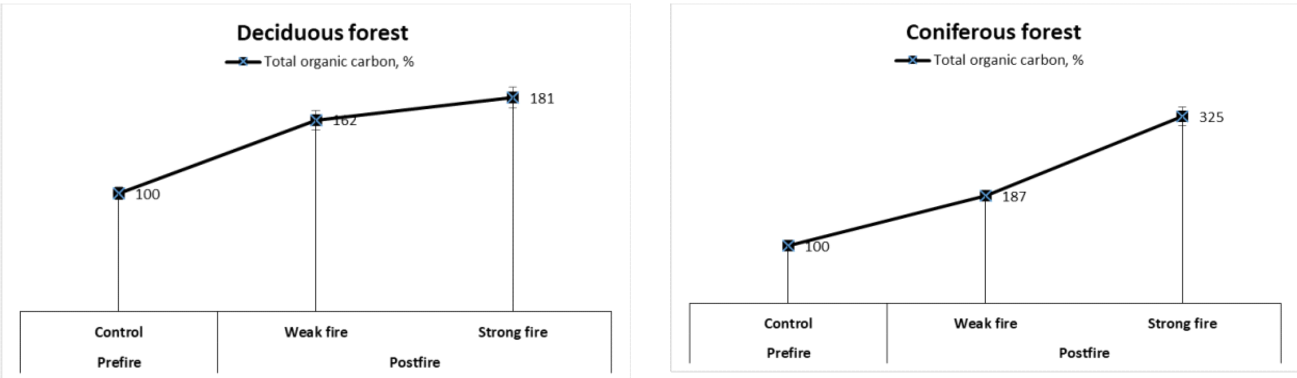

Fig. 5. Change in organic matter after wildfire, % of control

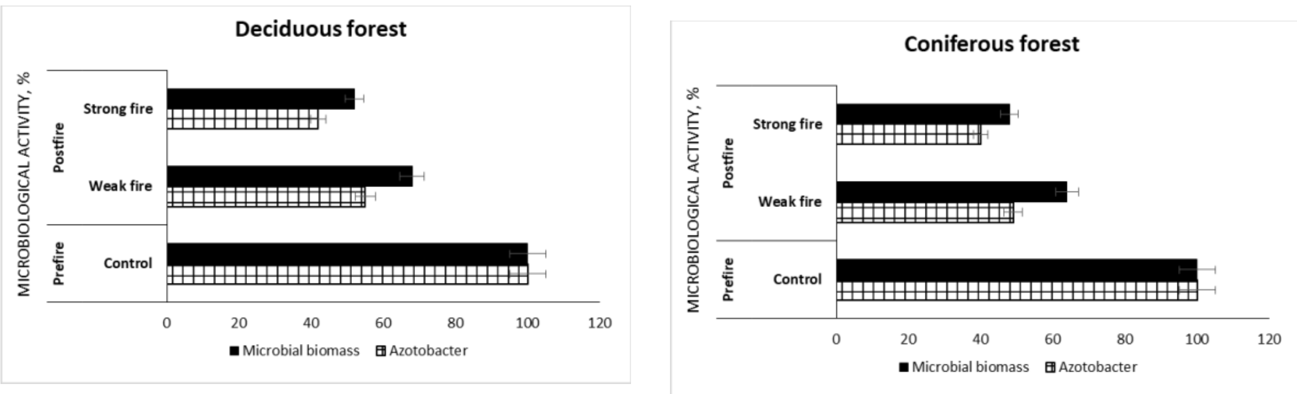

Fig. 6. Change in microbiological properties after wildfire, % of control

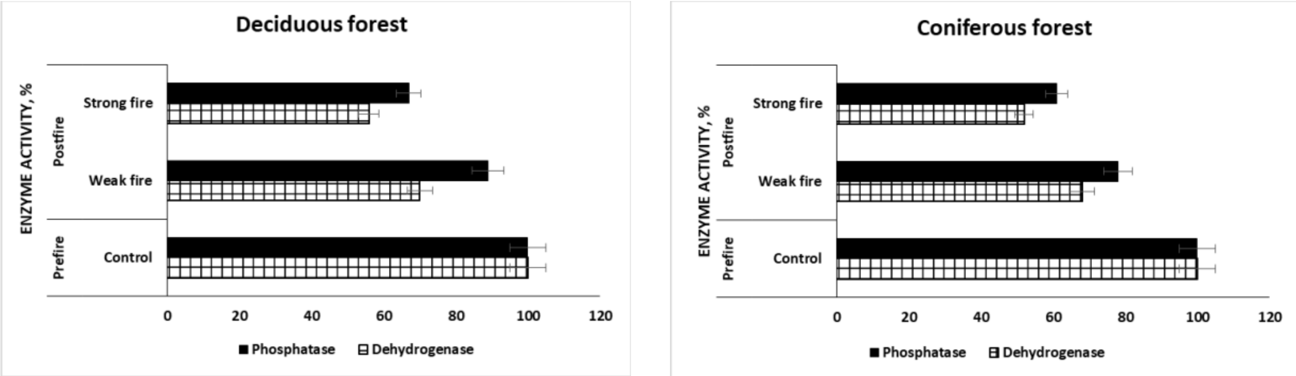

Fig. 7. Change in biochemical properties after wildfire, % of control

CONCLUSIONS

Forest wildfire leads to various changes in the soil under study: increase in pH level and electrical conductivity, decrease in microbiological (12-38 per cent) and enzyme activity (11-50 per cent). Forest wildfire causes significant changes in biological activity of sandy soil, regardless of fire intensity. Activity of soil enzymes strongly depends on temperature, i.e. high temperatures inactivate enzyme activity. Decrease in biological activity indicates a negative effect of pyrogenic factor two weeks after wildfire. That the pyrogenic factor has long-lasting impact on soil, and restoration of ecological and biological functions of soil takes a long time. Sandy soils have low water retaining capacity and, therefore, are subject to drying. Such soils are not able to retain nutrients, so they are easily washed out of soil. Consequently, any changes in soil can lead to significant changes. Decrease in microbial biomass affects enzyme activity. Dehydrogenase activity decreased more strongly than phosphatase activity. Phosphatase was more resistant to pyrogenic effects. Wildfire may have diverse effects on soil, including decrease in microbial biomass and changes in physical, chemical and biochemical properties. The following indicators can be used in soil biological diagnostics after pyrogenic exposure: dehydrogenase and phosphatase activity, abundance of nitrogen-fixing bacteria and total microbial biomass.

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REFERENCES

Bartoli F, Burtina G and Guerif J 1992. Influence of organic matter on aggregation in Oxisols rich in gibbsite or in goethite. *Geoderma* **54**(1-4): 259-274.

Bogdanov S 2012. Forest fire influence on soil texture in burned forests in Bulgaria, *Forestry Ideas* **18** (2): 155-162.

Braund A, Hartmann C and Lesturgez G 2005. Physical properties of tropical sandy soils: a large range of behaviours. In: Hartmann Christian (dir.), Chinabut N. (dir.) *Management of tropical sandy soils for sustainable agriculture: A holistic approach for sustainable development of problem soils in the tropics: proceedings.* Bangkok: 148-158.

Certini G 2015. Fire as a soil-forming factor. *Ambio* **43**: 191-195.

Choromanska U and DeLuca TH 2001. Prescribed fire alters the impact of wildfire on soil biochemical properties in a ponderosa pine forest. *Soil Science Society of America Journal Soil* **65**:232-238.

DeLuca TH and Aplet GH 2007. Charcoal and carbon storage in forest soils of the Rocky Mountain West, *Frontiers in Ecology and the Environment* **6**: 1-7.

DeLuca TH and Sala A 2006. Frequent fire alters nitrogen transformations in ponderosa pine stands of the inland northwest. *Ecology* **87**: 2511-2522.

Galstyan A Sh 1978. Unification of methods for studying the activity of soil enzymes // *Eurasian Soil Science* **2**:107-114. (in Russian)

Granged AJP, Zavala LM, Jordan A and Barcenas G 2011. Post-fire evolution of soil properties and vegetation cover in a Mediterranean heathland after experimental burning: A 3-year study. *Geoderma* **164**: 85-94

Grisso RD, Alley MM, Wysor WG, Holshouser D and Thomason W 2009. Precision farming tools: Soil electrical conductivity. Virginia cooperative extension precision farming tools: Soil electrical conductivity, *Virginia Cooperative Extension* **442-508**: 1-6.

Kazeev K Sh, Kolesnikov SI, Akimenko Yu V and Dadenko EV 2016. Methods of bio-diagnostics of terrestrial ecosystems. Rostov-on-Don: *Publishing House of the Southern Federal University*, p 356. (in Russian)

Khaziev F Kh 2005. Methods of soil enzymology. M.: *Science*. p 252. (In Russian)

Killham K 1994. SoU ecology. Cambridge: *Cambridge University Press.* p 242.

Neary DG, DeBano LR and Ffolliott PF 2000. Fire impacts on forest soils: A comparison to mechanical and chemical site preparation: 85-94.

Neary DG, Carole C, Klopatek CC, Debano LF and Ffoliott PF 1999. *Forest Ecology and Management* **122**: 51-71.

Neary DG, Daniel G, Ryan K, Kevin C and DeBano LF 2005 (revised 2008). Wildland fire in ecosystems: Effects of fire on soils and water. *General Technical Report Gen.* **4**. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p 250.

Pietikäinen J, Kiikkilä O and Fritze H 2000. Charcoal as a habitat for microbes and its effect on the microbial community of the underlying humus. *OIKUS* **89**(2): 231-242.

Raison RJ, Khanna PK and Woods PV 1985. Mechanisms of element transfer to the atmosphere during vegetation fires. *Canadian Journal of Forest Research* **15**(1):132-140.

Robichaud PR 2000. Fire effects on infiltration rates after prescribed fire in northern Rocky Mountain forests, USA, *Journal of Hydrology* **231–232**: 220-229.

Schoch P and Binkley D 1986. Prescribed burning increased nitrogen availability in a mature loblolly pine stand. *Forest Ecology and Management* **14**(1): 13-22.

Schumacher BA, Neary AJ and Palmer CJ 2002. Methods for the determination of total organic carbon (TOC) in soils and sediments. *Ecological Risk Assessment Support Center*. p 25.

Shakesby RA, Bento CPM, Ferreira CSS, Ferreira AJD, Stoof CR, Urbanek E and Walsh RP 2015. Impacts of prescribed fire on soil quality: an assessment based on an experimentally burned catchment in central Portugal. *Catena* **128**: 278-293.

Smithwick EA, Turner HM, Mack MC and Chapin CFS 2005. Post fire soil N cycling in Northern conifer forests affected by severe, stand replacing wildfires. *Ecosystems* **8**: 163-181.

Stevenson FJ and Cole MA 1999. Cycles of Soil (Carbon, Nitrogen Phosphorus Sulfur, Micronutrients). *John Wiley and Sons Publishers*, Hoboken, p 427.

Wardle DA, Zackrisson O and Nilsson MC 1998. The charcoal effect in boreal forests: mechanisms and ecological consequences. *Oecologia* **115**: 419-426.

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Estimation of Biological Filter of Closed Fish Farming System

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Abstract: The aim of this study is to solve one of the most important problems faced fisheries in the closed fish farming system to estimate the efficiency of biological filter and whether the biological filter reached the highest level of effectiveness. This study was conducted in Kazan governmental university for Energy Science, Kazan city in the Russian Federation (R38V+GG) for the period from February to May 2018. The results showed the efficiency of the biological filter is determined by the relationship between the quantity of O_2 and the time. The lower time required for the consumption of O_2 in the filter after stopping the flow of water and air to the filter, the less time needed to consume O_2 increased the efficiency of the biological filter and closer to highest level. The efficiency when the time required for consumption of all O_2 reaches less than 10 minutes. The study recommends finding a table for amount of ammonia provided by fish depending on the amount of food eaten by the fish as well as depending on the amount of protein in the diet by through the equation above.

Keywords: Biological filter, Closed farming system, Fish

Aquaculture in enclosed systems is one of the most important modern techniques used in fish and other aquaculture, which reduces the negative environmental impact. This technology relies on the use of mechanical and biological filters to purify the water and return it to the ponds. Biological filters are used to help control the amount of dissolved ammonia in pond water. The main indicator of water quality in this closed system is the feeding rate when fish digest the protein; it releases ammonia as the result of digestion of the diet protein. The role of the biological filter is to convert these ammonia into nitrite and then to nitrate by nitrogenous bacteria known for its ability to analyze ammonia. Bacteria grow on the outer layers of the biological filter although their growth is rather slow. However, the oxidizing bacteria of ammonia grow faster than the nitrite oxidizing bacteria. There is no uniform way to evaluate the efficiency and productivity of biocompatible filters, although some researchers point to the need to develop industrial standards for biological filters such as Gutierrez and Malone (2006). In addition, the size of the filter and surface area of the biological filter often affect the amount of peak and water circulation, affecting the amount of total nitrogen ammonia (TAN), which can be removed (Summerfelt 2006, Pfeiffer and Wills 2011). The main source of pollution in the closed system is the resulting fish waste after digestion and representation of the food intake and the rest of the unreachable food, so that food becomes a source of water pollution. Quantum pollution is estimated by producing ammonium and organic compounds. The production of organic compounds is based on the amount of oxygen consumed as a result of the oxidation of the material, The quantity of organic pollutants is calculated chemical oxygen demand (COD) and biological oxygen demand (BOD. The aim of the study is to determine the efficiency of the biological filter and the amount of ammonia that this filter can analyze during a certain period and thus know the weight of fish that can be placed in the basin according to the efficiency of the filter and the level of nutrition.

MATERIAL AND METHODS

The trials were conducted in Kazan, Respublika Tatarstan, Russia, R38V+GG. Two closed fish farming systems were installed. Each system consisted of a mechanical filter for the disposal of solid waste, undigested food residues and a biological filter consist of 160 liter plastic filter. Small plastic parts were placed as a surface for bacterial growth of 300 m2 per filter and one tank to fish breeding for each system. In addition to an ultraviolet irradiation a 110-liter Chinese-made device for the purpose of sterilizing the water after leaving the biological filter and returning it to fish ponds again. Carp fish were used, with 55 fish per tank and with an initial weight of 100 g. The fish were gradually placed in the system. On the first day, three fish were placed for each tank and the fish were then sequenced according to the pH value. The fish were fed on a ready-made meal brought from a fish-processing factory in Ufa (Russian city) composed: protein (22.5%), fat (5%), carbohydrates (40%), moisture (7%) (Zheltov and Yu 2004). The temperature and oxygen were measured by MABK300 (Russian-made). The temperature ranged between 22-27C$^{\circ}$ temperature regulators were also controlled by using local heaters, И-160МИ was used to measure pH. The experiment was repeated five times, to reach the goal of the experiment after the system is fully operational, the water and air pumps are closed which supply the water and air to the biological filter basin, the amount of oxygen in the biological filter after closing the water pumps Then measure the amount of O2 and pH in the biological filter for certain periods until reaching the lowest possible level. The temperature and pH was recorded at the beginning and in the end of all trials.

The quantity of ammonia consumed in the biological filter can be estimated by knowing the amount of oxygen consumed within 24 hours by:

$$\text{NH4-N} + 2O_2 \longrightarrow NO_2 + 2H_2O$$

MW 64 17 g (3.765) g

(1)

That is mean 1 gram of NH4-N consume 64/3=3.765 gram of oxygen to be NO2 thus we can calculate the amount of ammonia that can be analyzed in the biological filter by knowing the amount of oxygen consumed by the bacteria in the biological filter and can be measured by the following equation:

$$NH_4 - N_{mg/day} = \frac{02}{3.765} \times L \times \left(\frac{1440}{t}\right) \quad (1)$$

O2 amount of oxygen consumed in the biological filter, L size of biological filter in liters, t Time to consume all oxygen in the biological filter per minute.

RESULTS AND DISCUSSION

The dissolved oxygen can be considered as a vital indicator of the presence of bacteria in the biological filter. In addition, oxygen can be considered as a vital indicator of bacterial growth. The oxygen consumption can be considered as evidence of ammonia consumption. The value of pH decreased in two directions, the first at the beginning and end of the experiment and the second during the five measurements of the experiment (Table1). The increasing efficiency of the biological filter increases with the number of operating days. The oxygen consumption in the first experiment is lower than the rest of the experiments (230 minutes). However, when the biological filter was run for a longer period of time, less time was required to consume all the oxygen in the biological filter (Fig. 1). And is less than 18 minutes in the fifth measurement. This difference is due to the growth of the bacteria well in the biological filter. It can be said that the less time needed to consume oxygen in the biological filter, the efficiency of the biological filter increased due to the consumption of oxygen by the bacteria when the system is shut down. The efficiency of the biological filter can be measured by measuring the rate of oxygen consumption. The less time needed for oxygen consumption, that is mean more efficiency of the biological filter, thus increasing the consumption of ammonia especially in the first 30 minutes. If the oxygen consumption takes less than 12 minutes, the effectiveness of the filter is very good (Table1) (Fig. 1).

In order to determine the amount of ammonia consumed by the biological filter, the biological weight (total weight of the fish) can be determined. Density of rearing for this biological filter or any other vital filter by: Food ratio (from any feed table), proportion of protein in feed, which can give a clear understanding of the amount of ammonia exported by fish and food conversion ratio. From the above we have reached the following equation to know the efficiency of the biological filter in any system:

Efficiency of biological filter = A/B .... (2)

Where: A: The amount of ammonia analyzed by the biological filter within 24 hours

B: Amount of ammonia introduced by fish within 24 hours (By identifying the amount of ammonia introduced by the fish by knowing the percentage of protein in the diet, food quantity provided to the fish and the rate of food conversion of that diet.

The amount of ammonia consumed by bacteria in the biological filter increases the less time needed for oxygen consumption, which means that the filter efficiency increases over time (Table 2).

The increase in body weight reduces the amount of ammonia available as an accidental product of protein digestion. Carlos et al (2013) demonstrated that the amount of ammonia as waste is reduced by using larger fish weight. This is evidence that the largest amount of ammonia is put in the initials weight of growing (weights ranging from 50-150 g which is also the primary weights of growing). The weights used in this experiment. If the amount of fish ammonia is the largest amount possible in the early stages of growth, can conclude that measuring the amount of ammonia in the first

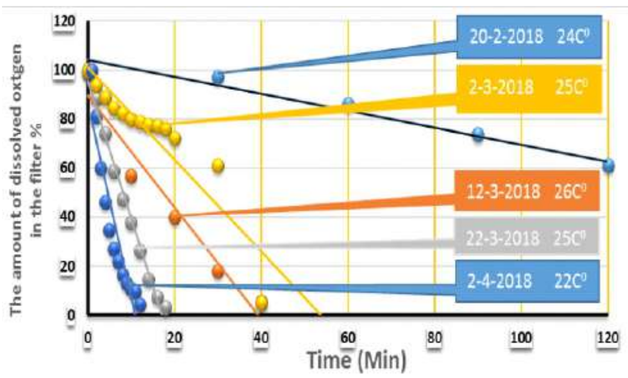

Fig. 1. Dissolved O2 in water, in percent to initial concentration

Table 1. Water temperature and pH at the beginning and end of the experiments and the amount of oxygen per 1 mg l^{-1} in Biofilter at certain time periods during 2018

Period of study		22 February	2 March	12 March	22 March 8	2 April
Temperature ^{0}C		24	25	26	25	22
pH Biofilter	At beginning	8.17	7.89	7.71	7.62	7.42
	At end	7.77	7.32	7.16	6.82	6.72
Amount of oxygen (mg l^{-1}) at different periods(minutes)						
Time-min.		22 -2- 2018	2 -3-2018	12-3-2018	22-3-2018	2-4-2018
0		5.28	6.14	6.98	5.24	5.34
2		5.27	5.75	6.01	4.25	4.49
4		5.25	5.44	5.42	3.13	3.96
6		5.23	5.18	4.75	2.42	3.32
8		5.21	5.05	4.41	1.81	2.64
10		5.19	4.91	3.97	1.42	2.13
12		5.18	4.83	3.64	1.14	1.69
14		5.16	4.77	3.47	0.86	1.17
16		5.15	4.74	3.25	0.68	0.66
18		5.14	4.67	3.01	0.57	0.14
20		5.13	4.44	2.8	0.51	-
30		5.12	3.74	1.27	0.22	-
40		4.91	2.54	0.38	-	-
60		4.54	2.34	-	-	-
90		3.89	1.92	-	-	-
120		3.23	1.45	-	-	-
150		2.83	1.02	-	-	-
180		2.03	0.53	-	-	-
210		1.74	0.31	-	-	-

Table 2. Amount of oxygen in the filter, the time needed for its consumption and the amount of NH_4-N ammonia consumed per mg day^{-1}

Measurement number	O_2 in the Biofilter	Time to consume O_2 (min)	Amount of ammonia NH_4-N consumed (mg day^{-1})
1.	5.28	300	1077.03
2	6.14	210	1789.23
3	6.98	40	10678.56
4	5.24	30	10688.76
5	5.34	18	18154.58

primary weights gives us the concept that the biological filter is sufficient to raise that quantity of fish if they grow and reach the weight of marketing, The size of the biological filter does not need to be changed if the live mass of the fish is increased in that case.

CONCLUSIONS

The results of this experiment can be used to calculate the amount of biomass grown in breeding ponds depending on the size and efficiency of the biological filter and the amount of protein in the feeds fed to the fish.

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REFERENCES

Carlos A, David R and Wálter V 2013. Dietary protein and body mass affect ammonium excretion in white cachama (Piaractus brachypomus). *Revista Colombiana de Ciencias Pecuarias* **27**(2):121-132.

Gutierrez Wing MT and Malone RF 2006. Biological filters in aquaculture-trends and research directions for freshwater and marine applications: Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA*: Aquaculture Engineering* **34**: 163–171.

Pfeiffer TJ and Wills PS 2011. Evaluation of three types of structured floating plastic media in moving bed biofilters for total ammonia nitrogen removal in a low salinity hatchery recirculating aquaculture system. *Aquacultures Engineering* **45**(2): 51–59.

Summerfelt ST 2006. Design and management of conventional fluidized-sand biofilters. *Aquacultural Engineering* **34**(3): 275–302.

Zheltov B and Yu A 2004. Feeding fish with extruded pellets of mixed fodders when growing them in different conditions. *Agrarian Science* **2**(3): 78-83.

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Effect of Physico–chemical and Biological Parameters on Growth of Indian Major Carps in Micro Watershed of Southern Rajasthan

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Abstract: The present study was conducted to assess the growth of Indian major carps in four micro-water sheds (Ogna, Jogiwada, Ghumania-Ka-Naka and Bhanvar Samala) of Udaipur and Pratapgarh district of Southern Rajasthan. The water quality parameter values were within the recommended range for raring of Indian Major Carps. The average primary productivity was the highest (0.44 gC/m^3/hr) in Ogna and lowest (0.07 gC/m^3/hr) was observed in Jpgiwada. The maximum (0.59 gC/m^3/hr) Net Primary Productivity was observed in Bhanvar Samala, while the minimum of (0.04 gC/m^3/hr) was in Jogiwada. The net weight gain, net length gain and Specific Growth Rate were higher in Ognaas compared to Bhanvar Semala, Ghumania-Ka-Naka and Jogiwada.

Keywords: Abiotic factors, Primary productivity, Specific growth rate, Micro water sheds, Fish growth

In southern Rajasthan and especially in Udaipur and Pratapgarh districts a large number of micro- watersheds have been constructed primarily for the purpose of rain water harvesting and for increasing irrigation facilities (Anonymous 2011, DLS 2010-11). Though, these water resources were initially created for irrigation/water harvesting purpose, but now these aquatic resources are serving multipurpose (domestic, irrigation, fisheries.) Due to the increasing interest in fish culture, micro- watersheds are the first choice as these resources are easily available with local tribes of this region. The Rajasthan Tribal Area Development Cooperative Federation, Udaipur has initiated fish farming in micro-water sheds with participation of local tribes. Though, quality seed and other facilities are provided by the RTADCF to farmers, but they are unable to get good outcomes, as the production and productivity reported by RTADCF is very low

The quality of an aquatic system depends upon the physical and chemical characteristics as well as its biological diversity. The physical and chemical properties of freshwater bodies are characterized by the geochemical, climatic, geomorphologic and pollution condition (Chaurasia and Pandey 2007). In order to utilize freshwater bodies successfully for aquatic life and fish production and human consumption, it is very important to study the physico-chemical factors, which influence the biological productivity of the water body (Mishra et al 2016). Looking to the importance of water quality parameters present investigation was conducted to assess the water quality parameters and fish production potentials in selected micro watersheds of southern Rajasthan. Keeping the above backdrop in mind, the specific objectives of the present study are summarized as: To assess the dynamics of selected abiotic factors in selected micro water sheds of southern Rajasthan and correlate fish growth with abiotic factors.

MATERIAL AND METHODS

The present study was carried out during January 2016 to June 2016 with a view to investigate abiotic factors such as water quality, primary productivity and growth parameters in selected micro-water sheds *at* Aquaculture Research and Seed Unit, MPUAT, Udaipur *while field study was conducted in the field.*

Experimental area: The study was conducted on selected micro-water sheds of southern Rajasthan mainly Udaipur and Pratapgarh district (Table 1).

Collection of water sample: To monitor the status of water quality in selected micro-watersheds, water samples were collected monthly (January 2016 to June 2016) using wide mouth sterile transparent plastic bucket. The water samples were secured in one liter plastic bottles with air tight cap. Through-out the experimental period dissolved oxygen, pH and water temperature were recorded *in situ,* whereas TDS, conductivity, hardness, free carbon-dioxide, alkalinity, salinity, nitrate-nitrogen, orthophosphate and ammonium-nitrogen were analysed in the laboratory by following standard protocols (APHA 2005).

Biological Parameter

Primary productivity: Primary productivity was measured in situ with light and dark bottles method. The, glass stoppered black and white BOD bottles of 250 ml were used. The bottles were suspended about 15 cm below the waterline. The incubation period was kept one hours. Oxygen (O_2) estimations in the BOD bottles were made using Dissolved oxygen meter (HACH HQ 30).

Gross oxygen production (GOP) mg l^{-1} = LB-DB

Net oxygen production (NOP) mg l^{-1} = LB-IB

Community respiration (CR) mg l^{-1} = IB-DB

The values of gross and net primary productivity were calculated as follows

A. Gross primary productivity (GPP), gC/m³/hr = GOP×0.375/PQ×h

B. Net Primary Productivity (NPP) gC/m³/hr = NPP×0.375/PQ×h

C. Rate of Community respiration (CR) gC/m³/hr = CR×0.375/PQ×h

Where, LB = Dissolved oxygen in light bottle

DB = Dissolved oxygen in dark bottle

IB = Dissolved oxygen in initial bottle

H = Duration of incubation or exposure

1.2 = A constant

0.375 = A factor value (1 g of oxygen is equal to 0.375 g carbon).

PQ – Photosynthetic quotient (Normally PQ value of 1.2 is considered for field experiments) (Thomas et al 1980).

Fish growth studies: The selected water bodies were stocked with IMC fingerling @ 2500 nos ha^{-1} in the ratio of 3:4:3 of catla, rohu and mrigala. The initial respective size and weight of catla, rohu and mrigala fingerling was 7.2±0.05cm/ 6.19±0.01g, 8.00±0.03cm/5.32±0.02g and 6.9±0.09 cm/4.85±0.02g.

On the basis of initial size of seed stocked and size (length and weight) of harvested/sampled fish growth rate performance was estimated as below.

1. Net weight gain (NWG in gm) = Final weight – Initial weight x 100/ Initial weight.
2. Net length gain (NLG in (cm) = Final length – Initial length x 100/ Initial length
3. Specific growth rate = Ln (Final weight) – Ln (initial weight) × 100/ Day of culture period

RESULTS AND DISCUSSION

Water quality parameters: The water temperature ranged between 28.6 to 32.6 °C. The lowest (30.8 °C) mean water temperature was in Ogna while, the highest (31.25 °C) in both Gumaniya – Ka- Naka and Bhanvar (Table 1). In all the selected micro water bodies the water remained alkaline with mean pH values of 7.3 to 10.8. The highest mean pH value (9.85) was in GumaniyaKa-Naka followed by Bhanvarsemla (Ogna) and Jogiwada. The moderate to slightly alkaline pH has been considered as most suitable for fish culture while pH above 9 is unsuitable. Ujjania (2003) has also observed that alkaline water in the three water bodies of southern Rajasthan. The mean dissolve oxygen ranged between 6.05 to 17.0 mg l^{-1} with lowest in Jogiwada and highest in Gumaniya- Ka- Naka (Table 2). Similar values of dissolved oxygen were also observed by earlier workers in different water bodies of Rajasthan (Sarang et al 2002, Sharma et al 2000, Ojha et al 2019). The free CO_2 was negligible in all selected water bodies. The, total alkalinity varied from 21 to 120 mg l^{-1} h highest in Bhanvarsemla and lowest in Ogna. Similarly the lowest (360 µS Cm^{-1}) and highest (486 µS Cm^{-1}) mean of conductivity was in Ogna and Gumaniya-Ka-Naka, respectively. The amount of total dissolved solids in different

Table 1. Selected water bodies and their geographical location

Water shed name	District	Area (ha)	Longitude	Lattitude	MSL
Ogna	Udaipur	80	24°31.288'N	73°20.251'E	549
Jogiwada		20	24°26.886'N	73°12.803'E	369
Gumaniya-Ka-Naka		10	24°29.993'N	73°08.066'E	420
Bhanvarsemla	Pratapgarh	24	23°59.336'N	74°43.746'E	425

Table 2. Water quality parameters in selected micro-water sheds of southern Rajasthan

Water shed name	Temperature (°C)	pH	DO (mg l^{-1})	Conductivity (µS Cm^{-1})	Alkalinity (mg l^{-1})	Hardness (mg l^{-1})	Salinity (ppt)	TDS (mg l^{-1})	NO_3-N (mg l^{-1})	HPO_4^{-3} (mg l^{-1})	NH_3 (mg l^{-1})
Ogna	29-32.6 (30.8)	7.3-10.8 (9.05)	7.01-9.1 (8.31)	308-413 (360.5)	21-78 (49.5)	122-146 (134)	0.1-0.1 (0.1)	147.9- 199.2 (173.55)	0.135-0.154 (0.140)	0.04-0.5 (0.27)	0-0.24 (0.12)
Jogiwada	28.6-32.1 (30.35)	7.3-10.7 (9.0)	7.22-7.53 (7.375)	411-480 (445.5)	92-110 (101)	170-172 (171)	0.1-0.2 (0.15)	198-233 (215)	0.025-0.096 (0.50)	0.02-0.25 (0.135)	0-0 (0)
Gumaniya-Ka-Naka	28.7-33.8 (31.25)	9.5-10.2 (9.85)	6.05-17.0 (11.525)	453-519 (486)	88-110 (99)	108-148 (128)	0.2-0.2 (0.2)	256-282 (269)	0.175-0.185 (0.180)	0.06-0.14 (0.1)	0-0.45 (0.225)
Bhanvarsemla	30-32.1 (31.05)	9.1-10.2 (9.65)	6.94-7.12 (7.03)	375-375 (375)	108-120 (114)	112-142 (127)	0.1-0.1 (0.1)	180.5-180.8 (180.65)	0.158-0.211 (0.1845)	0.05-0.22 (0.135)	0-0.1 (0.05)

CO_2 – Not detected (ND) in above water bodies water bodies ranged from 173.55 to 269 mg l^{-1}. The mean of all these water quality parameters were within acceptable limits for fish growth and health (Yadav et al 2017, Surnaret al 2018). The highest (0.18 mg l^{-1}) and lowest (0.50 mg l^{-1}) values of nitrate-nitrogen were in Gumaniya-Ka-Naka and Jogiwala. The orthophosphate concentration in micro-water sheds varied between 0.02 mg l^{-1} to 0.25 mg l^{-1} with lowest in Gumaniya-Ka-Naka and Jogiwala. The higher concentration of ammonia is an indication of toxicity in natural water. In the present study, the concentration of ammonia ranged from 00 to 0.6 mg l^{-1} with mean values of 0.0 to 0.45 mg l^{-1}. The highest ammonia content was in Gumaniya-Ka-Nak (Table 2). Similar range of water in water bodies of arid and semi-arid regions of Rajasthan was observed by earlier worker (Sarang 2001, Rajkumar 2005, Balai 2007).

Primary productivity: During the present study, the maximum values of GPP and NPP were observed during summer and subsequently the lower values found during rainy season which corresponds to the intensity of light energy. Lower rate of primary production during rainy season is the result of limitation of sunshine period and low light energy due to interruption of clouds. Subsequently, the dilution effect tof rain on phytoplankton density and as well as the increased in allochthonous turbidity from nearby area are prime causes of lowering primary productivity during rainy season. Gross primary productivity was highest (0.44 gC/m^3/hr) in Ogna and lowest (0.07 gC/m^3/hr) in Jogiwada. The water bodies of Rajasthan are highly productive as compared to those located in other parts of India. The maximum (0.59 gC/m^3/hr) NPP was in BhanvarSamala, while the minimum of in Jogiwada. The highest (0.25 gC/m^3/hr) and lowest (0.05gC/m^3/hr) CR were in Ghumania-Ka-Naka and BhanvarSamala respectively (Table 3 and Fig. 1). Rajkumar (2005) also reported higher average GPP (0.45 gC/m^3/hr) in the Daya reservoir of southern Rajasthan region.The variation of primary productivity of microwater shed is a function of autotrophs associated with utilization of radiant energy. The solar energy that required for biological activities is first converted to chemical energy by the process of photosynthesis primarily executed by phytoplankton and macrophytes.

Table 3. Primary productivity (Rang) of selected micro-watersheds in southern Rajasthan

Water-shed name	GPP (gC/m^3/h)	NPP (gC/m^3/h)	RQ (gC/m^3/h)
Ogna	0.13-0.73	0.08-0.46	0.04-0.30
Jogiwada	0.09-0.14	0.02-0.06	0.03-0.3
Ghumania- Ka -Naka	0.34-0.53	0.12-0.25	0.09-0.41
Bhanvar Samala	0.09-0.13	0.06-0.06	0.03-0.08

Fish growth: The highest growth in terms of net weight gain of Indian major carps was in Ogna as compared to Jogiwada, Ghumania-Ka-Naka and BhanvarSemla (Table 4). Among different species of Indian major carp catla had shown the highest growth in terms of gain in weight and length of 931.91g and 24.39 cm respectively in Ogna followed by

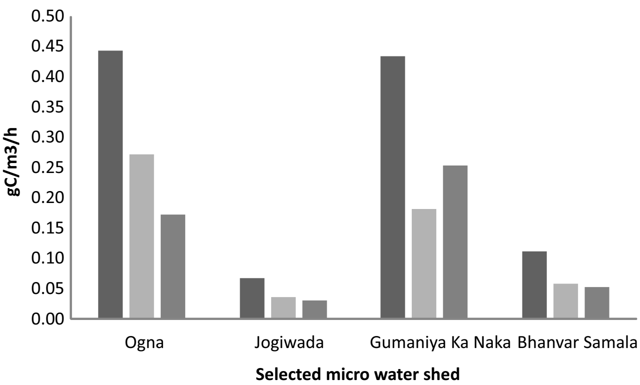

Fig. 1. Primary Productivity (mean) of different micro water shed of Udaipur and Pratapgarh district

Table 4. Growth of Indian major carps (catla, rohu and mrigal) in selected micro-watersheds of southern Rajasthan

Water Body	Species	Weight (g)			Length (cm)		
		Initial	Final	NWG	Initial	Final	NLG
Ogna	Catla	6.19±0.01	938.10	931.91	7.2±0.05	31.59	24.39
	Rohu	5.34±0.02	735.58	730.24	8.0±0.03	25.36	17.36
	Mrigal	4.85±0.01	445.63	440.78	6.9±0.09	18.57	11.67
Jogiwada	Catla	6.19±0.01	768.57	761.81	7.2±0.05	25.88	18.68
	Rohu	5.34±0.02	633.65	628.31	8.0±0.03	21.85	13.85
	Mrigal	4.85±0.01	396.12	391.27	6.9±0.09	16.50	9.60
Ghumania-Ka-Naka	Catla	6.19±0.01	823.81	817.62	7.2±0.05	27.74	20.54
	Rohu	5.34±0.02	644.23	638.89	8.0±0.03	22.21	14.21
	Mrigal	4.85±0.01	491.26	486.41	6.9±0.09	20.47	20.47
Bhanvar Semala	Catla	6.19±0.01	879.05	872.86	7.2±0.05	29.60	22.40
	Rohu	5.34±0.02	671.15	665.81	8.0±0.03	23.14	15.14
	Mrigal	4.85±0.01	449.51	444.66	6.9±0.09	18.73	11.83

NWG= Net Weight Gain; NLG= Net Length Gain; SGR= Specific Growth Rate

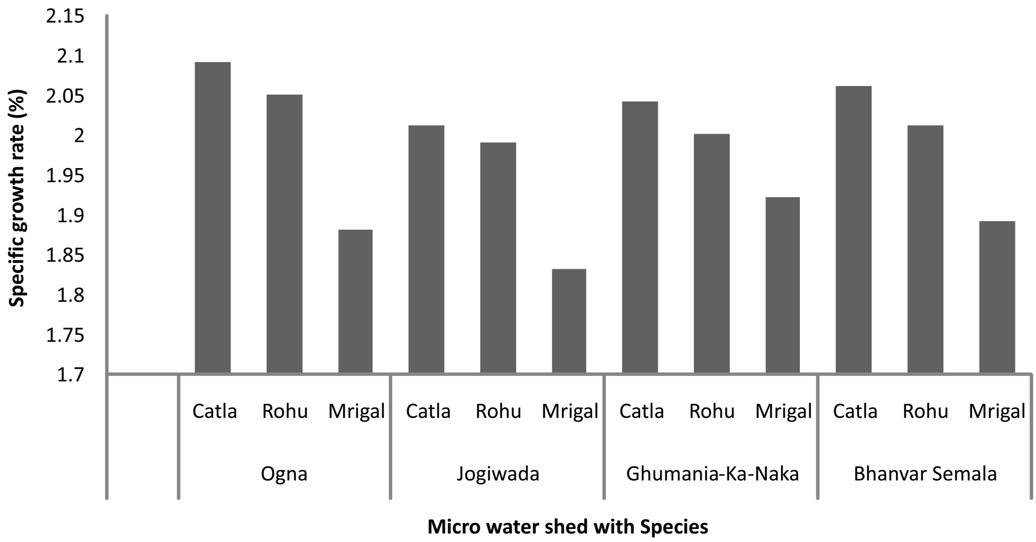

Fig. 2. Specific growth rate of Indian major carps in different micro water sheds of Udaipur and Pratapgarh districts

BhanvarSemala (Pratapgarh), Ghumania Ka-Naka and Jogiwada. A similar trend was noticed for the growth of rohu with highest in Ogna and lowest in Jogiwada. However, mrigal has shown highest growth in Ogna (724.8 g and 26.8 cm) followed by Ghumania-Ka-Naka, BhanvarSemala and Jogiwada. The specific growth rate (2.09%) of catla and rohu was in Ogna followed by BhanvarSemala, Ghumania-Ka-Naka and Jogiwada (Fig. 2). However, the specific growth rate of mrigal was highest in Ghumania-Ka-Naka (1.92%) followed by BhanvarSemala Ogna and Jogiwada. Thus the productivity reported from different micro-water sheds further intensifies the findings of these researches (Ojhaet al 2019). Yadav et al (2016) also studied on the growth performance of Indian major carps in micro water shed of Southern Rajasthan and these result shows similar trend of fish growth.

CONCLUSION

The present experiment is helpful to understand thePhysico-chemical parameter of micro water shed of Udaipur and Pratapgarh districts of Southern Rajasthan. This study concluded that the high productive water and fish growth observed from selected micro water shed was from Ogna followed by BhanvarSemala, Jogiwada and Ghumania-Ka-Naka. All the physico-chemical parameters revealed monthly variation and were within the recommended standard for fresh water bodies.

REFERENCES

Anonymous 2011. Agriculture Statistics at Glance, Directorate of economics & statistics, Ministry of Agriculture, Government of India.

APHA 2005. Standard Methods for Examination of water and wastewater. *17th edition.* American Public Health Association, American water work association and water pollution control Federation, *Washington D.C.* 1193 pp.

Ayyappan S and Gupta TRC 1980. Limnology of Ramasamudra Tank. *Journal of the Inland Fisheries Society of India* **12**: 1-12.

Balai VK 2007. *Current fish and planktonic biodiversity in the reservoir Jaisamand, Udaipur, Rajasthan*. Ph.D. thesis submitted to MPUAT, Udaipur.

Bharadwaj R and Sharma LL 1999. Study of some physico-chemical characteristics of a sewage fertilized seasonal pond of Udaipur (Rajasthan). *Journal of Environment and Pollution* **6**: 255-260.

Chaurasia M and Pandey GC 2007. Study of physico-chemical characteristics of some water ponds of Ajodhya, Faizabad. *Indian Journal of Environmental Protection* **27**(1):1019-1023.

DLS (Department of Land Resources) 2010-11. Status Report, Government of Rajasthan. Retrieve from, https://www.dolr.gov.in/sites/default/files/PPR10-11.pdf.

Ganapati SV and Kulkarni PD 1973. *Primary production in the siddanath temple tank at Baroda, India*. Supplementary paper submitted in the IBP-PP synthesis meeting, Aberystwyth.

Gupta MC, Rajabanshi VK and Sharma LL 1991. Primary productivity and zooplankton of a shallow pond of southern Rajasthan. In: *Current Trends in Fish and Fishery Biology and Aquatic Ecology*, University of Kashmir, Srinagar (India) **15**: 365pp.

Jhingran VG 1977. Optical appearance and interpretation of Annuli on scales *Gadusiachapsia*. *Journal of the Inland Fisheries Society of India* **9**: 138-153.

Jhingran VG 1983. Fish and fisheries of India. *Hindustan Publishing corporation*, Delhi: 666 pp.

Kannel PR, Lee S, Lee Y, Kanel SR and Khan SP 2007. Application of water quality indices SPELLING and dissolved oxygen as indicator for river classification and urban impact assessment. *Environmental Monitoring and Assessment* **132**: 93-110.

Kaushik A, Kansal A, Meena S, Kumari S and Kaushik CP 2009. Heavy metal contamination of river Yamuna, Haryana, India. Assessment by metal enrichment factors of the sediments. *Journal of Hazardous Material* **164**: 265-270.

Kumar A and Singh LK 2002. Eco-strategies of water management in India in ecology of polluted water. (Ed. A. Kumar). Ashish publishing houseNew Delhi, pp. 597-619.

Kumar A, Ravi C, Chanu TI, Mishra S, Kumar U and Das PC 2017. Effect of different weaning strategies on survival and growth of endangered fish Pengba, *Osteobrama bengeri* (Valenciennes,) larvae. *International Journal of Pure & Applied Bioscience* **5**: 951-957.

Mazik PM, Hinman ML, Winkleman DA, Kleine SJ, Simco BA 1991. Influence of nitrite and chloride concentrations on survival and hematological profiles of striped bass. *Transactions of the American Fisheries Society* **120**: 247-254.

Mishra Varun, Surnar Sharad R and Sharma SK 2016. Some limnological aspects of Goverdhan Sagar Lake of Udaipur, Rajasthan to suggest its fisheries. *International Journal of Science, Environment and Technology* **5**(5): 2943–2948.

Nandan S N and Magar UR 2007. Limnological studies of Girna Dam of Nashik with relation to algae. *Proceedings of DAE-BRNS National Symposium on Limnology,* Udaipur (Rajasthan), 19-21 Feb, 274-277.

Ojha ML, Suman AK, Saini VP and Surnar SR 2019. Effect of selected abiotic factors on fish growth in micro-water sheds of southern Rajasthan (Dungarpur).*I nternational Journal of Pure & Applied Bioscience* **7**(1): 83-91.

Prabhakar VM, Vaidya SP, Garud VS, Swain KK 2009. Trend in Primary Production in Khdakwasla Reservoir.13th World Lake Conference, Wuhan, China, 2009.

Rajkumar 2005. *Some aspects of fish biology and fisheries potential in relation to current water quality status of Daya reservoir, Udaipur (Rajasthan)*. Ph.D. (limnology) thesis *MPUAT*, Udaipur.

Sarang N 2001. *Selected aspects limnology and productivity of Jaisamand Lake, Udaipur, (Rajasthan).* M.Sc. thesis submitted to MPUAT, Udaipur.

Sarang N, Sharma LL and Devaradi B 2002. Impact of accidental bio-manipulation on water quality of Jaisamand lake: A case study from Udaipur, Rajasthan. *Proceedings of XI National Symposium on Environment*, Udaipur (Rajasthan), 5-7 June, 335-338.

Received 09 May, 2019; Accepted 31 July, 2019

Sharma D and Jain R 2000. Physico-chemical analysis of Gopalpura Tank of Guna district (M.P.). *Ecology Environment and Conservation* **6**: 441-445.

Sharma MS and Durve VS 1985. Tropic status and fishery potential of Rajasthan waters. *Proceeding of Zoological Survey of India* **94**: 395-402.

Sugunan VV 1995. Reservoir fisheries of India.FAO, Rome, Italy. *Fisheries Technical Paper,* 345-421.

Surnar Sharad Raosaheb, Ojha ML, ThongamI bemcha Chanu, Saini VP and Sharma Arun 2018. Effect of water depth with respect to survival of *Clariasmagur*(Hamilton, 1822) larvae in two tier larval rearing system. *Journal of Entomology and Zoology Studies* **6**(5): 2192-2197.

Swingle HS 1967. Standardization of chemical analysis of water and pond muds, *FAO Fish. Report* **44**:397-348.

Talling JF, Wood RB, Prosser MV and Baxter RM 1973. The upper limit of photosynthetic productivity by phytoplankton. Evidences from Ethiopian Soda Lakes. *Freshwater Biology* 53-76.

Ujjania NC 2003. *Comparative performance of Indian major carps (Catlacatla, Labeorohita and Cirrhinus mrigala) in Southern Rajasthan*. Ph.D. thesis submitted to CIFE, (ICAR), Mumbai.

Wassink EC 1975. Photosynthesis and Periodicity in different environments. In: *Photosynthesis and Productivity in different environments* (Ed. J.P. Copper).

Yadav Rohitash, Sharma OP, Saini VP and Surnar SR 2017. Growth performance of Indian major carps in microwater sheds with special reference to supplementary feeding. *Ecology Environment & Conservation* **23**(3): 219-223.

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Using Pre-chemical and Membrane Bioreactor for Dairy Effluent Treatment

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Abstract: In this research, the performance of the biological aerobic treatment accomplished with chemical primary treatment using alum system has been tested and aerobic biological treatment then comparing it with aerobic biological treatment alone in reducing the concentration of organic load, phosphorus and nitrogen from dairy waste water plants. The average water flow of the effluent from the system 1 m^3 hr^{-1}. and consists of sedimentation tank volume of 2.5 m^3, aerobic reactor size of 5 m^3 and membrane bioreactor size of 5 m^3 inside the one piece of hollow fiber membrane submersible. The use of pre-treatment with alum and then membrane bio reactor reduced the concentration of total solids TSS to less than 1 mg l^{-1}, the concentration of phosphorus as PO4 decreased to less than 2 mg l^{-1}, and nitrate NO_3 to less than 8 mg l^{-1}. The alum primary treatment was able to reduce the residual Chemical Oxygen Demand COD= < 40 mg l^{-1}. Thus, from that specifications of the water from biological treatment with alum limits of the total suspended solid TSS <1 mg l^{-1}, the concentration of phosphate PO4-P < 5 mg l^{-1}, nitrate NO3< 25 mg l^{-1} and the concentration of organic material of COD 150-90 mg l^{-1} to dispose of organic materials and to obtain safe water for agricultural rivers.

Keywords: Dairy, Membrane, Alum, Phosphate, Hallow fiber

Fresh water is expected to become a rare coin in the 20th century due to the growing world population, increased urbanization, climate change and widespread industrial pollution, making water the most expensive resource in the future and the major and human issues of these successive generations (Buzatu and Lavric 2011). Therefore, developed countries are devoting their efforts to the exploring new and diverse technologies for the treatment of wastewater from different manufacturing plants (Yusmel et al 2014). The dairy industry is the largest source of wastewater in many countries of the world. Huge amount of wastewater generated from dairy industry contains high organic and inorganic with high levels of chemical oxygen demand (COD), biological oxygen demand (BOD), oils and grease, nitrogen and phosphorus (Ashish and Omprakash 2014). The changing nature of this water in terms of flow rates and the organic matter content of nitrogen, phosphorus and solids make the selection of an effective treatment system difficult (Asian 2005, Buzatu and Lavric 2011). Discharging this water directly to the sources of natural water or treating it inefficiently requires issuing more stringent environmental protection instructions and laws than those currently in force (Cui et al 2003). For the past ten years, most food and dairy processing plants in the developed world have been forced to investigate and find the most profitable ways to treat wastewater (Sun and Zuo 2009, Chandrasekhar et al 2017). Due to the scientific development in the field of wastewater and industrial treatment, several treatment techniques were developed, notably membrane bio reactor (MBR) (Medhat 2011, Yusmel et al 2014). Bio-treatment with bio-submersible membranes has been used to obtain pure water below the minimum allowable amount of water before returning it to the environment by (Singh 2006). The membranes form a natural barrier preventing the passage of biomass and other pollution (Steven et al 2001). This process allows a high level of suspended solids known as mixed liquor volatile suspended solids(MLVSS) up to 12,000-15000ppm, allowing a long retention time for Sludge Retention Time (SRT) and a 75-day ventilation reactor reduces sludge production by 70% (Gander et al 2001). The first use of this technique by the world Dorr-Oliver since then has been many improvements in many features (Wiesmann et al 2007), especially membrane performance and quality of the use of this technique as well as the lack of cost of membranes and increase the number of producers in different countries of the world, which gave them an important role in the reuse water treatment (Judd 2006, George 2012, Anrade et al 2015). There are different types of membrane binding systems are available in many markets, but most often there are two distinct types of membranes: uses hollow fiber membranes or a flat sheet inside a ventilator called the submerged membrane bio reactor (SMBR), where the flow of wastewater from outside to inside the membrane creates vacuum pressure inside the membrane by using a pull pump (Patsios and Karabelsa 2007, Robinson 2008). The second type is called a cross flow system, which uses pipes outside the ventilator and pumps in the wastewater to separate the treated water through a high pressure pump which requires high energy. The first type of SMBR technology was developed by (Dufresne et al 1997) characterized by complete removal of solids, high flow rate per unit area, production of small shovels and compressed volume and lower power consumption. The SMBR, defined as a system that combines biological degradation of wastewater effluents with membrane filtration (Cicek et al 1999). The aim of this study was to evaluate the applicability for treatment of dairy wastewater by using biological and pre-chemical methods for membrane bioreactor (MBR) through aerobic process for reuse water in various applications in the Abu-Ghraib plant/ in the capital of Baghdad.

MATERIAL AND METHODS

The samples were collected form an industrial effluent of Abu-Ghraib dairy plant. The water specifications with the national determinants required till water released to the environmental give in Table 1, according to (Asfary 2004). Water samples were withdrawn from influent water, Biological treatment, Combined treatment, and from water discharged to river in sterile polyethylene jars and kept until used for analysis in the dairy plant laboratory as in Table1.

System: An MBR pilot plant with a submerged membrane configuration is located in the town of Abu-Ghraib/General Establishment for Dairy Products Baghdad/Iraq. The components of the research processing system consisting of three rectangular tanks made from carbon steel material plated with epoxy Figure 3. First tank is the 2.5 cm^3 settling

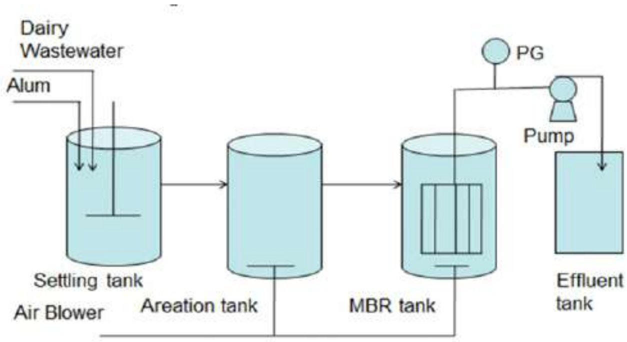

Fig. 1. Components processing system

tank equipped with a mixer to ensure the coagulation process. The second tank is the aerobic tank a $5m^3$ aerobic tank equipped with 6 air diffusers diffuser with 10cm diameter and installed at the base of the reactor. The third tank is the Submerged Membrane Bioreactor (SMBR) that a reservoir of 5 m^3 inside the tape cassette containing 24 pieces of membrane made in the form of hollow fiber of polypropylene material with 0.1μm, porosity, and the surface area of the membrane was 8 m^2 as in Figure 2. Continuous coarse bubble aeration by air diffuser was applied to promote local cross flow velocity along the membrane surface and simultaneously produce enhanced dissolved oxygen (DO). The membrane bioreactor separates the treated water from the biomass and then, treated water is pulled out by the diaphragm pump at a flow rate of 1 m^3 hr^{-1} and pumped into the effluent tank. The pressure differentials are monitored by the Trance Membrane Pressure (TMP) PG which is directly on the water withdrawal line produced and is usually 4-6psi, vacuum pressure in this experiment.

This system was fed with a volumetric flow of 1 m^3 hr^{-1} of wastewater, the characteristics of which are shown in Table 1. Specifically, the sludge retention time is around 30 days at the bottom of the membrane module, produces an air flow rate of 6 Lm^{-2} s^{-1} to generate coarse bubbles that cause strong turbulence so as to clean the surface of the membrane

Table 1. Specifications of Abu-Ghraib dairy plant water compared with the national determinants

Test	Industrial wastewater (Abu Ghraib Dairy Plant)	Standard specifications of water reuse (Abaoi and Hassan 1990)
Residual Bio-Oxygen (BOD)	2000 mg l^{-1}	<40 mg l^{-1}
Residual Oxygen Chemical (COD)	1200-3500 mg l^{-1}	<100 mg l^{-1}
Total Suspended Solids (TSS)	250 mg l^{-1}	60 mg l^{-1}
Nitrate NO_3^{-1}	125 mg l^{-1}	50 mg l^{-1}
Phosphate PO_4^{-1}	10 mg l^{-1}	3ppm
Turbidity	500 NTU	
Acid function (pH)	6-8	6-9.5
Fat and grease	316 mg l^{-1}	-

and thus limit membrane fouling. Membrane filtration is carried out in conventional sequential cycle mode: 9 min with filtration and 1 min without filtration (relaxation time). During the relaxation time, the coarse bubble aeration is on, so the membrane cleaning is carried out in a cycle mode: 1 min of coarse bubble aeration and 9 min. without such aeration according to (Andrade et al 2014).

Mechanism of system action: Two successive periods were followed: The first operation, biological treatment lasted about 70 days. The dairy wastewater was taken into aeration reactor then separate effluent water by using submerged membrane. The second stage of joint treatment between biological treatment and chemical treatment lasted about another 70 days by adding the settling tank to the research treatment system which represents the initial treatment of wastewater for the dairy factories, and with 50ppm dosing of alum (Aluminum sulfate).

Methods of analysis: The performance of the system is monitored by monitoring the quality of the water entering the system compared with produced water after passing through alum and membrane bio reactor by using different equipment and methods (Table 2).

Fig. 2. Submerged Membrane Bioreactor (SMBR)

Fig. 3. Experimental system for the treatment of wastewater of Abu Ghraib Plant/Baghdad

RESULTS AND DISCUSSION

Characterization of Dairy Influent and Effluent

pH: pH is one the important parameter of wastewater which shows acidic and alkaline based on its intensity. In this experiment initial pH of the industrial wastewater (feed) is about 3.7 because the dairy wastewater is acidic and we added NaOH to feed line. After that it was observed that the gradual increase in pH about (7.5-8) over two stages of experiment performance in which permeate comes to base which is nonhazardous to the environment. This result was lower than founded by (Sadik 2017, Bala and Nehru 2012).

Turbidity: Measurement of turbidity was used by

Table 2. Standard method used for estimation of different parameters

Waste water quality parameter	Analytical Instrument and method
BOD5	Oxitop-meter (OC100 – Germany).
COD	The titration method according to standard method NO.5220B
Turbidity	Turbidity meter (TURBO550,WTW,Germany)
Nitrate nitrogen	Colorimetric method, spectrometer (uv754,CANY,China)
TOC	UV 9200 (LTD,UK, biotech. engineering)
Dissolved oxygen (DO)	DO electrometer (pH,Oxi340i, WTW, Germany)
Mixed liquor suspended solid MLSS	The drying method according to standard method NO.2540D
pH	pH 110 (Senso Direct, Lovibond, Type 330)
Concentration	Jar Test
Total bacteria number	Most propal number
Coliform	Filtration method

TURBO550with the units NTU, and turbidity is strongly affected by wastewater pollution. Initially dairy plant wastewater turbidity (feed) value was 32 NTU, then gradually decreased by time and filtrate turbidity value reached to 5 NTU as in Fig. 4 and Table 1, after experimental process was carried out for 70 days by using both biological treatment and membrane process. This reduction in turbidity due to the increase of biological growth in the tank and the formation condense layer of gel on the surface of the membrane that will collect and adhesive any particles and bacteria founded there, thus will reduces the permeability of the membrane, which in turn leads to decrease the turbidity to 5 NTU Table 1. Then the turbidity value reached to less than 1NTU due to the coagulation and deposition of some suspended solids in the sedimentation tank and this finding was identical to finding by (Cui et al 2003; Chandrasekhar et al 2017).

Chemical Oxygen Demand (COD): Chemical oxygen demand (COD) test is used for measuring the pollutants and organic strength/cubic meter of effluents. This measurement qualifies the total quality of oxygen required for oxidation of carbon dioxide and water. COD was analyzed during the treatment of dairy plant wastewater with biological process for degradation of organic matter and it shows effectiveness for the treatment. Results of this study showed that the COD is reduced from 1000-3000 mg l^{-1} to 90-150 mg l^{-1} were performed for 70 days as in Figure 5. The COD reduction was takes places especially by biological treatment and membrane process. The removal efficiency of COD is due to the degradation of organic content which run through aerobic system of operation. This result was lower than (Bala and Nehru 2012).

Phosphorus removal : Phosphorus is deposited in the form of aluminum phosphate using alum. The graph showed that phosphorus is gradually reduced by time (Fig. 6). It content was ranged from 0.8 -10 mg l^{-1} which is less than standard 2 mg $l^{-1}$by this treatment (Sedlak 1991). pH value of wastewater was 7.3, relatively high values due to the excess phosphorus produced by biological treatment alone, then decreased to a minimum limit 0.8 mg l^{-1} affected by the amount of load reaching the biological treatment tank. This result comparable to (Drews et al 2005, Gauthier 2011).

Result of this study showed that the concentration of nitrates in the wastewater entering the research treatment system up to 125 mg l^{-1} as in Table 3. Over time, and by continuous operation of the system decreased the concentration of nitrate to 10mg / l in this treatment.

Microbial content: After collection of dairy plant effluent which was serially diluted on nutrient agar plates for the growth of microbial culture. The serially diluted nutrient agar plates were performed from 10^0 to 10^{-6}. The colonies were

Table 3. Characteristics of Abu-Ghraib dairy waste water

Quality parameter	Units	Feed value	Effluent value
pH	-	3.7	8.0
TDS	Mg l^{-1}	2230	10
TSS	Mg l^{-1}	450	250
Turbidity	NTU	35	<1
COD	Mg l^{-1}	3000	<40
BOD_5	Mg l^{-1}	1570	200
Nitrate $(NO_3)^{-1}$	Mg l^{-1}	10	10
Phosphate $(PO_4)^{-1}$	Mg l^{-1}	500	15

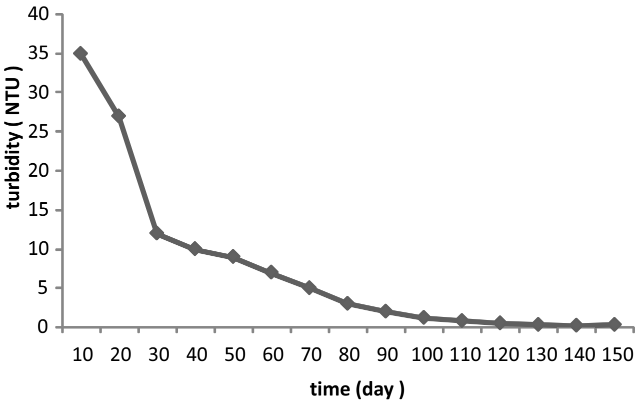

Fig. 4. Reduction of turbidity in effluent water with time

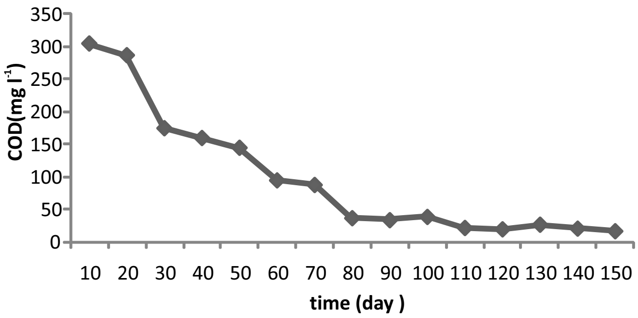

Fig. 5. Reduction of COD in effluent water with time

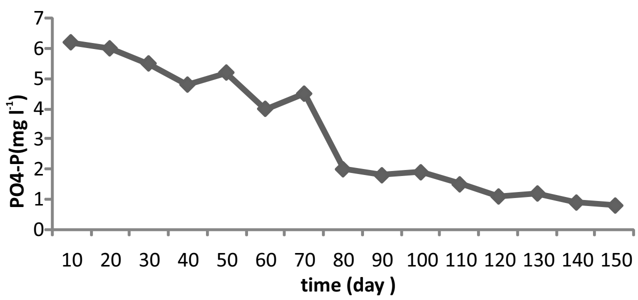

Fig. 6. Reduction of Phosphate in effluent water with time

Table 4. Rate of wastewater specifications from the Abu Ghraib plant compared with national determinants

Test	Water				
	A	B	C	D	E
Biological oxygen demand ($BOD_{)}$	2000 mg l^{-1}		<15 mg l^{-1}	<40 mg l^{-1}	10 mg l^{-1}
Chemical oxygen demand (COD)	3000 mg l^{-1}	150-90 mg l^{-1}	<40 mg l^{-1}	<100 mg l^{-1}	40 mg l^{-1}
Total suspended solids(TSS)	250 mg l^{-1}	-	-	60 mg l^{-1}	10 mg l^{-1}
Nitrate $(NO_3)^{-1}$	10 mg l^{-1}	<25 mg l^{-1}	<10 mg l^{-1}	50 mg l^{-1}	50 mg l^{-1}
Phosphate $(PO_4)^{-1}$	500 NTU	<5 mg l^{-1}	<2 mg l^{-1}	3 ppm	12 ppm
Turbidity	6 - 8	<5 mg l^{-1}	<1 mg l^{-1}		
Acid function (pH)	4.5	7.5-8.5	7.3-8	6-9.5	6 – 8
Total bacterial count (TNC)		54-60 unit/100ml	54-60 unit/100ml	50 unit 1ml^{-1}	
Fecal coliform bacteria (E-coli)		_	_	0 coliform/ 100ml in2 unit	2.2 coliform/ 100 ml
Worms eggs	>2500 mg l^{-1}	_	_		
Total dissolved solids (TDS)	10 mg l^{-1}	<1000 mg l^{-1}	<1000 mg l^{-1}	2500 mg l^{-1}	2500 mg l^{-1}

A=Abu-Ghraib dairy wastewater (feed), B= Water withdrawn from Biological treatment, C= Water withdrawn from Combined treatment, D=Specification of water discharged to river water and E=Specification of reused water

isolated from 10^{-3} agar plate and were inoculated into the nutrient broth for experimental performance along with membrane process. The total count bacteria, fecal coliform bacteria (E-coli) and Worms's eggs were 54-60 unit/100ml, 54-60 unit/100ml and zero respectively as shown in Table 4. This finding was comparable to (Kim et al 2011, Le-Clech et al 2006). There is a discrepancy in the water characteristics resulting from the biological treatment compared to the water produced by the combined treatment and its conformity with the national determinants (Iraqi standard Quality 2012, Abaoy et al 1990). Thus, it is a necessary need for an initial chemical treatment of the discharged water from the dairy factories to control the production of eco-friend water with fixed specifications.

CONCLUSION

In this study, the treatment of dairy effluent was conducted by using an efficient technology Membrane bio-reactor with an integrated pre-chemical treatment setup. The performance of experiment was assessed based on COD, TDS, Turbidity, $(PO_{4)})^{-1}$, $(NO_3)^{-1}$and microbial count values. The removal of both organic and in-organic pollutants was very high and good quality of permeate which is colorless has been achieved. The MBR integrated with pre-chemical treatment with alum did however achieve a higher rejection of COD and TDS compared to the MBR alone, this integration revealed new insights in terms of effluent treatment compared to conventional techniques. In this hallow fiber Ultra filtration membrane of 0.1 µm was used for the treatment of dairy effluent which exhibited a considerable reduction in TDS, COD and turbidity. The main advantage of MBR integrated with alum treated water can be recycled for industrial purpose in cooling towers, cleaning plant floor's, green irrigation purposes, gardening, toilet flushing and other indirect human use. We could recommend: 1-Develop the experimental treatment system to develop successful water reuse projects using MBR technology in Iraq. 2-Training the engineering and technical staff to design and implement MBR processing systems and work on the operation of larger production systems to identify the difference between the research systems and the largest processing units in terms of operation and maintenance.

REFERENCES

Asfary AF 2004.Guidance in the design, operation and maintenance of wastewater treatment plants, WHO, Regional Office for the Eastern Mediterranean, Regional Center for Environmental Health Activities, Amman / Jordan.

Abaoy S, Abid S and Suliman M 1990. Practical engineering of water testing environment. Dar Al-Hikma for Printing and Publishing / Mosul Ibn Al-Atheer Street. 248-253.

Andrade LH, Mendes FD, Espindola DS and Amaral MC 2015. Reuse of dairy wastewater treated by membrane bioreactor and nanofiltration: Technical and economic feasibility. *Brazilian Journal of Chemical Engineering* **32**(3): 735-747.

Ashish T and Omprakash S 2014. Study of characteristics and treatments of dairy industry waste water. *Journal of Applied and Environmental Microbiology* **2**(1): 16-22.

Asian J 2005. Adaptability of membrane for dairy waste management. *Expanded Science* **19**(2): 105-112.

Bala K and Nehru K 2012. Performance evaluation of MBR for treating dairy effluent stream. *International Journal for Research - Science& Advance Technology* **1**(1): 050-05.

Buzatu P and Lavric V 2011. Optimal operating strategies of a submerged membrane bioreactor for wastewater treatment. *Chemical and Biochemical Engineering Quarterly* **25**(1): 89–103.

Chandrasekhar S, Srinath D, Nivedita S and Sridhar S 2017. Treatment of dairy industry effluent using membrane bioreactor. *International Journal of Pure & Applied Bioscience* **5**(6): 71-79.

Cicek N, Franco JP, Suidan MT, Urbain V and Manem J 1999. Characterization and comparison of a membrane bioreactor and a conventional activated sludge system in the treatment of wastewater containing high molecular weight compounds. *Water Environment Research* **71**: 64-70.

Cui ZF, Chang S and Fane AG 2003. The use of gas bubbling to enhance membrane process. *Journal Membrane Science* **2211**: 1-3.

Drews A 2010. Membrane fouling in membrane bioreactors–characterisation, contradictions, cause and cures. *Journal of Membrane Science* **363**: 1-28.

Dufresne R, Lebrun RE and Lavallee HC 1997. Comparative study on fluxes and performances during papermill wastewater treatment with membrane bioreactor. *The Canadian Journal of Chemical Engineering* **75**: 95-103.

Gander M, Jefferson B and Judd S 2000. Aerobic membrane bioreactors for domestic wastewater treatment: A review with cost considerations. *Separation and Purification Technology* **18**(2): 119-130.

Gauthier R 2011. *Water Solution Phosphorus Removal from Wastewater*. The Water Plant Company (www.kemira.com).

George S, Tom C, Arnota S, Firas F, Mouna J and Sami S 2012. Operation of a submerged aerobic membrane bioreactor for decentralised municipal wastewater treatment in North Africa. *Water Practice and Technology* **7**(3): doi:10.2166/wpt.2012.055

Judd S The MBR Book 2006. Principles and applications of membrane bioreactors in water and wastewater treatment, 1st Ed., Great Britain 225-229.

Kim MJ, Sankararao B and Yoo CK 2011. Determination of MBR fouling and chemical cleaning interval using statistical methods applied on dynamic index data. *Journal of Membrane Science* **375**: 345–353.

Le-Clech P, Chen V and Fane AG 2006. Fouling in membrane bioreactors used for wastewater treatment – A review. *Journal of Membrane Science* **284**: 17-53.

Medhat AE Moustafa 2011. Effect of the pre-treatment on the performance of MBR, Berghausen WWTP, Germany. *Alexandria Engineering Journal* 198-202.

Patsios SI and Karabelas AJ 2007. Advanced Wastewater Treatment Processes: Membrane Bioreactors for Water Reuse "Modern Techno-logies for Water and Wastewater Treatment", Workshop, *INTERREG III A / CARDS*, *Greece – F.Y.R.O.M.*

Robinson A 2008. *New Developments in the Application of Membrane BioReactors (MBR) for Industrial Wastewater Treatment*. Wehrle Environmental, Witney, Oxfordshire, UK.

Sadik H 2017. Effect of the pre-treatment on the performance of MBR, Al-Kut WWTP, Wasit Governorate. *Journal of Chemical Engineering and Process Technology* **8**(10): 320.

Sedlak R 1991. *Phosphorus and Nitrogen Removal from Municipal Wastewater*: *Principles and Practice*. 2nd ED. Chelsea, MI: Lewis Publishers.

Singh R 2006. *Hybrid Membrane Systems for Water Purification*. 1st Ed, Elsevier Science and Technology Books, p. 27-30.

Steven T and Henry M 2001. Membrane bioreactors: Wastewater treatment applications to achieve high quality effluent. 64th Annual Water Industry Engineers and Operators' Conference All Seasons International Hotel-Bendigo 5 and September, 2001.

Sun Z and Zuo J 2009. Influence Factor and Membrane Fouling in SMBR for Food Wastewater Treatment. 2009 IITA International Conference on *Control, Automation and Systems Engineering* (case 2009). 11-12

Wiesmann U, Suchoi I and Dombrowski E 2007. *Fundamentals of Biological Wastewater Treatment*. 1st Ed., betz-druck Gmb H, 27-31

Yusmel H, Ulises H, Claire A and Marion A 2014. Development of a submerged membrane bioreactor simulator: A useful tool for teaching its functioning. *Education for Chemical Engineers* **9**(2): 32-41.

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Soil Organic Carbon and Soil Respiration in Dry Deciduous Forest and Grass Land of Kadapa hill ranges, Andhra Pradesh, India

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Abstract: Soil organic carbon (SOC) and soil respiration (SR) were estimated in two different land uses (dry deciduous forest and grass land). The estimated SOC down to 30 cm depth was 36.35 Mg C ha^{-1} and 8.69 Mg C ha^{-1} in forest and grass land respectively. On forest and grassland, SOC at 0-10 cm and 10-30 cm were 44.67 Mg C ha^{-1} and 28.47 Mg C ha^{-1} and 10.14 Mg C ha^{-1} and 7.24 Mg C ha^{-1}, respectively. On grass land, SOC were 10.14 Mg C ha^{-1} and 7.24 Mg C ha^{-1} at the 0-10 cm and 10-30 cm. SOC decreased from top surface layer to sub surface layer in both land use. Lower bulk density values were in dry deciduous forest (1.46 g cm^{-3}) than grass land (1.61 g cm^{-3}) revealing a significant negative correlation between SOC and BD. The soil respiration rate in the forest was 107.8 CO_2mg/m^2/h but was low in grass land (31.16 CO_2mg/m^2/h). A strong positive correlation existed between SR and SOC values.

Keywords: Bulk density, Dry deciduous forest, Grass land, Soil organic carbon, Soil respiration

Forests are considered to play a major role in global carbon cycle as they constitute 2150 GtC in their biomass and soils and they hold at least three times higher carbon than in the world's vegetation and two times higher carbon content present in the atmosphere (Sahu et al 2015). Soils are considered as the largest carbon reservoirs of the terrestrial carbon cycle (Clara et al 2017). Especially forest soils under natural vegetation are regarded as one of the major sinks of carbon (Dinakaran et al 2011). The primary way that carbon is stored in soil is soil organic carbon (SOC) which mainly includes plant, animal and microbial residues in all stages of decomposition (Lal 2004). Tree density is the most important factor for carbon stock (Gupta et al 2019). The undisturbed forest ecosystems are highly productive and can support more carbon per unit area compared to other land use systems (Devagiri et al 2013). The presence of high organic input in the form of litter makes the top 0-30 cm soil profile more dynamic which plays a significant role in the carbon cycle (Gandhi and Sundarpandian 2017). The soil organic carbon concentration varies across land use types as a function of climate, and vegetation (Sreenivas et al 2016). Soil respiration is an ecosystem process in which CO_2 is released from soil via root respiration, microbial decomposition of litter and soil organic matter and faunal respiration (Arora and Chaudhry 2017). In forest ecosystems, soil respiration (SR) constitutes nearly 30-80 per cent of the whole ecosystem respiration (Davidson et al 2000) and this largely depends up on soil temperature, moisture conditions and different vegetation types (Panda et al 2011). Apart from few sporadic works on floristic composition of Kadapa hill ranges, studies on soil organic carbon and soil respiration are lacking. Hence, a study was undertaken to generate baseline information on SOC and SR in forests and grass lands of Kadapa hill ranges.

MATERIAL AND METHODS

Study site: The present study was carried out in a dry deciduous forest and grass land of Vangimalla Reserve Forest in Kadapa hill ranges, Andhra Pradesh, India. Forests are dominant in 541m to 604 m elevation and down wards along the foot hills grass lands were common. Dry deciduous forests comprised of dominant tree species such as *Anogeissus latifolia, Lannea coromandelica, Chloroxylon swietenia and Pterocarpus santalinus* and the grass land comprise of herbaceous cover dominated by grasses like *Cynadon dactylon, Aristida hystrix, Hetropogon contortus*. Red loamy soil type with pebbles and quartzite rock boulders are commonly present in the forest, while the soil is loamy sand with 62.6 percent of sand and pebbles in grass land. The study area receives a mean annual rainfall of 680 cm and the mean temperature range is 26°C-43°C.

Data collection and analysis: A total of three soil samples were collected from three different areas in triplicates from forest (N14°16' 44.3" E 078°51' 52.3") as well as in grass land (N14°17'30.1" E 078° 53'12.4"; from two different depths - top surface layer (0-10 cm) and subsurface layer (10-30 cm). The soil samples of each site were air dried and passed through 2 mm sieve. Mean SOC values of each site were obtained by Walkley and Black (1934) titration method. The estimated SOC were converted to Mg C ha^{-1} using the formula SOC (Mg C ha^{-1}) =10000m^2 x Soil depth x Bulk density x SOC %. Physico-chemical soil variables such as pH, electrical conductivity were measured in soil: water ratio of 1:5 (weight/volume), moisture content by oven dry weight basis method, temperatures at top surface layer and sub-surface layer were recorded by Digital multi thermometer-Eurolab ST 9283, soil texture was analysed by pipette method and bulk density was estimated by core method by following standard procedures (Kapur and Sudharani 2004). Soil respiration rate was estimated by measuring the amount of CO_2 evolved per unit area and time, based on alkali absorption method (Gupta and Singh 1977). The experiment was carried out at three different locations by fixing three open ended cylindrical boxes (30 cm diameter x 20 cm height) at both land uses a 50 ml beaker containing 20 ml 1M NaOH was hung on a thin wire in each cylinder. At each place the above ground vegetation was clipped and the cylinder was pushed up to 3 cm depth. The evolved CO_2 was collected in 20 ml 1 M NaOH over a 24 h period. The amount of CO_2 absorbed was estimated by titrating with 1 M HCl using two drops of phenolphthalein indicator and estimated by using the formula ($mgCO_2$= V x N x 22 where V= Blank value-sample titration value, N= Normality of Hcl). The CO_2 evolved during the experiment was calculated as described by Misra (1968). Statistical analysis was made by using IBM SPSS20 software.

RESULTS AND DISCUSSION

The forest soils comprised of 36.35 Mg C $ha^{-1}$of SOC (soil organic carbon) and in the grass land 8.69 Mg C ha^{-1}in 30 cm depth. SOC in forest at the top surface layer (0-10 cm) and sub-surface layer (10-30 cm) were 44.67 and 28.47 Mg C ha^{-1} respectively and in grass land were 10.14 and 7.24 Mg C ha^{-1} at the 0-10 and 10-30 cm (Table 1). The SOC decreased from top surface layer to sub surface layer with significant difference up to 30 cm depth between forest and grass land. Forests comprised of 1.02 per cent SOC in top surface layer and 0.65 per cent in sub surface layer against 0.21 and 0.15 in the subsurface layer in grassland. A significant difference in SOC was observed between 0-10 cm to 10-30cm layers among forests but not in grassland.

The mean bulk density (BD) in forest and grassland were 1.46 g $cm^{-3}$and 1.61 g cm^{-3}. The higher BD in grass land than forest indicating a negative relationship with bulk density (Fig. 1). Soil texture indicated a higher value of clay content (8.25%) in forest than grassland clay content (3.12%) revealing a positive relationship between clay content and SOC stock. The soil pH revealed near neutral to weak acidic conditions in forests at 0-10 cm (6.66-6.86) and 10-30 cm (6.61-6.91) and alkaline at both the layers 8.01-8.31 (0-10 cm) and 8.11-8.66 (10-30 cm) of grass land. The mean soil temperature in forest surface layer was 32.92˚C and it decreased to 28.96˚C at 10 cm depth (Table 2). In grassland land the mean soil surface layer temperature was 43.32˚C and at 10 cm depth the value decreased to 34.08˚C. The soil moisture content in forest was 1.84% at top surface layer (0-10 cm) and increased to 8.19% at sub surface layer (10-30 cm) and similar trend was observed in grass land. The mean soil respiration (SR) rate in forest was 107.8 $CO_2mg/m^2/h$ and was low in grass land(31.16 $CO_2 mg/m^2/h$). A strong positive correlation was observed between SR and SOC (r= 0.967) in both land use types (Fig. 2).

The significantly higher SOC in dry deciduous forest than grass land may be due to the higher litter fall and plant residues available on the forest floor provided by 43 tree species with a density of 322 individuals per hectare in the Vangimalla forest. Such a higher SOC values were also

Table 1. Estimated soil organic carbon at varied depths in dry deciduous forest and grass land

Land use type	Depth(cm)	Soil organic carbon (%)			Mean ±SD	Mg C ha^{-1}
		Site 1	Site 2	Site 3		
Forest	0-10	0.9	1.02	1.15	1.02±0.125	44.67
	10-30	0.52	0.87	0.56	0.65±0.191	28.47
Grass land	0-10	0.15	0.22	0.28	0.21±0.065	10.14
	10-30	0.19	0.17	0.1	0.15±0.045	7.24

Table 2. Physico-chemical parameters of the soil in dry deciduous forest and grass land

Land use type	Depth (cm)	pH	Moisture content (%)	Temperature ˚C	Bulk density (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)
Forest	0-10	6.66-6.86	1.84	32.92	1.46	62.61	29.14	8.25
	10-30	6.61-6.91	8.19	28.96				
Grass land	0-10	8.01-8.31	1.35	43.32	1.61	69.48	27.4	3.12
	10-30	8.11-8.66	3.98	34.08				

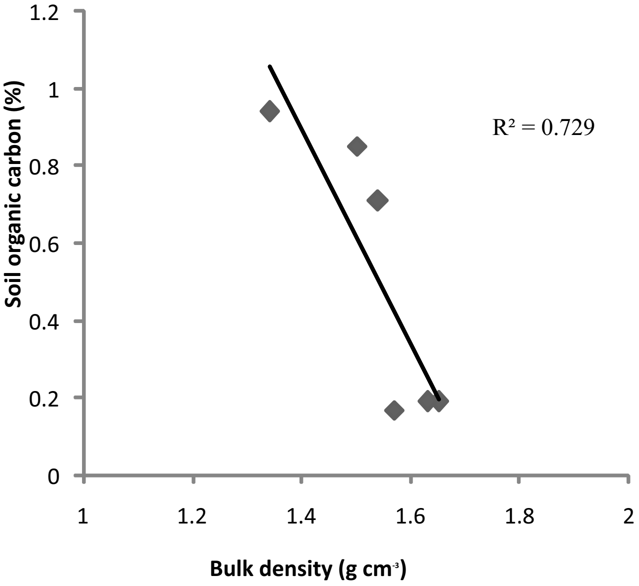

Fig. 1. Relationship between soil organic carbon and bulk density

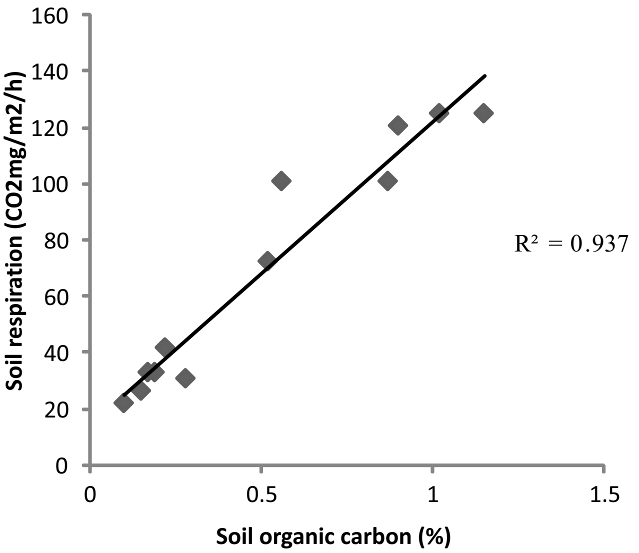

Fig. 2. Relationship between soil organic carbon and soil respiration

reported in Achankmar Amarkantak Biosphere Reserve dry forests than agro forestry, agriculture, grass land and waste land (Iqbal and Tiwari 2016). Similarly the declining order of SOC from Mawlong sacred forest (236 Mg C ha^{-1}), Ramjadang forest (158 Mg C ha^{-1}), home garden (116 Mg C ha^{-1}) and grass land (50 Mg C ha^{-1}) was reported in Karst landscape of North eastern India (Bdoor 2018). The study on carbon stock in the forests of western Himalaya indicated an increase in SOC values in the order - reserved forest> protected forest> Un-classified forest (Rai and Gupta 2018).

A study carried out in dry forests of Sathanur showed that SOC stocks showed variation due to changes in species composition, litter quality and quantity, bulk density, soil pH, soil texture, and anthropogenic pressures (Gandhi and Sundarapandian 2017). In the present study in dry deciduous forest, higher SOC values were at top surface layer (0-10cm) than sub surface layer (10-30 cm) in both land uses. Such a decrease in SOC values from top surface layer to sub surface layer was also reported in primary and secondary sites of tropical moist deciduous forests of Manipur (Vashum et al 2016). A negative relationship between bulk density and SOC was reported as low bulk density values were recorded in forest soils. The aggregation capacity of SOC will usually increase the porosity and reduce the bulk density leading to high permeability and thus the bulk density of a soil depends upon soil type, texture, soil organic matter, and mineral composition (Santos et al 2015). Such negative relation between BD and SOC was recorded in Guvvalacheruvu dry forest (Ramana et al 2017), tropical moist deciduous forests of North east India (Vashum et al 2016). The dry deciduous forest soils featured weak acidic soil condition and grass lands showed alkaline nature and a shift of alkaline to acidic after afforestation was observed in Iranian arid soils thus suggesting a negative relationship between soil pH and SOC values (Moradi et al 2017). In present study the clay content had positive relationship with SOC, the SOC will have high residence time in clay and silt suggesting that soil texture will strongly influence the soil carbon dynamics (Paul et al 2002). In comparison to the similar studies on SOC up to 30cm depth, the present SOC values were in the comparable range of the Sathanur Reserve dry deciduous forest SOC value (16-47 Mg C ha^{-1}; Gandhi and Sundarapandian 2017). The SOC values were higher than the Nanmangalam reserve forest (0.12 - 0.41%, Radhapriya et al 2014) and lower than the other tropical and subtropical forests of Africa (57 Mg C ha^{-1} Kirsten et al 2016), tropical dry deciduous forests of Odisha (57.9 Mg C ha^{-1} Sahu et al 2015), and semi arid tropical forests Telangana (76.51 Mg C ha^{-1}, Venkanna et al 2014).

The most commonly used a-biotic variables explaining the observed respiration patterns are temperature and moisture. Soil respiration showed a positive correlation with soil moisture content and a negative relationship with temperature in the present study sites. The present study SR values are lower than moist deciduous forests of Odisha - 124-360 CO_2 mg m^{-2} h^{-1} of Ghumusar, southern Odisha (Mohanty and Panda 2011) and this indicates that the forest type and rainfall plays an important role in the mean soil respiration rates in the forests.

CONCLUSION

Dry deciduous forest in Kadapa hill ranges recorded four times higher SOC values than the grass land use. SOC values decreased from top surface layer to sub surface layer in both land uses; but lower variation of SOC values was observed between the top surface layer to sub surface layer in grass land than forest land. The higher SOC values in the top surface layer and positive relation between soil physico-chemical properties in the top layer indicate the importance of soil features in addition to the canopy vegetation which provides the litter. The results suggest that the presence of tree vegetation in forest has led to higher SOC and SR rate than grassland. In addition factors such as soil moisture and soil temperature have markedly influenced the variation in soil respiration rate between forest and grass land.

REFERENCES

Arora P and Chaudhry S 2017. Dependency of rate of soil respiration on soil parameters and climatic factors in different plantations at Kurukshetra, India. *Tropical Ecology* **58**(3): 573-581.

Bdoor BS 2018. Organic carbon stocks in various land use types of Karst landscape in North eastern India. *Indian Journal of Ecology* **45**(1): 77-83.

Clara L, Fatma R, Virdiana A and Liest W 2017. *Soil organic carbon, the hidden potential*: Food and agriculture organization of United Nations, Rome, Italy, p. 77.

Davidson EA, Verchot LV, Cattnio JH, Ackerman IL and Carvalho JEM 2000. Effect of soil water content on soil respiration in forests and cattle pastures of eastern Amazonia. *Biogeochemical* **48**(1): 53-69.

Devagiri GM, Money S, Singh S, Dadhwal VK, Patil P, Khaple A, Devakumar AS and Hubbali S 2013. Assessment of above ground biomass and carbon pool in different vegetation types of south western part of Karnataka, India using spectral modeling. *Tropical Ecology* **54**: 149-165.

Dinakaran J, Mehta N and Krishnayya NSR 2011. Soil organic carbon dynamics in two functional types of ground cover (grasses and herbaceous) in the tropics. *Current Science* **101**(6): 776-783.

Gupta DK, Bhatt RK, Keerthika A, Mohammad NBM, Shukla AK and Jangid BL 2019. Carbon sequestration potential of *Hardwickia binata* Roxb, based agroforestry in hot semi-arid environmental of India: An assessment of tree density impact. *Current Science* **116**(1): 112-116.

Gupta SR and Singh JS 1977. Effect of alkali concentration volume and absorption area on the measurement of soil respiration in a tropical sward. *Pedobiologia* **17**: 233-239.

Iqbal S and Tiwari SC 2016. Soil organic carbon pool under different land uses in Achanakmar Amarkantak Biosphere reserve of Chattisgarh, India. *Current Science* **110**(5): 771-773.

Kapur P and Govil SR 2004. *Experimental plant Ecology,* CBS publishers, New Delhi, p 156.

Received 24 May, 2019; Accepted 31 July, 2019

Kirsten M A, Kaaya T, Klinger and Feger KH 2016. Stocks of soil organic carbon in forest Ecosystems of the Eastem Usambara Mountains, Tanzania. *Catena* **137**: 651-659.

Lal R 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* **304**: 1623-1627.

Misra R 1968. *Ecology work Book,* IBH Publishing Company, New Delhi, 243 pp.

Mohanty RB and Panda T 2011. Soil respiration and microbial population in a tropical deciduous forest soil of Odisha, India. *Flora* **206**: 1040-1044.

Moradi MF, Imani HR, Naji SM, Behbahani and Ahmadi MT 2017. Variation in soil carbon stock and nutrient content in sand dunes after afforestation by *Prosopis juliflora* in the Khuzestan province (Iran). *Forest* **10**: 585-589.

Paul KI, Polglase PJ, Nyakuengama JG and Khanna PK 2002. Change in soil carbon following afforestation. *Forest Ecology Management* **168**: 241-257.

Radhapriya PA, Ramachandran P, Dhanya K, Remya and Malini P 2014. An appraisal of physiochemical and microbial characteristic of Nanmangalam reserve forest soil. *Journal of Environmental Biology* **35**: 1137-1144.

Rai P and Gupta B 2018. Estimation of Biomass and carbon stock variation in vegetation of differently managed *Quercus leucotrichophora* forest along an elevation gradient in Western Himalaya, India. *Indian journal of Ecology* **45**(1): 100-106.

Ramana VC, Naga Raju K, Osman Basha P and Sridhar Reddy M 2017. Estimation of soil organic carbon and soil respiration in a dry forest- Guvvalacheruvu Reserve Forest of Kadapa hill ranges. *International academy of Ecology and Environmental science* **7**(4): 90-96.

Sahu SC, Sharma J and Ravindranath NH 2015. Carbon stocks and fluxes for forests in Odisha India. *Tropical Ecology* **56**(1): 77-85.

Sanjay Gandhi D and Sundarapandian SM 2017. Soil carbon stock assessment in the tropical dry deciduous forest of the Sathanur reserve forest of the Eastern Ghats, India. *Journal of sustainable forestry* **36**(4): 358-374.

Santos LTD, Marra DM, Trumbore S, Camargo PB, Chambers JQ, Negron Juarez RI and Higuchi N 2015. Wind throws increase soil carbon stocks in a Central Amazon Forest. *Biogeosciences Discussions* **12**: 19351-19372.

Sreenivas K, Dadhwal VK, Kumar S, Harsha GS, Mitran GT, Sujatha G and Ravisankar T 2016. Digital mapping of soil organic carbon and inorganic carbon status in India. *Geoderma* **269**: 160-173.

Vashum KT, Woshi TK and Jaya Kumar S 2016. Soil organic carbon sequestration potential of primary and secondary forests in Northeast India. *International academy of Ecology and Environmental science* **6**(3): 67-74.

Venkanna K, Mandal UK, Raju AJS, Sharma KL, Ravikant VA, Pushpanjali B, Reddy BS, Masane RN, Venkatravamma K and Babu BP 2014. Carbon stocks in major soil types and land-use systems in semiarid tropical region of southern India. *Current Science* **106**(4): 604-611.

Walkley A and Black IA 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

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Assessment of Energy Potential of Muskmelon Crop for Power Generation

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Abstract: The present study has focused on *Cucumis melo* crop for biomass power generation. The maximum agri-residues of 391.1 tons ha^{-1} were available in the district of Kapurthala and the minimum for Moga i.e. with the power potential of 0.1615 MW and 0.1635 MW respectively. The calorific value increased after the grinding process, leading to an increase in the overall potential and efficiency of the fuel. The maximum increase in the calorific value of root after grinding was because of less dust particles, less ash and more combustion. Hence, grinding is the better option to increase the energy utilization of the crop.

***Keywords*:** Biomass, Energy, Potential, Muskmelon

The biomass is a reliable, economical, and readily available resource of renewable energy, which can be used as a fuel for power generation and has been a major source of household energy in India. It meets the cooking energy needs of most rural households and half of the urban households. The availability of affordable energy supply is an important component in improving the quality of life. Though looking to reduce fossil fuel use, India faces a tough task in meeting its energy needs, especially rural energy needs. In such a scenario, biomass can play an important role in providing sustainable energy solutions in rural areas. The cultivation of crops and its use as bio-energy sources have positive or negative impacts is a widely dubious and violently debatable as a current issue globally (McKendry 2002). Biomass and bio-fuels have gained an increasing interest as a sustainable and non-conventional energy rising technologies related to inventions in field of renewable energy sources are detected by analyzing the average clustering of publications in a year. As per the results, bio-diesel and hydrogen production are the most quickly developing domains amongst the biomass bio-fuel researches (Robertson 2006). Studies have been done on bio-energy and its comparative distribution in different fields of generation of energy with biomass energy and the methods for calculating production the greenhouse gas which balances of bio-energy systems that are producing electricity (Ladanai et al 2009, Cherubini 2010). The growth of renewable energy sources has marked itself as a capable policy towards enhancing the delicate world energy system with its limited resources of conventional energy sources. Fossil fuel resources, and in addition growth of use of conventional resources for the electricity generation helps the world to deal with the problem of global warming and reduces many environmental problems (Iakovou 2010). In many countries there is a rapid increase power generation from Non-conventional Energy Sources and it is slowly becoming a perfect solution to reduce global warming related issues and increases the sustainable development in this growing world (Viana et al 2010, Bazmi et al 2011).

There have been numerous global efforts to provide frame works for sustainability assessment of bio-energy programs including international certification schemes and national policies or guidelines. This study aims to analyze the potential of recovering energy from major source of biomass residues by optimization of biomass residues makes the country the best utilized for biomass (Shafie et al 2012, Chauahan 2012). For the better efficiency of biomass power plants many different biomass conversion techniques has been utilised based upon the calorific values (Patel et al 2012) of the biomass of different crops (Oyedepo 2012) and in addition to this optimization of the transportation network and medium of transportation is very much necessary which act as a part of logistic support can ensure the consistent supply of biomass to the power plant, while it can reduce transportation cost as well (Asadullah 2014). Furthermore, to increase the efficiency of bio mass power plant blending of biomass fuel with fossil fuel is used and in parallel way heat rate is improved (Patil et al 2013).

Agro-residues, however, do suffer from two major constraints: high moisture content and relatively low bulk density. These constraints inhibit their economical transportation over long distances, thereby necessitating their utilization near the sources of production. Unlike fossil fuels, which are concentrated sources of energy and chemicals, the management strategy for agro-residues utilization has to be different. The processing of the agricultural produce and utilization of agro-residues, therefore, can contribute their maximum share to rural development. Extensive work has been done on cotton sticks, mustard husk, firewood, paddy crops to be used as bio-mass fuel. But, hitherto there is dearth of studies evaluating energy potential in *Cucumis melo* crop (as bio-mass fuel for electric power generation. Against this backdrop, the present study was conducted to the evaluate district wise biomass based power generation according to residues availability of *Cucumis melo* crop.

MATERIAL AND METHODS

Data: The present study based on primary as well as secondary data was conducted in the year 2013-14 in Punjab. The secondary data on the pertinent variables were obtained from Statistical Abstract of Punjab, 2014, Punjab Energy Development Agency (PEDA) and District Agriculture Offices. The primary data collection involved intensive field surveys, group discussions with farmers. Crop samples of *C. melo* were collected from all over the districts of Punjab. The calorific value of these samples was evaluated after sun-drying and grinding using Bomb Calorimeter. After sun-drying and grinding the crop residues, comparative analysis was carried for various plant parts namely leaf, branch, stem and root. By using grain production per acre and residues generation ratio (RGR), total agri-residues per district and then total agri-residues of whole state were calculated (Table 1).

Table 1. Crop wise total agri-residues

Crop name	Residues generation ratio values
Sugarcane leaves and trash	0.10
Wheat	1.15
Pulses	1.52
Maize	2.13
Paddy straw	1.20
Paddy husk	0.16
Potato	0.40
Mustard	1.72
Cucumis melo	0.30

Quantity of agri-residues available per acre can be determined by:

Total agri-residues = Residues per acre (q) ×Area under crops (ha)

Residues per ha (q)= Residues generation ratio × Crop yield per ha (q ha^{-1})

Residues generation ratio (RGR) of a crop (Chauhan 2012). As per the quantity of agri-residues available of the respective crop and by considering calorific value of all the selected crops total energy potential can be calculated as under:

Available agri-residues* calorific value = Energy potential of crop .

Biomass power plants which involves direct combustion of bio-fuel i.e. agri-residues use travel grade burner which is very much suitable for burning biomass. The calculated energy potential can be converted to power potential:

Energy potential (kCal)*Generation factor (40%) = Net useful Energy

Net useful Energy*0.0011627= Net Energy in kWh

Net –Energy in kWh/8760=KW

By using equations biomass based power generated from *Cucumis melo* crop can be calculated in different districts of Punjab in the above work.

RESULTS AND DISCUSSION

Total agri-residues available: The maximum agri-residues of 391.1 tons ha^{-1} were available in the district of Kapurthala and almost nil for the districts of Bathinda, Faridkot, Mansa, Sri Muktsar Sahib, Fazilka and Pathankot as the crop is not grown in these districts and minimum were in Moga district i.e 1.96 tons ha^{-1}. Total residues of1114.5 tons ha^{-1} of *Cucumis melo* crop were available from all the districts of Punjab during 2013-14.

Total energy potential available: The availability of agri-residues were maximum in districts of Kapurthala and Jalandhar and these may identified as central hubs for the collection of agri-residues. The total energy potential available for crop in all districts of Punjab was 465.9 KW. This value overall seems to be very low but as most of the power plants suffers the non-availability of paddy straw or other crops at the time of operation when these crops are unavailable, *C. melo* crop can play an important role at that time to fulfill the energy requirements.

Total Agri-Residues available from different districts of Punjab: The district of Jalandhar accounted for the maximum acreage (1978.8 ha) under *Cucumis melo crop* followed by Kapurthala (1663.5 ha) (Table 2).

The findings revealed that the total residues for *C, melo* crop available from all the districts of Punjab were 1114.5 tons ha^{-1}. The maximum agri-residues were available in the district of Kapurthala and the value were minimum for Moga i.e. 1.96 tons ha^{-1}.

Comparison of energy potential after sun-drying and after grinding crop: The maximum improvement in energy potential is found after the grinding process rather than sun-drying in majority of the districts. On an average, improvement of 5 per cent in energy content is observed at the Punjab level (Table 3).

Comparing energy generated from leaves and branches: The result revealed that after grinding the leaves there was decrement of about 30 per cent after grinding the leaves, may be due to the dust particles on the leaves which get mixed completely with the leaves creating difficulty in combustion and hence more ash and low calorific value. The grinding the branch, there is an improvement of 5.4 per cent in generated energy potential and the maximum improvement was observed for the districts of Sangrur, Hoshiarpur and Moga.

Comparing energy generated from stem and roots: After grinding the stem, there is an improvement of 12.7 per cent in generated energy potential which is an average value. The maximum improvement of 12.9 per cent is observed for Tarn Taran district. After grinding the root, there is an improvement of 30.9 per cent in generated energy potential which is an average value (Table 5).

Energy content of different parts of *Cucumis melo* crop: The energy potential of *C. melo* is low in sun-drying and to improve the energy content, grinding of different parts of the crop was done before combustion. Significant difference in the calorific value of *C. melo* crop was recorded after sun-drying and after grinding (Table 6). There was change in the

Table 3. Total improvement of energy generated from crop

Name of district	Energy potential of crop after (MW)		Percentage improvement
	Sun-drying	Grinding	
Gurdaspur	0.007	0.007	5.06
Kapurthala	0.164	0.172	5.00
Bathinda	0.000	0.000	0.00
Sangrur	0.007	0.007	5.01
Patiala	0.043	0.045	5.01
Ropar	0.004	0.004	4.96
Hoshiarpur	0.006	0.006	5.04
Jalandhar	0.162	0.170	5.01
Ludhiana	0.029	0.031	5.02
Ferozepur	0.007	0.007	5.01
Amritsar	0.001	0.001	4.96
Faridkot	0.000	0.000	0.00
Mansa	0.000	0.000	0.00
Fatehgarh Sahib	0.004	0.005	5.00
Moga	0.001	0.001	4.88
Shri Muktsar Sahib	0.000	0.000	0.00
SBS Nagar	0.006	0.006	5.04
SAS Nagar	0.019	0.020	5.00
TarnTaran	0.002	0.002	4.80
Barnala	0.004	0.004	5.05
Fazilka	0.000	0.000	0.00
Pathankot	0.000	0.000	0.00
Total	0.466	0.489	5.01

Table 2. Agri-residues available from different districts of Punjab, 2013-14

Name of District	Area under crops (ha)	Residues heneration ratio (RGR)	Crop yield (q ha^{-1})	Residues (q ha^{-1})	Total agri residues available for this season (q)
Gurdaspur	73.2	0.3	3.1	0.9	42408.8
Kapurthala	1663.5	0.3	3.1	1.0	977819.7
Bathinda	0.0	0.3	0.0	0.0	0.0
Sangrur	77.1	0.3	2.9	0.9	42484.8
Patiala	477.4	0.3	2.9	0.9	258893.2
Ropar	44.5	0.3	2.9	0.9	24098.2
Hoshiarpur	63.2	0.3	2.8	0.8	33364.1
Jalandhar	1978.8	0.3	2.9	0.9	965899
Ludhiana	326.1	0.3	2.8	0.8	174043
Ferozepur	79.0	0.3	2.8	0.8	41729.1
Amritsar	15.8	0.3	2.8	0.8	8448.0
Faridkot	0.0	0.3	0.0	0.0	0.0
Mansa	0.0	0.3	0.0	0.0	0.0
Fatehgarh Sahib	54.4	0.3	2.6	0.8	26865.9
Moga	9.9	0.3	2.6	0.8	4908.1
Shri Muksar Sahib	0.0	0.3	0.0	0.0	0.0
SBS Nagar	72.1	0.3	2.6	0.8	35594.9
SAS Nagar	222.4	0.3	2.7	0.8	111222.0
Tarn Taran	27.7	0.3	2.6	0.8	13678.0
Barnala	50.4	0.3	2.6	0.8	24878.4
Fazilka	0.0	0.3	2.8	0.8	0.0
Pathankot	0.0	0.3	2.8	0.8	0.0

Table 4. Total improvement in energy generated from leaves and branches

Name of district	Energy potential of *Cucumis melo* crop after (MW)				Percentage improvement	
	Sun-drying		Grinding			
	Leaves	Branches	Leaves	Branches	Leaves	Branches
Gurdaspur	0.007	0.006	0.005	0.007	-29.47	5.39
Kapurthala	0.172	0.147	0.121	0.155	-29.48	5.39
Bathinda	0.000	0.000	0.000	0.000	0.00	0.00
Sangrur	0.007	0.006	0.005	0.007	-29.47	5.40
Patiala	0.045	0.039	0.032	0.041	-29.48	5.39
Ropar	0.004	0.004	0.003	0.004	-29.48	5.40
Hoshiarpur	0.006	0.005	0.004	0.005	-29.48	5.40
Jalandhar	0.170	0.145	0.120	0.153	-29.48	5.39
Ludhiana	0.031	0.026	0.022	0.028	-29.48	5.39
Ferozepur	0.007	0.006	0.005	0.007	-29.48	5.39
Amritsar	0.001	0.001	0.001	0.001	-29.48	5.39
Faridkot	0.000	0.000	0.000	0.000	0.00	0.00
Mansa	0.000	0.000	0.000	0.000	0.00	0.00
Fatehgarh Sahib	0.005	0.004	0.003	0.004	-29.48	5.39
Moga	0.001	0.001	0.001	0.001	-29.48	5.45
Shri Muksar Sahib	0.000	0.000	0.000	0.000	0.00	0.00
SBS Nagar	0.006	0.005	0.004	0.006	-29.48	5.39
SAS Nagar	0.020	0.017	0.014	0.018	-29.48	5.40
Tarn Taran	0.002	0.002	0.002	0.002	-29.48	5.38
Barnala	0.004	0.004	0.003	0.004	-29.48	5.39
Fazilka	0.000	0.000	0.000	0.000	0.00	0.00
Pathankot	0.000	0.000	0.000	0.000	0.00	0.00
Total	0.489	0.419	0.345	0.442	-29.48	5.39

Table 5. Total improvement in energy generated from stem and root

Name of district	Energy potential of *Cucumis melo* crop after (MW)				Percentage improvement	
	Sun-drying		Grinding			
	Stem	Root	Stem	Root	Stem	Root
Gurdaspur	0.007	0.008	0.008	0.010	12.70	30.93
Kapurthala	0.155	0.181	0.174	0.236	12.72	30.92
Bathinda	0.000	0.000	0.000	0.000	0.00	0.00
Sangrur	0.007	0.008	0.008	0.010	12.78	30.93
Patiala	0.041	0.048	0.046	0.063	12.71	30.93
Ropar	0.004	0.004	0.004	0.006	12.80	30.91
Hoshiarpur	0.005	0.006	0.006	0.008	12.73	30.93
Jalandhar	0.153	0.178	0.172	0.234	12.72	30.92
Ludhiana	0.028	0.032	0.031	0.042	12.71	30.92
Ferozepur	0.007	0.008	0.007	0.010	12.73	30.91
Amritsar	0.001	0.002	0.002	0.002	12.69	30.88
Faridkot	0.000	0.000	0.000	0.000	0.00	0.00
Mansa	0.000	0.000	0.000	0.000	0.00	0.00
Fatehgarh Sahib	0.004	0.005	0.005	0.006	12.71	30.93
Moga	0.001	0.001	0.001	0.001	12.82	30.87
Shri Muksar Sahib	0.000	0.000	0.000	0.000	0.00	0.00
SBS Nagar	0.006	0.007	0.006	0.009	12.79	30.94
SAS Nagar	0.018	0.021	0.020	0.027	12.73	30.93
TarnTaran	0.002	0.003	0.002	0.003	12.96	30.91
Barnala	0.004	0.005	0.004	0.006	12.69	30.92
Fazilka	0.000	0.000	0.000	0.000	0.00	0.00
Pathankot	0.000	0.000	0.000	0.000	0.00	0.00
Total	0.441	0.515	0.497	0.674	12.72	30.92

Table 6. Energy content of different parts of *Cucumis melo* crop

Cucumis melo Crop parts	Calorific value (Kcal Kg^{-1}) after		Difference in C.V	Difference (%)
	Sun-drying	Grinding		
Leaves	3305.8	2331.27	-974.53	-29.48
Branch	2833.63	2986.46	152.83	5.39
Stem	2979.51	3358.52	379.01	12.72
Root	3479.46	4555.48	1076.02	30.92

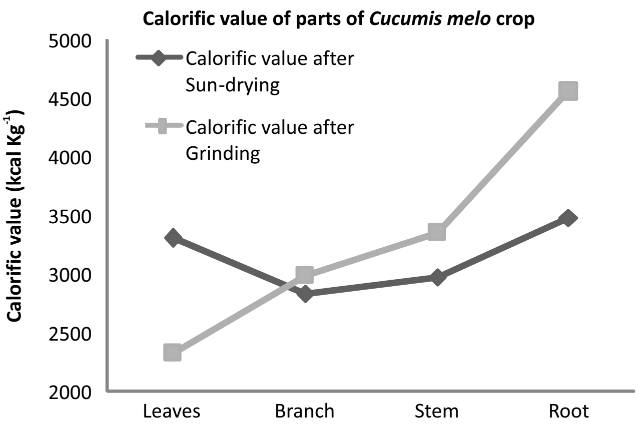

Fig. 1. Calorific value of different parts of *Cucumis melo* crop

calorific value of different parts of *Cucumis melo* crop. The total energy content for all the districts of Punjab after grinding registered an increase of 23.32 KW.

CONCLUSIONS

The present study has focused on *Cucumis melo* crop for biomass power generation. Calorific value was observed to increase after the grinding process, leading to an increase in the overall potential and efficiency of the fuel. The maximum increase in the calorific value was for root after grinding. Total residues of 1114.5 tons ha^{-1} of *Cucumis melo* crop were available from all the districts of Punjab. The maximum agri-residues were found in the district of Kapurthala and the minimum for Moga with the power potential of 0.1615 MW and 0.1635 MW respectively. The total power potential for Punjab after grinding comes out to be 0.466 MW.

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REFERENCES

Asadullah M 2014. Barriers of commercial power generation using biomass gasification gas: A review. *Renewable and Sustainable Energy Reviews* **29**: 201-215.

Bazmi AA, Zahedi G and Hashim H 2011. Progress and challenges in utilization of palm oil biomass as fuel for decentralized electricity generation. *Renewable and Sustainable Energy Reviews* **15**(1): 574-583.

Chauhan S 2012. District wise agriculture biomass resource assessment for power generation: A case study from an Indian state. *Biomass and Bioenergy* **37**: 205-212.

Chauhan S, Paul V, Mohapatra KK and Mehar M 2006. District level biomass assessment study in Punjab State", *New Delhi, India: The Energy and Resources Institute (TERI)*, 382.

Cherubini F 2010. GHG balances of bioenergy systems–overview of key steps in the production chain and methodological concerns. *Renewable Energy* **35**(7):1565-1573.

Hiloidhari M and Baruah DC 2011. Crop residues biomass for decentralized electrical power generation in rural areas (part 1): Investigation of spatial availability. *Renewable and Sustainable Energy Reviews* **15**(4): 1885-1892.

Iakovou E, Karagiannidis A, Vlachos D, Toka A and Malamakis A 2010. Waste biomass-to-energy supply chain management: A critical synthesis. *Waste Management* **30**(10):1860-1870.

Ladanai S and Vinterback J 2009. *Global potential of sustainable biomass for energy*. Swedish University of Agricultural Sciences, Department of Energy and Technology Report 013, ISSN 1654-9406, Uppsala 2009.

McKendry P 2002. Energy production from biomass conversion technologies. *Bio-resource Technology* **83**(1): 47-54.

Oyedepo SO 2012. Energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews* **16**(5): 2583-2598.

Patel B and Gami B 2012. Biomass characterization and its use as solid fuel for combustion. *Iranica Journal of Energy and Environment* **3**(2): 123-128.

Patil SA, Chigome S, Hagerhall C, Torto N and Gorton L 2013. Electrospun carbon nano fibers from polyacrylonitrile blended with activated or graphitized carbonaceous materials for improving anodic bioelectrocatalysis. *BioresourceTechnology* **132**: 21-126.

Robertson KA 2006. *Estimating regional supply and delivered cost of forest and wood processing biomass available for bioenergy.* Masters Dissertation, University of Canterbury, New Zealand.

Shafie SM, Mahlia TMI, Masjuki HH and Ahmad-Yazid A 2012. A review on electricity generation based on biomass residues in Malaysia. *Renewable and Sustainable Energy Reviews* **16**(8): 5879-5889.

Shukla PR 1996. Wood energy and global climate change-FAO/ RWEDP. *Wood Energy News* **11**: 112-118.

Viana H, Cohen WB, Lopes D and Aranha J 2010. Assessment of forest biomass for use as energy. GIS-based analysis of geographical availability and locations of wood-fired power plants. *Applied Energy* **87**(8): 2551-2560.

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Prevalence and Risk Factors of Metabolic Syndrome among Overweight/Obese Female College Students

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Abstract: A sample of 120 undergraduate subjects falling in the age group 18-22 years were selected purposively from different colleges of Ludhiana, Punjab which were grouped into normal (BMI-18.5-24.99 kg m^{-2}), overweight (BMI- 25-30 kg m^{-2}) and obese (BMI- >30 kg m^{-2}) on the basis of BMI classification to study the prevalence of metabolic syndrome and its risk factors among adolescents. The metabolic syndrome was prevalent among 52 per cent of obese subjects whereas, it was 12 per cent in case of overweight group. Overall metabolic syndrome was prevalent among 25 per cent of the subjects. The waist circumference was the major determinant factor for prevalence of metabolic syndrome among the subjects followed by lower HDL-cholesterol levels. Thirty two per cent of the subjects were at the risk of having metabolic syndrome. Based on the results of the study, it is recommended that nutrition awareness and self discipline needs to be promoted among young girls so that they can achieve desirable body weights.

***Keywords*:** Body mass index, Obesity, Overweight, Metabolic syndrome, Waist circumference

The prevalence of non-communicable diseases is increasing rapidly around the world. According to World Health Organization reports, these diseases will account for almost three quarters of all deaths in the developing countries by the year 2020 (Santos et al 2007). Increasing prevalence of childhood obesity leads to metabolic syndrome among children and young people that will emerge as public health issue thereby creating huge socio-economic and public health burden in the near future for all countries (Steele et al 2008). Increase in prevalence of metabolic syndrome in obese adolescents raises the issue of research on metabolic syndrome in young adults as they have more proclivities to fast/junk foods, rich in calories and low volume. Often, college/university students are in a grave situation of their lives. They are taking their own decisions with respect to their food and activity that can affect their future health. If proper habits are not developed during this time, they can ultimately culminate in negative health consequences. Lifestyle modification is one approach to prevent, as well as to treat, metabolic syndrome. Adoption of healthy lifestyle habits during this changeover period into adulthood is the best time as dietary intake and physical activity pattern can affect the metabolic syndrome. During this time, if poor habits related to lifestyle are developed, they will be carried into adulthood and keep on affecting negatively on health status of an individual's.

As metabolic syndrome become one of the major public health challenges worldwide, early identification of causative factors of metabolic syndrome consist an essential target for young people. Remarkable rise in obesity particularly in young adults is considered as a powerful force for the increasing prevalence of metabolic syndrome in developing countries. Young college girls are not routinely screened for metabolic syndrome. Metabolic syndromes have gained greater attention in young population because of its adverse effects and its early identification results in better health. So, it is very important to analyze causative factors of metabolic syndrome among young college girls so that proper strategies for early detection and targeted interventions can be deployed to control obesity and the risk of metabolic syndrome to support good health among young adults. There is lack of sufficient information with respect to the metabolic syndrome prevalence among young adults in India, so this study was carried out to explore the problem among young students.

MATERIAL AND METHODS

The present study was carried out in Ludhiana city of Punjab state. A sample of 120 undergraduate subjects falling in the age group 18-22 years were selected purposively from different colleges of Ludhiana, Punjab to assess the metabolic syndrome and its risk factors which were grouped into normal (BMI-18.5-24.99 kg m^{-2}), overweight (BMI- 25-30 kg m^{-2}) and obese (BMI- >30 kg m^{-2}) on the basis of BMI classification. The Body Mass Index (BMI) was a criterion for the assessment of incidence of overweight/obesity. According to WHO (2004) classification for Asian population the girls have BMI ranging between 18.5-24.99 were considered normal whereas, girls having BMI more than 25kg/m^2 were taken as obese and were falling in the categories of Overweight, Obese Class-I, Obese Class-II and Obese Class-III.

The data was collected from January to March 2018 through an interview schedule including demographic profile and socio-economic factors of the subjects. The anthropometric parameters namely height, weight, waist circumference were measured using standard methods given by Jelliffe (1966). Further derived anthropometric measurement namely BMI (Garrow 1981) was computed. Regarding physical activity pattern, total time spent daily on exercises, sports, household work such as brooming and mopping of floor, making beds, dusting, cleaning utensils, washing clothes manually cooking and serving meals was recorded. Daily time spent on sedentary activities like computer, watching television and using smart phone was also recorded. Physical Activity Ratios (PAR) given by FAO/WHO/UNU (2004) was used to calculate Physical Activity Level (PAL) of the subjects. The mean PAL was calculated using the following formula:

$$\text{PAL} = \frac{\text{(time spent on each activity (min)} \times \text{energy cost of each activity (kcal)}}{\text{1440 min}}$$

FAO/WHO/UNU (2004) classification was used to classify the subjects into lifestyle categories.

The blood samples were assayed for the estimation of fasting blood glucose level, HDL (High density lipoprotein) cholesterol and triglycerides (TG) of the subjects. Fasting blood glucose was estimated by the kit supplied by Miles India Limited. Serum triglycerides and HDL cholesterol were estimated using kits from Roche Diagnostics. The subjects were clinically examined for their systolic and diastolic blood pressures. The blood pressure (BP) was measured with a sphygmomanometer by the method of Mcleod (1984). Waist circumference, blood pressure, fasting blood glucose, HDL cholesterol and triglycerides were compared with the reference values of NCEP (2004) guidelines.

The NCEP ATP III (National Cholesterol Education Program's Adult Treatment Panel III and International Diabetes Federation (IDF) criteria for Metabolic Syndrome were used for metabolic syndrome criteria. The mean, standard deviation and percentages were calculated. Analysis of variance was applied to study the determinants of obesity using factorial experiment in completely randomized design. Correlation coefficients (r) were derived to determine the relationship of physical activity and anthropometric parameters with features of metabolic syndrome using SAS software version 9.1.

RESULTS AND DISCUSSION

Prevalence of overweight and obesity among college girls: On the basis of Body Mass Index, 25, 35 and 40 percent subjects were under normal (18.5-24.99 kg m^{-2}), overweight (25.0-29.99 kg m^{-2}) and obese (more than 30), respectively. Not even a single subject was underweight. The average Body Mass Index of normal, overweight and obese subjects was 21.24 kg m^{-2}, 27.78 kg m^{-2} and 33.16 kg m^{-2}, respectively (Table 1). Ranjit (2014) revealed that the BMI of normal girls was 21.62 kg m^{-2} and 21.20 kg m^{-2} in urban and rural groups, respectively, while it was 27.97 kg m^{-2} and 27.44 kg m^{-2} for obese girls of two groups.

General information of the subjects: The general information of the subjects is shown in Table 2. The mean age of the subjects falling in normal, overweight and obese group was approximately 21 years. Majority of the subjects had monthly family income of Rs. 50000 to 100000 in all three groups.

Anthropometric, biochemical and clinical parameters: The average waist circumference of the normal girls was 74cm, while for overweight and obese subjects were 94.29 and 106.94 cm, respectively with significant difference in normal, overweight and obese subjects. Babitha and Kusuma (2009) reported the waist circumferences of obese and non obese Rajasthani women were 83.2 and 67.7 cm, respectively. Ranjit (2014) reported that the average waist circumference of normal and obese girls in urban group were 72.68 and 84.26 cm, respectively. The mean fasting blood glucose level of the normal, overweight and obese girls was 80.8, 84.03 and 87.21 mg/dl, respectively, which indicate that all the subjects having normal fasting blood glucose level.

Table 1. Distribution of the subjects into normal, overweight and obese on the basis of Body Mass Index (N=120)

Categories of body mass index (kg/m²)	Subjects N (%)	BMI of the subjects Mean (Range) (kg/m²)
Normal (18.5-24.99)	30 (25)	21.24 (19.8-22.5)
18.5-22.9	27 (90)	
23.00-24.99	3 (10)	
Overweight (25.0-29.99)	42 (35)	27.78 (25.3-29.9)
Pre obese (25.00-27.49)	18 (43)	
(27.50-29.99)	24 (57)	
Obese(>30)	48 (40)	33.16 (30.0-47.6)
Obese Grade I (30.00-34.99)	38 (79)	
Obese Grade II (35.00-39.99)	9 (19)	
Obese Grade III (≥40)	1 (2)	
	P value	0.001**

Figures in parentheses represent percentages ,Number of subjects who were underweight –Nil, **Significant at 1% level

However, there was a significant difference between the glucose levels of the subjects falling in the three groups (Table 3).

The mean HDL-cholesterol of the normal weight girls was 53.7 mg dl^{-1} while it was lower in overweight (49.19 mg dl^{-1}) and obese (45.90 mg dl^{-1}) subjects with 25 per cent normal subjects having normal HDL-C levels. However, a significant difference was observed in the HDL-C of normal, overweight and obese subjects. The mean triglyceride (TG) of the normal, overweight and obese subjects was 86.4, 111.30 and 113.31 mg dl^{-1}, respectively. However, a significant difference was in the TG level of the three groups. The average TG level of the overweight and obese subjects was more than the standard value while the mean TG of the normal girls was within the range. The average systolic blood pressure of normal and overweight girls was 119.7 and 120.0 mm Hg while of obese girls was 122.29 mm Hg. The difference was significant in the blood pressure of the three groups. The average systolic blood pressure of the obese girls was higher when compared to the normal and overweight. The average diastolic blood pressure of normal, overweight and obese girls was 79.7, 80.8 and 82.92 mm Hg, respectively. The average diastolic blood pressure of girls in the three groups was within range; however, significant difference among the three groups was seen.

Table 2. General information of selected normal, overweight and obese subjects

Particulars	Normal (n=30)	Overweight (n=42)	Obese (n=48)
Age, years			
Mean±SD	20.9±1.6	21.04±1.58	20.94±1.72
Type of family			
Joint	7 (23)	9 (21)	19 (40)
Nuclear	23 (77)	33 (79)	29 (60)
Family composition			
<3	-	-	-
3-5	16 (53)	25 (60)	21 (44)
5-7	13 (43)	17 (40)	21 (44)
>7	1 (4)	-	6 (12)
Monthly family income, Rs			
Below 50000	5 (17)	3 (7)	1 (2)
50000-100000	23 (77)	35 (83)	39 (81)
More than 100000	2 (6)	4 (10)	8 (17)

Figures in parentheses indicate percentage

Table 3. Metabolic syndrome parameters of normal, overweight and obese subjects

Variables	Normal (n=30)	Overweight (n=42)	Obese (n=48)	P value
Waist circumference, cm				
Mean	74.00 (69-86)	94.29 (81-112)	106.94 (93-134)	0.007**
Fasting glucose, mg dl^{-1}				
Mean	80.8 (74.3-86.4)	84.03 (76.8-92.4)	87.21 (74.23-96.15)	<0.001***
HDL-cholesterol, mg dl^{-1}				
Mean	53.7 (44-61)	49.19 (35-57)	45.90 (39-54)	<0.001***
Triglycerides, mg dl^{-1}				
Mean	86.4 (64-109.8)	111.30 (87.9-141.0)	113.31 (98.2-163.0)	<0.001***
Systolic blood pressure, mmHg				
Mean	119.7 (110-120)	120.0 (110-130)	122.29 (120-130)	0.001***
Diastolic blood pressure, mmHg				
Mean	79.7 (70-80)	80.8 (70-90)	82.92 (80-90)	0.0011***

** and *** Significant at 5 and 1% level, Figures in parentheses indicate range

Physical activity level (PAL): The duration of exercise was higher in obese girls (34.38 min day^{-1}) followed by normal (22 min day^{-1}) and overweight girls (12.86 min day^{-1}). Further, more time spent by obese girls than their normal and overweight counterparts could be attributed to more awareness regarding importance of physical activity to overcome obesity. Maximum time spent by the subjects was on smart phones, out of which obese group spent more time as compared to other groups (Table 4). Popkin et al (1999) reported that increasing sedentary work is linked with great risk of obesity. Marshall et al (2004) and Matusitz and McCormick (2012) reported that television and computer use may cause sedentarism, which in turn may increase obesity. The physical activity level showed that mean PAL value of girls from all the groups had fallen in the category of sedentary workers. Byrd-Williams et al (2010) also reported that increasing sedentary work is linked with greater risk of obesity.

Risk factors of metabolic syndrome: Overweight and obese participants with metabolic syndrome had higher mean waist circumference, higher fasting blood glucose and lower HDL-cholesterol levels. The least prevalent factor among the subjects was elevated triglycerides (Table 5). The biochemical measures namely fasting blood glucose had a positive correlation with watching television (r= 0.196), while a negative correlation with the PAL value (r= 0.278) of the subjects, respectively. Further, HDL-cholesterol and TG were positively correlated with the usage of computer (r= 0.548 and r= 0.351) and phone (r= 0.652 and r= 0.576), respectively. The systolic blood pressure had a positive correlation with usage of phone (r= 0.180) and watching television (r= 0.236) where as diastolic blood pressure had a positive correlation with usage of computer(r= 0.211), phone (r= 0.278) and PAL value (r= 0.197), respectively. Increased television viewings were significantly associated with overweight in young children as reported by Kuriyan et al (2007). The fasting glucose had a significant and positive correlation with anthropometric parameters viz. weight (r= 0.591), BMI (r= 0.526) and waist circumference (r= 0.542). However, HDL-C was negatively correlated with weight (r= 0.365), BMI (r= 0.425), waist circumference (r= 0.493). Further, TG had a positive and significant correlation with weight (r= 0.439) and a negative correlation with BMI (r= 0.362). Clinical parameters i.e. systolic and diastolic blood pressure had a positive correlation with weight (r= 0.267 and r=0.197) and waist circumference (r= 0.175 and r=0.312), respectively. The prevalence of metabolic syndrome in overweight and obese subjects was 25 per cent (Table 6). The prevalence was higher among obese (52%) as compared to overweight (12%). Thirty two percent of subjects were having two criteria of metabolic syndrome which means they were at the risk of having metabolic syndrome. Young adults are at greater risk of developing metabolic syndrome. Fernandes and Lofgren (2011) showed an overall prevalence of metabolic syndrome among the selected subjects was 3.7 per cent, and 28.0 and 7.4 per cent with 1 or 2 of metabolic syndrome criteria, respectively. The most prevalent criteria was low high-density lipoprotein (20.1%) and increased triglycerides (17.5%). This study suggests identification of risk factors of metabolic syndrome in early life and screening young adults will help in intervention programmes to decrease Coronary Heart Disease risk.

Table 4. Physical activity pattern of selected normal, over weight and obese girls

Variables	Normal	Overweight	Obese
Duration of physical exercise or sport, min day^{-1}			
Mean	22 (0-180)	12.86 (0-60)	34.38 (0-120)
Time spent in household activities, min day^{-1} (Mean± S.D)			
Brooming of floor	6±6.62	6.43±5.66	3.31±5.22
Mopping of floor	4.5±7.81	1.79±5.39	0.42±2.89
Making beds	5.0±3.71	5.83±3.30	3.85±3.89
Dusting	2.5±6.53	1.31±3.83	0.52±2.58
Cleaning utensils	9.0±7.81	10.48±7.05	4.48±6.29
Washing clothes (manual)	4.8±7.25	3.33±6.12	3.33±5.95
Cooking and serving food	6.0±12.21	15.00±23.81	9.38±16.56
Time spent on computers, hours day^{-1}			
Mean	0.53 (0-4)	1.0 (0-5)	0.56 (0-6)
Time spent on watching television, hours day^{-1}			
Mean	0.73 (0-2)	0.86 (0-3)	0.72 (0-2)
Time spent on Smart Phones, hours day^{-1}			
Mean	2.8 (1-4)	2.60 (1-5)	3.23 (1-6)
PALvalue			
Mean	1.49 (1.31-1.73)	1.46 (0.91-1.71)	1.46 (0.99-1.64)

Figures in parenthesis indicate range

Table 5. Comparison of risk factors for metabolic syndrome

Metabolic syndrome variables	Ranges	Normal (n=30)	Over weight (n=42)	Obese (n=48)
Waist circumference	> 88 cm	-	34 (81)	48 (100)
Elevated TG	≥ 150 mg dL^{-1}	-	-	1 (2)
Low HDL-cholesterol	< 50 mg dL^{-1}	22 (73)	23 (55)	12 (25)
Fasting glucose	≥ 100 mg dL^{-1}	1 (3)	17 (41)	27 (56)
Systolic blood pressure	≥ 130 mm Hg	-	2 (5)	11 (23)
Diastolic blood pressure	≥ 85 mm Hg	-	5 (12)	14 (29)

Figures in parentheses are the percentages

Table 6. Distribution of subjects on the basis of presence of number of metabolic syndrome criteria

Metabolic syndrome	Normal (n=30)	Overweight (n=42)	Obese (n=48)	Overall (N=120)
0 criterion	21(70)	4 (9)	-	25 (21)
1criteria	9 (30)	15 (36)	2 (4)	26 (22)
2 criteria	-	18 (43)	21 (44)	39 (32)
3 criteria	-	2 (5)	14 (29)	16 (13)
>4 criteria	-	3 (7)	11 (23)	14 (12)

Figures in parentheses indicate percentages

Not surprisingly, the individual risk factors of metabolic syndrome (central obesity, high triglyceride, low HDL-cholesterol, high blood pressure and high fasting blood glucose) were higher in overweight and obese group in comparison to the non-obese group. Overweight and obese adolescents with metabolic syndrome were also with larger waist circumference, higher triglyceride levels and lower HDL cholesterol levels compared to the non-metabolic syndrome group. Intervention programmes aimed at combating metabolic syndrome are necessary to reduce early cardiovascular disease and type 2 diabetes mellitus. Previous studies have shown an association of physical activity (Brage et al 2004, Nyugen et al 2010) with obesity and other metabolic risk factors.

CONCLUSION

The waist circumference was the major determinant factor for prevalence of metabolic syndrome among the subjects followed by lower HDL-cholesterol levels. The prevalence of metabolic syndrome increased with increase in body mass index and was notably higher among obese college students than normal and overweight students. It is recommended that regular screening, nutrition awareness, increased physical activity and self discipline targeting weight reduction needs to be promoted among young girls so that they can achieve desirable body weights.

REFERENCES

Babitha B and Kusuma DL 2009. Chronic energy deficiency and obesity among rural women-relationship between BMI and selected body composition parameters. *Indian Journal of Nutrition and Dietetics* **46:** 386-392.

Brage S, Wedderkopp N, Ekelund U, Franks PW, Warenham NJ, Andersen LB and Froberg K 2004. Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children. The European Youth Heart Study (EYHS). *Diabetes Care* **27:** 2141-2148.

Byrd-Williams CE, Belcher BR, Spruijt-Metz D, Davis JN, Ventura EE, Kelly L, Berhane K, Azen S and Goran MI 2010. Increased physical activity and reduced adiposity in overweight Hispanic adolescents. *Medical and Science in Sports and Exercise* **42:** 478-484.

FAO/WHO/UNU 2004.Human Energy Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation, Rome.

Fernandes J and Lofgren IE 2011. Prevalence of metabolic syndrome and individual criteria in college students. *Journal of American College Health* **59**(4)**:** 313-321.

Garrow JS 1981.*Treat Obesity Seriously: A Clinical Manual.* Churchill Livingstone, London.

Jelliffe DB1966.*The assessment of nutritional status of community*. World Health Organization Monograph series No. 53, Geneva pp 50-84.

Kuriyan R, Bhat S and Kurpad AV 2007. Television viewing and sleep are associated with overweight among urban and semi-urban South Indian children. *Nutrition Journal* **6:** 25.

Mcleod J1984. *Davidson's Principles and Practice of Medicine*.14th Edition Edinburgh ELBS/Churchill Livingstone, London.

Marshall SJ, Biddle JH, Gorely T, Cameron N and Murdey I 2004. Relationships between media use, body fatness and physical activity in children and youth: a meta analysis. *International Journal of Obesity* **28:** 1238-1246.

Matusitz J and McCormick J 2012. The effects of internet use on human obesity in the United States. *Social Work in Public Health* **27:** 250-269.

NCEP 2004. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection: Evaluation and treatment of high blood cholesterol in adults (Adult Treatment Panel III) update. National Heart, Lung and Blood Institute, National Institutes of Health, NIH Publication No. 02-5215.

Nyugen TH, Tang HK, Kelly P, van der Ploeg HP and Dibley MJ 2010. Association between physical activity and metabolic syndrome: a cross sectional survey in adolescents in Ho Chi Minh City, Vietnam. *BioMed Central Public Health* **10:** 141.

Popkin BM, Horton S, Kim S, Mahal A and Shuigao J 1999. Trends in diet, nutrition status and diet related no communicable diseases in China and India: The Economic Costs of the Nutrition Transition. *Nutrition Review* **59:** 379-390.

Ranjit A 2014. *Determinants of overweight and obesity among urban and rural college girls*. M.Sc. Thesis, Punjab Agricultural University Ludhiana.

Santos AC, Ebrahim S and Barros H 2007. Alcohol intake, smoking, sleeping hours, physical activity and the metabolic syndrome. *Preventive Medicine* **4**: 328-334.

Steele RM, Brage S, Corder K, Wareham NJ and Ekelund U 2008. Physical activity, cardio respiratory fitness, and the metabolic syndrome in youth. *Journal of Applied Physiology* **105**: 342-351.

WHO 2004. Appropriate body mass index for Asian populations and its implications for policy and intervention strategies. *Lancet* **363:** 157-163.

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