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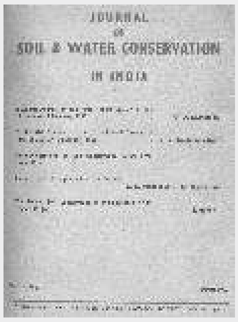

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Contents

Pledge

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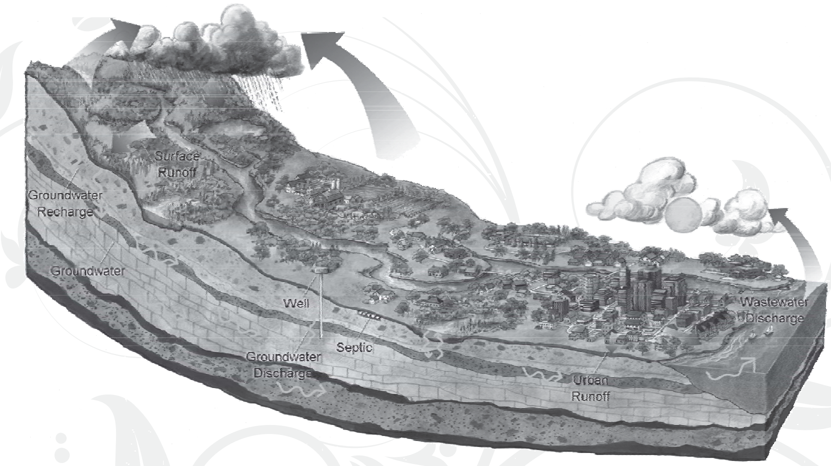

I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

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Land capability classification and land resources planning using remote sensing and GIS

A.K. PALI[1], S. SURYAVANSHI[2], B. L. SINHA[3] and JITENDRA SINHA[4]

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ABSTRACT

Land capability classification and land resources action plan were developed for Malegaon watershed in the district of Nasik, Maharashtra; using remote sensing and GIS techniques. The watershed comprises of 5th order drainage stream, having different soil series. Various thematic maps including soil series, hydrogeomorphology and ground water potential, slope, land use capability and land cover maps were generated. Based upon the land capability classification, land resources development plan was formulated. The study revealed that the Malegaon watershed comprises of III, IV, VI and VII land capability classes. About 21% area was found under class III, 41% under class IV, 34% under class VI and only 4% under class VII. Land resources development plan map prepared by making unique combination of land capability map with the land use map suggested that 4.3% area of the watershed was under intensive agriculture 10.3% for double cropping, 23% for horticulture, 25.2% for agro-horticulture and 18.6% for silvi-pasture. Besides this a total of about 18.5% was planned for afforestation and fuel wood plantation and only 0.05% area was considered for water bodies.

Key words: Malegaon, fluvial origin, Godavri catchment, Dissected plateau, Hydrogeomorphology

INTRODUCTION

Land use and land cover is of dynamic nature and needs proper monitoring for the sake of optimum utilization of land resources (Farooq et al. 2008). In classifying land-use capability, answer to these questions is first sought: Is the land suited for the production of crops? Can it be cultivated without controlling soil erosion? Is it safe and permanent use limited to the production of perennial vegetation? Land use and conservation of land are influenced by the nature of the soil, the degree to which it has been affected by erosion, the slope, the wetness of the soil or its doughtiness and climate. Land capability classification is then developed as a method to assess the extent of limitation such as erosion risk, soil depth, wetness and climate that create problems in agricultural activities for crop production. The objective of the classification is to recognize the land into a unit with similar kinds and degree of limitations and potentials. The method recognizes the whole land into eight classes from class I to class VIII. The first four classes are considered suitable for cultivation depending on the degree of the risk involved, while the last four classes are considered unsuitable for crop cultivation.

Planning with conventional data base often becomes difficult by virtue of time required for collecting and collating data especially when it is to be dealt with spatial data (Selvi, *et al.* 2008). The use of remote sensing and geographic information system (GIS) can prove to be very effective and rapid techniques to classify the land as per its land capability potential. These techniques are the scientific tools to measure the various earth resources maps and its potential. Using satellite based remote sensing data, various resource maps can be generated and by the use of GIS, these maps can be further analyzed to derive composite maps with numerous information, which finally derives new maps like land capability and land suitability maps.

The present study was conducted at Malegaon watershed in district Nasik of Maharashtra with

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an objective of generating and interpreting the various thematic maps of the watershed using remote sensing and GIS techniques and thereby preparing land capability classification map for developing effective management plan.

MATERIALS AND METHODS

Physiography and climate of the study area

The study area covered the Malegaon watershed in Nasik district of Maharashtra, which is located in south-western part of the district (Fig. 1). The study area falls in Agro-climatic Zone No. 6 and lies between $72^0 28'$ to $73^0 37'$ E longitude and $20^0 00'$ to $20^0 05'$ N latitude. The Malegaon watershed is physiographically divided into alluvial plain, local valleys, undulating upland, plateau plain, high plateaus and foothills followed by the hill slopes. The boundary map of the Malegaon watershed is shown in Fig. 2. The area comes under sub-tropical, semi-arid monsoon climate and receives an average annual rainfall of 1100 mm. Heavier rainfall is experienced in the western part the study area whereas it gradually decreases towards the eastern part.

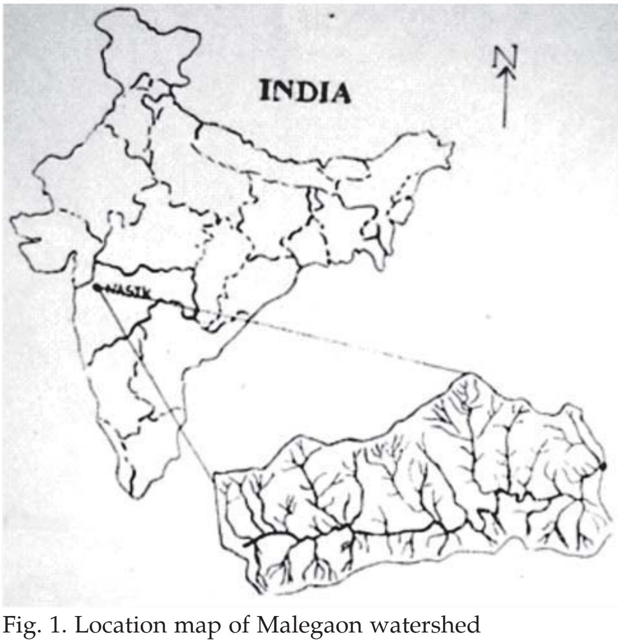

Fig. 1. Location map of Malegaon watershed

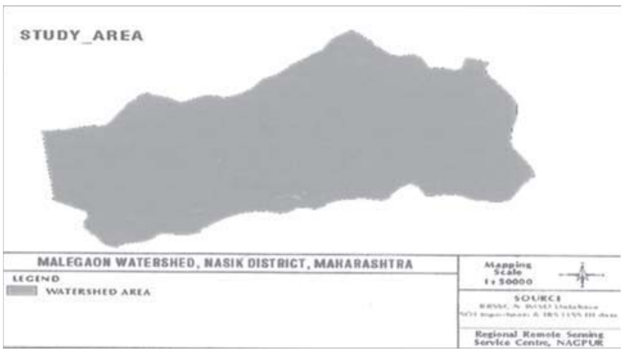

Fig. 2. Boundary of the Watershed

Generation of thematic maps

Using both interactive digital and visual techniques of remote sensing, various thematic maps of the watershed area were generated on 1:50,000 scale. The remote sensing satellite data of IRS-1B (LISS-II) for three seasons viz. Nov. 1993, Jan. 1994 and May 1994 were obtained from Regional Remote Sensing Service Centres (RRSSCs), Nagpur. The ground truth data were collected and used for preparing thematic maps. Base maps and derived maps were prepared using the collateral and satellite data. The base maps were then converted into digital maps with the aid of screen digitizer software.

Reconnaissance soil mapping

Soil mapping of the study area was carried out to study the characteristics, quality and classes of different soils, their locations and spatial distribution using IRS 1B (LISS-II) data. The soil map was then prepared in the category of soil series map based on soil depth, texture, slope, erosion etc. The soil series were termed as Wadholi, Mahirawani, Adgaon, Dhondegaon, Illunja, Nasalgaon, Manoli, Talyachiwadi, Kotamgaon, and Masrut. The existing soil series map of the study area is shown in Fig. 3.

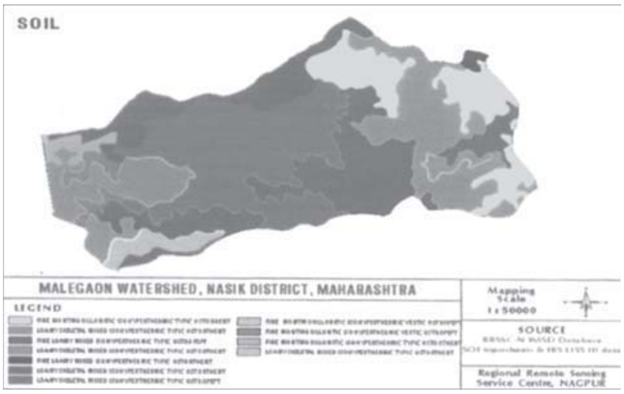

Fig. 3. Reconnaissance soil family map

Hydrogeomorhology and groundwater potential map

The hydrogeomorphlogy and groundwater potential map (Fig. 4) was prepared based on visual interpretation of IRS 1 B (LISS-II) data of three years and SOI topographic maps. The geomorphological units were classified based on the origin of the landforms and geological process acting upon it. Further, the units have been separated according to relief altitude and structural information. The geomorphology map was refined and updated with the field investigation and was broadly divided into three major units, namely structural origin, denundation origin, and fluvial origin.

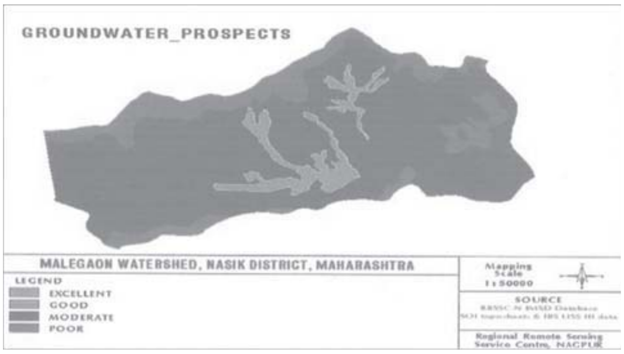

Fig. 4. Hydrogeomorphology and ground water potential map

Slope and land capability/land cover map

The digitized contort information was used for preparing the slope map in order to get the idea about the topography of the land and its capability. A slope map (Fig. 5) on 1:50,000 scales were generated from DEM grid. In order to prepare the accurate land capability map, it is necessary to study the physical characteristics of the soil, which

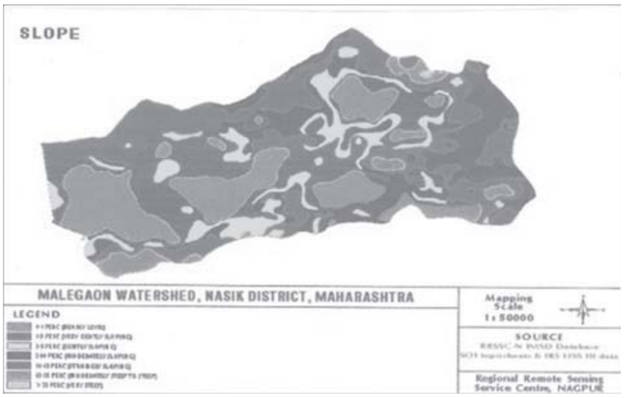

Fig. 5. Slope map

play an important role in land capability classification (Murthy *et al*, 2000). The parameters such as soil depth, texture, erosion, slope and permeability were taken into account while generating land capability map (Fig. 6). The integration of various thematic maps and attribute data, further manipulation for development of the land resource action plan (Fig. 7) was carried out. The action plan map was then prepared by combining land capability map representing various characteristics of the soil along with their limitations with the land use/land cover map, using GIS techniques.

Fig. 6. Land capability class map

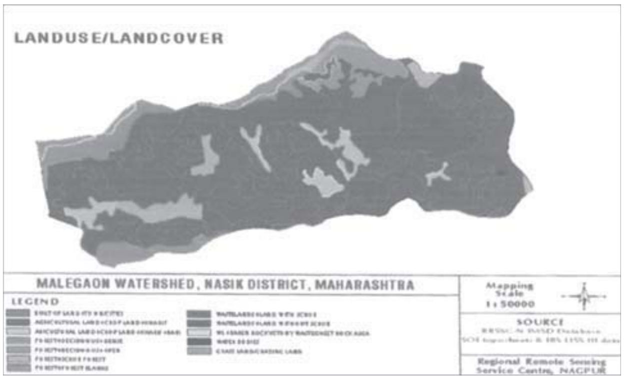

Fig. 7 Land resource development plan map

RESULTS AND DISCUSSIONS

The various thematic maps prepared and the derived layers of action plan and land capability maps were generated using computer programme. The results are discussed below.

Drainage map

The base map contains drainage network information and drainage orders. The highest drainage order, which flows through the watershed, was found to be of 5th order. It was also observed that the drainage pattern was dendritic and flows from west to south-west direction as a part of Godavari catchment (Fig. 8).

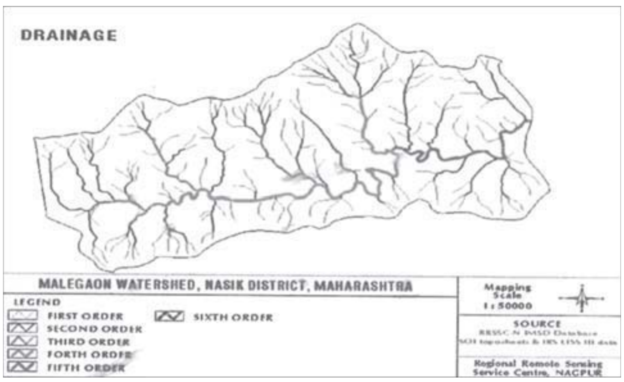

Fig. 8. Drainage network map

Land-use/land cover map

The land use/land cover map (Fig. 9) was classified in 9 classes (Table 1). It is evident that the total area of Malegaon watershed was about 5023 ha, out of which about 1761 ha was found under agricultural cropland in *kharif* season, covering about 35 per cent of the total geographical area of the watershed. Double cropped area (*kharif* + *rabi*) was about 4 per cent. Dense and open forest was covered under less than 1 per cent and about 7 per cent of the watershed area, respectively. Forest blank and scrub forest were found to be in about 5 per cent and 4 per cent area, respectively. Waste land and land with scrub was the highest, comprising of about 43 per cent of the total watershed area. Water bodies covered only 4 per cent area of the watershed.

Table 1. Area under different land use/land cover in Malegaon watershed

Land use/land cover	Area (ha)	Percentage of total area
Agricultural land: Crop land (*Kharif*)	1761.19	35.06
Agricultural land: Crop land (*Kharif* + *rabi*)	216.35	4.31
Forest (deciduous + dense)	44.23	0.88
Forest (deciduous + open)	343.62	6.84
Forest (scrub forest)	217.18	4.33
Forest (forest blank)	267.85	5.33
Waste lands + land with scrub	2169.58	43.19
Water bodies	2.18	0.04
Others	0.82	0.02
Total	**5022.97**	**100.00**

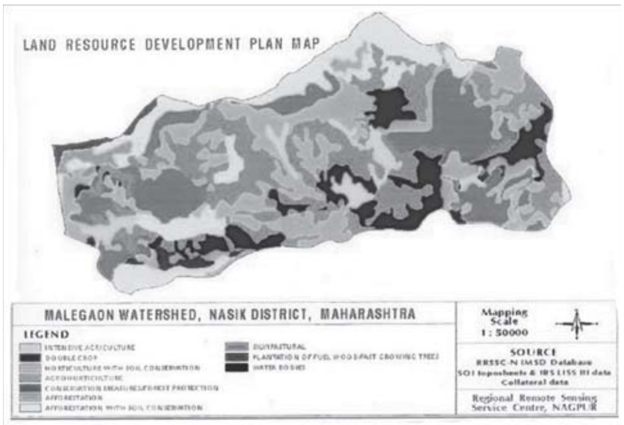

Fig. 9. Land use/ land cover map

Reconnaissance soil family map

Reconnaissance Soil Family map indicates variation in soil characteristics. Soils vary considerably in physical and morphological characteristics and thereby play important role in management of soil productivity and sustainable production. The details of existing soil families encountered in Malegaon watershed with their coverage area have been presented in Table 2 and locations and extent of these soil series are depicted in Fig. 3. It was found that a combination of Wadholi-Adgaon-Dhondegaon soil family was found in an area of about 19 per cent of the total watershed area. Combination of Mahirawani-Nasalgaon soil family was found in about 27 per cent area. Adgaon-Dhondegaon soil series was encountered in about 2 per cent area, whereas Dondegaon-Nasalgaon-Manoli soil family was found in about 12 per cent of the watershed area. The area under Illunja-Nasalgaon-Nandgaon soil series was found in about 24 per cent area. Nasalgaon-Koptamgaon-Masrul soil family occurred in only about 0.5 per cent area of the watershed and Illunja-Nandgaon soil family was consisted of about 1 per cent area of the watershed.

Table 2. Existing soil families at the study area

Soil family	Cultivability	Area (ha)	Percentage of total area
Fine loamy mixed isohyperthermic typic ustorthent	Cultivable	961.30	19.14
Loamy skeletal mixed isohyperthermic typic ustorthent	Cultivable	1356.37	27.00
Fine montmorillonitic isohyperthermic vertic ustorthent	Cultivable	98.50	1.96
Fine montmorillonitic isohyperthermic typic ustorthent	Cultivable	599.70	11.94
Loamy skeletal mixed isohyperthermic typic ustorthent	Uncultivable	1261.92	24.23
Loamy skeletal mixed isohyperthermic typic ustorthent	Cultivable	26.64	0.53
Loamy skeletal mixed isohyperthermic typic ustorthent	Uncultivable	58.62	1.18
Loamy skeletal mixed isohyperthermic typic ustorthent	Uncultivable	3.33	0.06
Fine montmorillonitic isohyperthermic vertic ustorthent	Uncultivable	141.27	2.81
Fine loamy mixed isohyperthermic typic ustorthent	Cultivable	76.04	1.51
Loamy skeletal mixed isohyperthermic typic ustorthent	Uncultivable	484.28	9.64
Total	5022.97	100.00	

The area under Tayachwadi-Rock was found in about 3 per cent of the total area. Dondegaon-Nasalgaon-Kotamgaon soil family was comprised of about 1.5 per cent area and Tayachwadi-Talegaon soil family was fond in little about less than 10 per cent area of the total geographical area of the watershed.

Hydrogeomorphology and groundwater potential map

As regards hydrogeomorphology and groundwater potential, it was found that most of the dug wells and bore wells were tapping water from basaltic aquifer, characterized by weathered material followed by fractured basalt. Groundwater was found to be confined along fractures, intertrapian beds, joints, vesicles and also in weathered zone. Based on the geological, geomorphological and ground truth data, quantitative assessment of groundwater potential was also analyzed (Table 3). The unconsolidated materials deposited by fluvial activity, mapped as alluvial plains and valley fill are generally known for very good groundwater potential. These areas are recharged by streams and mostly groundwater movement is towards these areas (Das *et al, 1997*). The area covered under this category was found to be about 7 per cent of the total watershed area. The dissected plateau- A is considered to be poor groundwater potential areas, where the water is very shallow. This kind of locations were found in northern most tract and in some portions of southern most tract, as also indicated in Fig. 5. It is mostly occupied by barren land in the higher altitudes. The area covered under this category was about 16 per cent of the total watershed area. Dissected plateau- B is considered as moderate groundwater potential area due to shallow thickness of weathered zone, moderate recharge and mostly in undulating terrain. It is mostly occupied by scrubland and agricultural land. The area covered under this category was found to be about 77 per cent of the total area (Fig. 4).

Table 3. Soil series according to land capability class

Land Capability Classes			
III	IV	VI	VII
Wadholi	Mahirgaon	Illunja	Nandgaon
Adgaon	Dhondegaon	Masrul	Talegaon
	Kotamgaon		Talyachwadi
	Nasalgaon		

Slope map

The slope categories found in the study area are given in Table 4 and spread of these slope categories is shown in Fig. 5. About 50 per cent of land is having slope less than 5 per cent, which is suitable for cultivation. For the topography having slope of about 45 per cent, conservation practices are necessary for cultivation purpose and on the remaining piece of land, different plantations should be undertaken. These inferences should then be integrated with the soil potential so as to generate land resource development plan.

Table 4. Hydrogeomorphology and groundwater potential at the study area

Hydrogeo-morphlogy	Groundwater potential	Area (ha)	Percentage of total area
Fluvial origin VF	Excellent	353.62	7.04
Dissected plateau - A	Poor	792.82	15.78
Dissected plateau - B	Moderate	3876.53	77.18
Total		**5022.97**	**100.00**

Land capability map

The land capability map as developed in the study is shown in Fig. 6 with different capability classes delineated in the watershed area. The areas under different land capability classes of the study area are given in Table 5. The results indicated that about 21 per cent and 41 per cent of the total geographical area of the Malegaon watershed falls under Class-III and Class-IV classes, respectively whereas about 34 per cent and 4 per cent area were under Class-VI and Class-VII categories respectively, which are uncultivable. The land

Table 5. Slope categories at the study area

Slope category	Area) (ha	Percentage of total area
Nearly level (< 1%)	1022.19	20.35
Very gentle slope (1- 3%)	1047.23	20.85
Gentle slope (3 – 5%)	498.58	9.93
Moderate slope (5 – 10%)	1009.85	20.10
Strong slope (10 – 15%)	1251.20	24.90
Moderately steep to steep (15 – 35%)	187.40	3.73
Very steep slope (> 35%)	6.52	0.14
Total	**5022.97**	**100.00**

capability map (Table 6) shows that the two soil series comes under the Class-III and Class-VI whereas four soil series come under Class-IV and three soil series under Class-VII (Table 6).

Table 6. Area under different land capability classes at the study area

Class	Cultivability	Area (ha)	Percentage of total area
III	Cultivable	1059.80	21.10
IV	Cultivable	2058.75	40.99
VI	Uncultivable	1701.20	33.87
VII	Uncultivable	203.22	4.04
	Total	5022.97	100.00

Land resource development plan

The land resource development plan was resultant of soils, hydrogeomorphology and slope with the present land use categories. Based on the capabilities of the composite units and other determinants such as socio-economic conditions, the appropriate land resource development plan was suggested (Table 7 and Fig 7). About 4.3 per cent area was considered for intensive agriculture under class III, which had fine textured soils with good groundwater potential and slopping between 1 to 3 per cent. About 10.3 per cent area was suggested for double cropping, falling under the same land capability class. Thus in total, about 14.6 per cent area was proposed solely for agriculture. Land falling under class VI and VII was considered for horticultural crops with some soil conservation practices as this may provide better economic yields besides protecting soil erosion. The existing single kharif copped area under shallow soils with moderate groundwater potential, having slope varying from 3 to 5 per cent was suggested for horticulture, which comes to about 23 per cent of the watershed area. About 25 per cent area falling under class IV was recommended for agro-horticulture. Most of the lands under current fallow having moderate deep soil and moderate groundwater potential represented class IV category. About 16.5 percent of the total watershed area was covered under afforestation with soil conservation measures in about 15 per cent. About 18.6 per cent area falling under land capability class-VI, was planned for silvi-pasture. The land units (1.1 per cent of the watershed area) presently under fallow, barren and forest plantation with land capability class-VII were recommended for plantation of fuel wood/fast growing trees. This will serve as fuel stock as well as medicinal and daily livelihood the people living in the watershed area. Depending upon the land topography, only about 5 per cent of the total watershed area was suggested for water bodies.

CONCLUSIONS

The effective land resources development plan needs to be prepared according to its land capability classes. These represent various characteristics of the land alongwith extent of limitations for different land uses. It also gives an strategic idea for better management of the land for maximizing the output from the watershed. The use of Remote sensing and GIS techniques are very effective for developing various thematic maps such as land use/land cover, soil series, hydrogeomorphology, slope drainage etc. with greater accuracy. Since, the generated maps were validated with the ground truth and base map, the remote sensing and GIS technique was found very suitable for the watershed.

Table 7. Suggested land resources development plan for the study area

Suggested land use plan	class	Area (h)	Percentage of total area
Intensive agriculture	III, IV, VI, VII	216.27	4.30
Double crop	III	518.28	10.32
Horticulture with soil conservation	VI, VII	1158.21	23.06
Agro-horticulture	IV	1265.66	25.20
Conservation measures/forest protection	Iv, VI, VII	44.23	0.88
Afforestation	III, IV	73.71	1.47
Afforestation with soil conservation	III, IV, VI, VII	755.35	15.04
Silvipasture	VI	932.99	18.57
Plantation of fuel wood/fast growing trees	VII	55.72	1.11
Water bodies	-	2.55	0.05
	Total	5022.97	100.00

REFERENCES

Anonymous, 1996. Technical Reports on Preparation of Land Capability Maps for Nasik and Dhule Districts of Maharashtra, Regional Remote Sensing Service Centre, Nagpur.

Das, S. Behra, S. C., Kar A., Narendra, P. and Guha, S., 1997. Hydrogeomorphological Mapping in Groundwater Exploration Using Remote Sensing Data- A Case Study in Keonjher District, Orissa. Photonivachak; J. Indian Soc. Remote Sensing, 25(4):247-260.

Farooq, M., Rashid, G. and Arora, S. 2008. Spatio-Temporal Change in Land Use and Land Cover of District Rajouri: A Geo-Spatial Approach. *Journal of Soil and Water Conservation* 7(4): 20-24.

Murthy, Y. V. N. K., Sinha, A. K., Jeyram, A. Shriniwas Rao S., Das, S. N., Pandit, D. S., Shrinivasan, D. S. and Rajendar, C. K. 2000. Integrated Watershed Developmental Planning Using Remote Sensing and GIS, Souvenir of workshop on Space Technology for Rural Development- NGOs Perspective, 18th April 2000, Nagpur.

Selvi, M.S., Kumar, S., Singh, D., Yadav, A.K., Kumar, M., Saha, S.K., Laghate, P., Sharma, R.K., Meena, R. L. and Das, S.N. 2008. Digital Microwatershed Atlas – A Tool for Watershed Development Planning. *Journal of Soil and Water Conservation* 7(4): 39-43.

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Morphometric analysis of chanavada micro-watershed using remote sensing and GIS

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ABSTRACT

The present work is an attempt to carry out a detailed study of linear and shape morphometric parameters in Chanavada micro-watersheds of Udaipur district Rajasthan covering an area of 1475 ha. Topographic maps of Survey of India on 1:50000 scale were utilized to delineate the drainage system, thus to identify precisely water divides using Geographic Information System (GIS). It has been found that in Chanavada micro-watershed 81 streams are belonging to different stream orders with the highest order of 4 are existing. The study has shown that the Chanavada micro-watershed is in conformity with the Horton's law of stream numbers and stream lengths.

Key words: Hydrological diagnosis, Morphometric analysis, GIS and Geomorphological analysis

INTRODUCTION

The quantitative analysis of morphometric parameters is of immense utility in river basin evaluation, watershed prioritization for soil and water conservation, and natural resources management at micro level. Geology, relief, and climate are the key determinants of running water ecosystems functioning at the basin scale (Frissel *et al.*, 1986). Morphometric descriptors represent relatively simple approaches to describe basin processes and to compare basin characteristics (Mesa 2006) and enable an enhanced understanding of the geological and geomorphic history of a drainage basin (Strahler 1964). A watershed is an ideal unit for management of Natural resources like land and water and for mitigation of the impact of natural disasters for achieving sustainable development. The morphometric assessment helps to elaborate a primary hydrological diagnosis in order to predict approximate behavior of a watershed if correctly coupled with geomorphology and geology (Esper 2008). The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams, etc. (Chorley 1969, Gregory and Walling 1973). Hence, morphometric analysis of a watershed is an essential first step, toward basic understanding of watershed dynamics. Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Morphometric analysis could be used for prioritization of micro-watersheds by studying different linear and aerial parameters of the watershed even without the availability of soil maps (Biswas *et al.*, 1999). Remote sensing and GIS are the most advanced tools for studies on prioritization of micro-watersheds for their development and management.

Study area

Chanavada micro-watershed is located in Girwa tahasil, of Udaipur district in Southern part of Rajasthan. The project area lies between $24^{0}15'21''$ to $24^{0}17'0.46''$ N latitude and $73^{0}35'39''$ to $73^{0}40'21''$E longitude. The total geographic area of micro watershed is 1475 ha. It is at 40 km away from Udaipur city.

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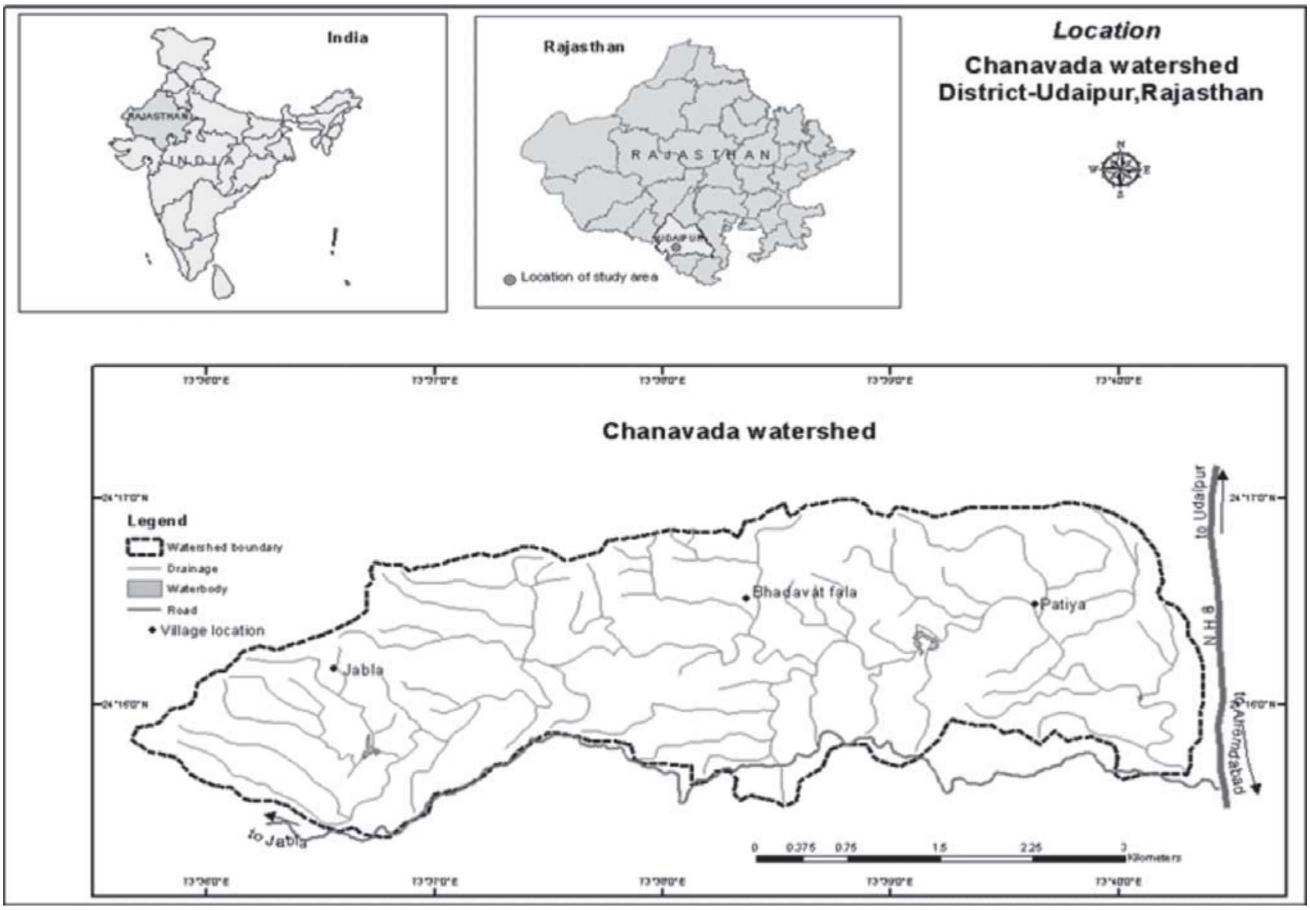

Fig.1: Location map of study area

MATERIALS AND METHODS

The Study was carried out on watershed level utilizing SOI toposheets, (1961). All the streams were digitized from Survey of India Toposheets, 1961 on 1:50,000 scale. The study was carried out in GIS environment. The GIS spatial database was composed of a number of thematic information on topography, soil, vegetation etc. Topography, drainage patterns and soil information were scanned using HP design jet copies CC 800 PS image scanner software. The scanned maps were then transferred into Arc INFO 9.1 and edited using Arc tools. These edited maps were used for further analysis.

Geomorphological analysis

Geomorphological analysis is the systematic description of watershed's geometry and its stream channel system to measure the (I) Linear aspects of drainage network (II) Areal aspects of watershed and (III) Relief aspects of channel network. The morphological parameters directly or indirectly reflect the entire watershed based causative factors affecting runoff and sediment loss. The surface features are the fundamental unit of analysis prior to adopting any sophisticated tool to monitor the watershed responses in connection to any of the hydrologic processes acting on it. The parameters can be conveniently worked out from the toposheet using the capability of GIS tools. The dimensionless geomorphological parameters can be presented under different groups as shown in table 1.

Table 1. Grouping of geomorphological parameters

Groups	Geomorphological Parameters
Linear Aspects of Drainage Network	Stream order, stream number, bifurcation ratio, stream length and stream length ratio
Areal Aspects of Watershed	Drainage density, form factor, circulatory ratio and elongation ratio
Relief Aspects of Channel Network	Relief ratio, relative relief, ruggedness number and geometric number

Strahler's system of stream analysis is probably the simplest, most used system and same has been adopted for this study. Each finger-tip channel is designated as a segment of the first order. At the junction of any two first-order segments , a channel of the second order is produced and extends down to the point where it joins another second order channel ,where upon a segment of third order results. The various morphometric parameters such as area, perimeter, stream order, stream length, stream number, bifurcation ratio, drainage density, stream frequency, drainage texture, length of basin, form factor, circulatory ratio, elongation ratio, length of overland flow, compactness coefficient, shape factor, texture ratio were computed using standard methods and formulae given in table 2.

For morphometric analysis, area, perimeter, maximum length, drainage map, stream length of each order, numbers of stream of each order and watershed relief values are required. These inputs were derived by using GIS software. Once these inputs were obtained, then by making use of the mathematical formulae as discussed above, all the necessary parameters for morphometric characteristics of micro-watershed were computed.

Table 2. Formulae for the Computation of Morphometric Parameters

Sr. No.	Parameter	Symbol/Formula	Description	Reference
1.	Stream Order	Hierarchical Rank		Horton (1945)
2.	Bifurcation Ratio (R_b)	$Rb = N_u / N_{u+1}$	N_u = No of streams of order u	
			N_{u+1} = No of streams of order u+1	
3.	Stream Length	$\bar{L}_u = \frac{\sum_{i=1}^{N} L_u}{N_u}$	L_u = Length of stream of order u	
4.	Stream Length Ratio (R_L)	$R_L = \bar{L}_u / \bar{L}_{u-1}$	L_u = Average length of stream of order u	Horton (1945)
			L_{u-1}= Average length of stream of order u-1	
5.	Area of the watershed (A)			
6.	Form Factor (R_f)	$R_f = A / L_b^2$	L_b = Length of basin	
7.	Basin Shape Factor (S_b)	$S_b = L_b^2 / A$		Horton (1932)
8.	Circulatory Ratio (R_c)	$R_C = \frac{A}{Ac} = \frac{4A\pi}{P^2}$	AC = Area of circle having equal perimeter as the perimeter of watershed	
			P = Perimeter of watershed	
9.	Elongation Ratio (R_e)	$R_e = \frac{D_c}{L_{bm}} = \frac{2\times\sqrt{A/\pi}}{L_b}$	DC = Diameter of circle with the same area as the watershed	Schumm (1956)
10.	Drainage Density (D_d)	$D_d = \frac{\sum_{i=1}^{K}\sum_{i=1}^{N} L_u}{A}$	K = Principal order = highest order stream	
11.	Constant of Channel Maintenance (C)	$C = \frac{1}{D_d} = \frac{A}{\sum_{i=1}^{K}\sum_{i=1}^{N} L_u}$		Schumm (1956)
12.	Stream Frequency (F)	$F = \frac{\sum_{i=1}^{K} N_u}{A_k}$	Ak = Basin area of principal order (K)	
13.	Relief (H)	(Elevation of basin mouth) - (Elevation of highest point on the basin perimeter)		
14.	Relative relief (R_r)	$R_r = H/L_p \times 100$	H = Watershed relief	
			L_p = Length of perimeter	
15.	Relief ratio (R_r)	$R_r = H/L_b$		Schumm (1956)
16.	Ruggedness number (R_N)	$R_N = H \times D_d$		
17.	Geometric number	G No. = H×Dd / Sg	Sg = Slope of ground surface	
18.	Time of concentration (T_c)	$T_c = 0.0195\ L_{0.77}\ S_{-0.385}$	L = Length of channel reach	
			S = Average slope of the channel reach	

RESULTS AND DISCUSSIONS

Geomorphological analysis

For the geomorphological analysis the measurement were made from the digitized drainage pattern and watershed boundary. Watershed boundary and digitized drainage pattern is shown in Fig. 2. The values of different Geomorphological Parameters were calculated by using the methodology as discussed in Table 2. The calculated values are presented in the Table 3.

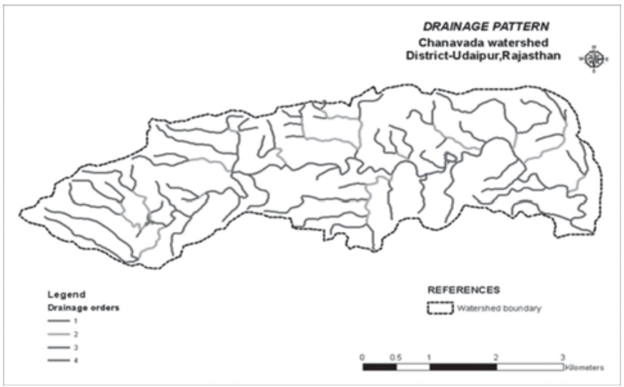

Fig. 2. Digitized drainage pattern of the study area

Table 3. Morphological characteristics of the watershed under study

Characteristics	Estimated value
Linear aspects	
Area	1475 ha
Perimeter	19755 m
Length of basin (aerial)	6970 m
Maximum length of basin (Sinusoidal)	13555 m
Highest elevation on watershed perimeter	680 m
Lowest elevation at mouth of watershed	430 m
No. of stream order	
I	60
II	17
III	3
IV	1
Stream length (L_u)	
I	39270 m
II	10093 m
III	3361.93 m
IV	8673.05m
Average stream length	
I	654.50m
II	593.71m
III	1120.64 m
IV	8673.05m
Characteristics	Estimated value
Bifurcation Ratio (R_b)	
B.R.$_1$	3.53
B.R.$_2$	5.67
B.R.$_3$	3
Average	4.07
Stream length ratio (L_u^-)	
RL_1	0.26
RL_2	0.33
RL_3	2.58
Average	1.06
Areal aspects	
Form factor (R_f)	0.30
Shape factor (S_b)	2.77
Circulatory ratio (R_c)	0.48
Elongation ratio (R_e)	0.62
Drainage density (D_d)	6.19 km/Sq km.
Stream frequency (F)	0.042 per ha
Constant of channel maintenance (C)	0.16
Length of overland flow	0.08sq. km/km
Relief aspects	
Relief	250 m
Relief ratio (R_r)	0.035
Relative relief (R_R)	1.265 %
Ruggedness number (N_R)	1.548
Geometric number	11.06
Time of Concentration (T_c)	43.08 min

Stream analysis

Stream analysis consisted of grouping of stream segment in different orders, measuring stream lengths, calculating cumulative stream length and calculating mean stream lengths.

Relation between stream number and stream order

According to the Horton's law, the plot of logarithm of stream number (ordinate) as a function of stream order (abscissa) should yield a set of points lying along a straight line. For the

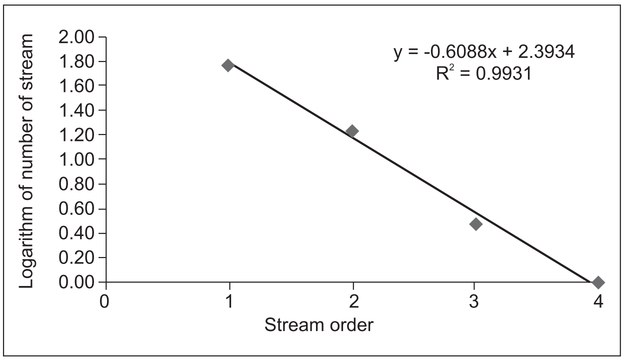

Fig. 3. Regression of logarithm of number of streams and stream order

present study, this graph was plotted for the watershed. The graph is presented in the Fig 3. The graph shows a straight line, satisfying the Horton's law (Kumar et al., 2001). From the Fig. 3, it is evident that the correlation coefficient for the straight line fit for the watershed is 0.993, which is quite satisfactory.

Relation between cumulative stream length and stream order

In the present study, an attempt has been made to establish the relation between the stream order and the cumulative stream length. The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for the watershed is a straight line fit as shown in Fig. 4. The straight line fit indicates that the ratio between cumulative stream lengths is constant throughout the successive order of a basin and suggests that geometrical similarity is preserved in basins of increasing order (Kumar et al., 2001 and Gupta, 2003). From the Fig. 4, it is evident that the correlation coefficient for the straight line fit for the watershed is 0.955, which is quite satisfactory.

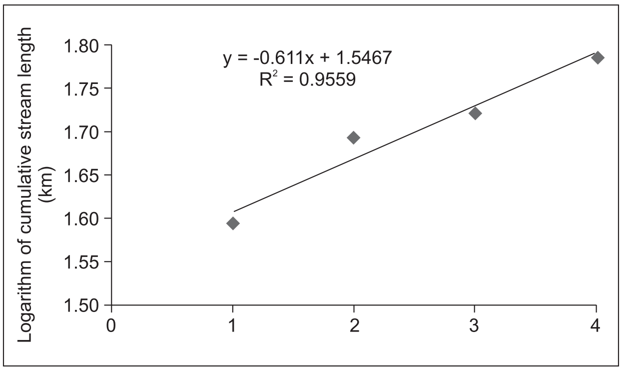

Fig. 4. Regression of logarithm of cumulative streams length and stream order

Linear aspects of drainage network

It refers to the analysis of stream order, stream number, bifurcation ratio and stream length ratio. After analysis it was found that the watershed is of 4th order type and drainage pattern is dendrite (Mittal, 2002). The numbers of stream of 1st, 2nd, 3rd and 4th order are 60, 17, 3 and 1 respectively and their corresponding lengths are 39270 m, 10093 m, 3361.93 m, 8673.05 m respectively. However, in general, the mean length of the stream of the particular order increases with the increase in the order of stream which means the mean length of a stream of a given order is greater than that of immediate lower order but less than that of the next higher order. This confirms the property of the stream order number and their corresponding length. The other important property bifurcation ratio (R_b) reflecting geological and tectonic characteristics of the watershed estimated as 4.07 for the watershed which confirms the research of Horton (1945). The value indicates that the watershed has suffered less structural disturbance and the drainage pattern has not been distorted by structural disturbance (Nag and Chakroborty, 2003). The average stream length ratio estimated is 1.06 and RL_1 , RL_{2-} and RL_3 are close to each other which confirms the property that length ratio tends to be constant throughout the successive orders of steam segments in the watershed.

Areal aspects of watershed

Under this aspect, the study gives the description of arrangement of area element mainly watershed shape which affects stream flow hydrographs and peak flow. The important parameters that describe the shape of the watershed viz. form factor, circulatory ratio and elongation ratio were computed. Referring Table 4.1, it shows that the value of form factor (R_f), circulatory ratio (R_c) and elongation ratio (R_e) are 0.30, 0.48 and 0.62 respectively. The high value of R_e compare to R_c indicates that the watershed is approaching towards the elongated shape (Singh et al., 2003). In this case elongated watershed with low R_f indicates that the watershed will have a flatter peak of flow for longer duration. Flood flow of such elongated watershed is easier to manage than from the circular watershed (Pandey et al., 2004).

Drainage density (D_d) and stream frequency are other important characteristics of watershed. The drainage density of watershed is 6.19 km/sq km indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole watershed. Further, it gives an idea about the physiographical properties of the underlying soils. Low value of D_d indicated that the region is having permeable subsoil material under vegetative cover and watershed relief is low (Strahler, 1964). The value of stream frequency is 0.042 per ha. Further, related to D_d another morphological characteristics property of drainage basin is constant of channel maintenance which was found to be 0.16 sq km/km for the study area. It indicates the number of square meters of basin surface required to maintain one linear meter of channel.

Relief aspects of channel network

This refers to the analysis of relief aspects of drainage basin and channel networks. Estimated value of relief is 250 m, based on which relief ratio (R_r) and relative relief (R_R) were found to be 0.035 and 1.265 respectively. This is an indication of erosion and reflects that the watershed be treated with soil and water conservation measures. Addition to these properties ruggedness number and geometric number were computed and values are 1.548 and 11.06 respectively. With low value of ruggedness number it is evident that watershed is having steep slope. Also time of concentration for watershed was computed and value is 43.08 min.

CONCLUSIONS

The present study demonstrates the usefulness of GIS for morphometric analysis of Chanavada micro-watershed. The study has shown that the Chanavada microwatershed is in conformity with the Horton's law of stream numbers and stream lengths. The graph between logarithm of stream number and stream order confirms the validity of the Horton's law. The low value of bifurcation ratio (4.07) revealed that the drainage pattern has not been distorted by structural disturbance. High value of elongation ratio (0.62) compare to circulatory ratio (0.48) indicates elongated shape of the watershed. Low value of drainage density (6.19 km/Sq km) shows that the region is having permeable subsoil material under vegetative cover and watershed relief is low. Relief ratio (0.035) and relative relief (1.265%) reflects that the watershed be treated with soil and water conservation measures. Morphometric analysis indicates the fact that watershed under study is elongated shape with steep slope. The value found for various morphological characteristics also reveals that watershed is under fairly good vegetation with permeable subsoil material.

REFERENCES

Biswas, S., Sudhakar S., V. R. Desai, 1999. Prioritization of sub watersheds based on morphometric analysis of drainage basin - A remote sensing and GIS approach. *J. Indian Soc. Rem. Sens.*, 27(3): 155–166.

Chorley, R.J., 1969. *Introduction to Fluvial Processes. Bungay*, UK: Methuen & Co Ltd.

Esper, A. M. Y., 2008. Morphometric Analysis of Colanguil River Basin and Flash Flood Hazard, SanJuan, Argentina *Environmental Geology*, 55, 107-111.

Frissel, C.A., Liss, W.J., Warren, C.E., Hurley, M.D, 1986. A Hierarchical Framework for Stream Habitat Classification-Viewing Streams in a Watershed Context. *Environment Management*, 10, 199-214.

Gregory, K.J and Walling, D.E (1973). Drainage Basin Form and Process- a Geomorphological Approach. London: Edward Arnold.

Gupta, A. K., 2003. Digital delineation and geomophometry for prioritization of watershed: A RS and GIS based approach. M. E. (Ag.) thesis, CTAE, MPUAT, Udaipur.

Horton, R. E., 1932. Drainage Basin Characteristics. Trans. American Geophysiacal Union, Vol. 3, pp. 350-361.

Horton, R.E, 1945. Erosional Development of Streams and their Drainage Basins: A Hydrophysical Juan, Argentina *Environmental Geology*, 55, 107-111.

Kumar, R., A.K. Lohani, S. Kumar, C. Chatterjee and R.K. Nema (2001). GIS based morphometric analysis of Ajay river basin upto Sarath gauging site of South Bihar. *Journal of Applied Hydrology.* 15(4):45-54.

Mesa, L. M, 2006. Morphometric Analysis of a Subtropical Andean basin (Tucuman, Argentina). *Environmental Geology*, 50, 1235-1242.

Mittal, H.K. 2002. An evaluatory study on morphological characteristics and groundwater status in selected treated watersheds. Unpublished Ph.D thesis, SWE Deptt., CTAE, MPUAT, Udaipur.

Nag, S. K. and S. Chakroborty, 2003. Influence of rock types and structures in the development of drainage networks in hard rock area. *Journal of Indian Society of Remote Sensing*, 31(1):25-35.

Pandey, A., V. M. Chowdary and B. C. Mal, 2004. Morphological analysis and watershed management using GIS. *Hydrology Journal.* 27 (3-4):71-84.

Schumm, S.A., 1956. "Evaluation of Drainage Systems and Slopes in Bad Lands at Parth Ambo, New Jersey", *Bull. Geol. Soc. Am.*, Vol. 67, pp. 597-646.

Singh, R. K., C. M. Bhatt and V. Hari Prasad, 2003. Morphological study of a watershed using remote sensing and GIS techniques. *Hydrology Journal.* 26(1-2):55-66.

Strahler, A. N., 1964. Quantitative geomorphology of drainge basins and channel networks. Section 4-11 in Handbook of Applied Hydrology (ed. by V. T. Chow), Mc Graw Hill, New York.

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Use of high RSC water for sustainable crop production under sprinkler irrigation system in Thar desert of Rajasthan

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ABSTRACT

Management of poor quality water in 'Thar desert' of Rajasthan is a major concern to increase the area and production of crops in this region. A field experiment was conducted at farmer's field having high RSC water (10.2 me l^{-1}) to evaluate the effect of partially neutralized irrigation water on pearl millet-wheat crop rotation in sandy soils of arid regions of Rajasthan. High RSC water was treated through gypsum tank before lifting for irrigation through sprinklers. Gypsum as per GR was added in soil before starting of experiment. Gypsum @ equivalent to 5.0 me/l RSC neutralization of each irrigation along with FYM @ 10 ton/ha was added in soil before sowing. Yield parameters (plant height, test weight and ear length) and seed and straw yields of both crops were increased with the application of gypsum @ equivalent to 5.0 me/l RSC neutralization of each irrigation along with FYM @ 10 t/ha with treated water (2.0-2.2 me/l RSC neutralization through gypsum tank). Addition of gypsum and organic matter decreased the pH and ESP of soil.

Key words: RSC neutralization, Gypsum tank, Wheat, Pearl millet, Sprinkler irrigation

INTRODUCTION

Thar desert extends in Punjab, Haryana, Rajasthan and Gujarat states of India with 650 km in length and 160 km in width. 62 per cent of its area comes in Rajasthan and lies west to Aravalis. It covers 58 per cent area and 40 per cent population of Rajasthan with 12 major districts. 4 to 6 km long and 8 to 35 m high sand dunes are main features of this region. It is mainly characterized by sandy soils, undulated topography, high percolation rates, low moisture and nutrient retentive capacity of soils, extreme of temperature (lowest in winter and highest in summer) with low RH and annual rainfall. Ground water which is very deep and of poor quality is the only source of irrigation in these areas. With the availability of electricity more and more tube wells are being installed/dug in western Rajasthan for last one decade by the farmers to irrigate the crops. However, the water table in these areas is very deep and the quality is also poor. In Bikaner, Jaisalmer and three tehsils of Churu district (Agro-climate zone 1c) the high RSC waters covers an area of 28.1%.

In 'Thar' desert of western Rajasthan soils are sandy having high infiltration rate and topography is undulating thereby, limiting the use of flood irrigation system efficiently. Through sprinklers problem of application of irrigation in these areas could be met out with regulated amount of water as per crop need. Ground water is being used for irrigation through sprinklers at many places in such areas has higher amounts of residual sodium carbonate. Due to high temperatures and high wind velocity in the desert, irrigation with these poor quality saline and alkali waters with sprinkler irrigation causes scorching of leaves particularly in day times. In uncommand area of western Rajasthan with the availability of electricity more and more tube wells are being dug for last one decade by the farmers to irrigate the crops. However, the water table in these areas is very deep and the quality is also poor. Jaisalmer, Nagaur, Sikar and Jhunjhunu districts have high residual alkalinity waters. In Bikaner district 16.1% waters have RSC > 2.5 me/l, whereas in Jaisalmer, Fatehgarh and Pokran tehsils of Jaisalmer district

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the high RSC water is 42.9%, 36.2% and 14.1%, respectively. Likewise in Sardar shahar, Sujangarh and Ratangarh tehsil of Churu district the high RSC water is 46.2%, 11.7% and 34.7%, respectively. In Nagaur district 31.8% water samples showed RSC > 2.5 me/l, whereas in Fatehpur tehsil of Sikar district 98% waters have RSC >2.5me/l (Lal *et al.*, 1998, Verma *et al*., 2003). Areas of north-eastern and southern parts of Rajasthan (Jaipur, Kota, Udaipur where rainfall is > 500 mm) also have residual alkalinity in the ground waters in significant amounts. In Punjab bicarbonate waters having high residual alkalinity cover nearly 25% of the total area of the state and pose a serious threat to sustained agricultural production (Handa, 1983 and Sehgal *et al.*; 1985).

High RSC water irrigation leads to development of high ESP and high pH, which in turn adversely affect soil structure, water and air movement through soil. The magnitude of adverse effects is variable depending on the magnitude of RSC in irrigation water, the mean annual rainfall and texture of soils. Irrigation with water containing more than 2.5 me/l RSC is considered hazardous (Eaton 1950; Wilcox *et al.* 1954). In arid region of Rajasthan (200-500 mm rainfall) irrigation with water containing more than 5 me/l RSC has been found hazardous. Irrigation with RSC water causes sodic conditions in soil. This leads to adverse physico - chemical properties of soils, poor plant growth and crop yields. High carbonate and bicarbonate concentration in irrigation water leads to precipitation of calcium and magnesium as carbonate and bicarbonate in the soil solution. This results in loss of Ca^{2+} and Mg^{2+} ions and in increase of Na^{+} ion on the exchange complex. These soils become highly sodic. As a result of irrigation with sodic water the soils acquire unusual hardness. Even the loamy sand soils, which are otherwise quite friable and loose, become very hard and compact. The soil clod attains close packing leaving little porosity for air and moisture movement. Penetration of plant roots is equally difficult. The water infiltration rate is greatly reduced. Water applied through irrigation or received as rainfall remains ponded on the surface (Joshi and Dhir, 1989).

Under such situations, specific management practices have to be developed, for sustaining soil productivity. To offset the harmful effects of sodic waters on physical and chemical properties of soil and crop yields, application of calcium-containing amendment such as gypsum is commonly recommended (Puntamkar *et al.,* 1972, Bajwa *et al.,* 1983 Ayers and Westcot, 1985). In western Rajasthan huge natural gypsum deposits are found in large areas. Therefore, it is the cheapest source of soil amendment for alkali soils in the region. The Government is also providing subsidy on transportation of gypsum to the farmer's fields. Properties of sodic soils are dominated by excessive exchangeable Na. Ca from gypsum replace exchangeable Na. It decreases pH of sodic soils, reduces soil crusting, improves water infiltration and percolation. It is a salt to maintain electrolyte concentration at soil surface, thereby, reduces clay dispersion and swelling. It is a source of Ca and S for plant nutrition. Its solubility is 2.5g/l, hence, contributes to ionic strength of soil solution.

The gypsum requirement for neutralizing residual alkalinity in sodic water is of recurring nature and is determined by factors such as current level of soil deterioration, cropping intensity and the water requirement of the crops to be grown. The quantity of gypsum for neutralization of each me/l of RSC is 86 kg /ha for 10 cm depth of irrigation. The gypsum available for agricultural use is 70-80% pure. Application of gypsum as per GR and RSC neutralization of water has also been suggested by Sharma and Mandal (1982), Minhas *et al.* (1995) and Tripathi and Sharma (1995). Gypsum can be used for mixing in the soil directly in the powdered form before applying high RSC waters. Even application of gypsum lumps in gypsum beds/tanks are found useful in reducing the harmful effects of these waters. Addition of gypsum in conjunction with organic materials is more effective in reducing the adverse effect of RSC of water. The increased partial pressure of CO_2 and organic acid produced due to addition of organic materials mobilize Ca from soil minerals. Applied organic matter had a preference for divalent cations than the naturally present organic matter in soils (Poonia *et al.*, 1980). However, addition of organic manure to soils may get deteriorated through the use of sodic waters, as organic materials are also known to increase the dispersion of soil particles at high pH (Gupta *et al.,* 1984). Therefore the addition of organic materials for use of sodic water should better be preceded by gypsum application.

While selecting crops for soils undergoing sodication irrigation water requirement is as important as sodicity of irrigation water (Gupta and Abrol, 1990). The efficient strategy should aim at selecting a crop with low water requirement for *rabi* and a crop that can thrive on rain water for *kharif.* Pearl millet and wheat are the staple food crops in the area and are also considered tolerant to irrigation with alkali water. Irrigation with waters having RSC of 10 me/l can be practiced annually for wheat crop on sandy loam soils, provided the SAR is low and field was kept fallow during monsoon season which received 500-550 mm rainfall (Gupta, 1980). This rainfall prevented sodicity build-up in soil to a level that could adversely affect the wheat yields, which is quite tolerant to sodicity (Ayers and Westcot, 1985). Therefore, the present study was undertaken to evaluate the effect of high RSC water through sprinkler irrigation and effect of amendments on yield of wheat and pearl millet crops.

MATERIALS AND METHODS

Due to non availability of high RSC water at research farm, instead of conducting experiment on artificial sodic water making through added salts, it was decided to conduct the experiment with natural alkali water at farmer's field. Therefore, the experiment was conducted at farmer's field in Dheerdesar village of Bikaner district during 2006-09. Soil of the experimental site was sodic (pH_2 9.4, EC_2 0.25 dSm^{-1} and ESP 29.2) because of high RSC water of existing tube well (pH 8.8 EC 1.44 dSm^{-1} and RSC 10.2 me l^{-1}) at farmer's field.

Design and layout of the experiment

Treatments comprised of two types of RSC water (W_1 - untreated water and W_2 - partially neutralized water) and four levels of amendments (S_1 - No organic manure, S_2 - Organic manure @ 10 tha^{-1}., S_3 - Gypsum equivalent to 5 me l^{-1} RSC neutralization and $S_4 = S_2 + S_3$).

The water was passed through a gypsum tank kept in the water reservoir (diggi) to neutralize the RSC of water. After passing through gypsum tank only 2.0 to 2.2 me l^{-1} RSC of water could be neutralized due to high discharge of tube well. For remaining RSC (8.0 me l^{-1}) in water the gypsum was incorporated in the soil before sowing as per treatments. The quantity of pure gypsum for neutralization of each me/l of RSC is 86 kg ha^{-1} for 10 cm depth of irrigation. Therefore, the amount of agricultural grade gypsum (about 70% pure) for each me/l RSC neutralization for each irrigation of 6.0 cm under sprinkler irrigation is 73.7 kg ha^{-1}.

FYM was also incorporated as per treatments. Before starting the experiment gypsum as per 50% GR was also incorporated in the experimental field to neutralize the initial sodicity of the soil. Pearl millet and wheat crops were sown in fixed plots during *kharif* (Rainfall) and *rabi* (Winter) seasons, respectively, in randomized block design with three replication. Depth of irrigation for both the crops was 6.0 cm and total number of irrigations for pearl millet and wheat were 3 and 7, respectively. Recommended agronomical practices were followed to raise both the crops.

Treatment evaluation

The treatments of the experiment were evaluated by recording yield attributes and grain and straw yields and soil analysis. Five plants selected and tagged randomly at harvest from each plot. Plant height and ear length were recorded from these plants and were averaged to express as plant height (cm) and ear length (cm) at harvest in both the crops. A random sample was drawn from the produce of each plot, 1000 seeds were counted, weighed and expressed as test weight in both the crops. After harvesting, weight of sun-dried grains and straw collected from each plot was recorded and the same was converted to express in grain and straw yield in q ha^{-1}.

Soil analysis

A composite soil sample was taken from the experimental field before starting of experiment and analyzed for EC_2, pH_2 and ESP. After harvesting of the experimental crops, soil samples were collected from 0-15 cm soil depth from different treatments and analyzed as per methods outlined by Richards (1954).

Statistical analysis

The significance of treatment effect was tested with the help of 'F' test and the difference between treatments by critical difference (CD) at 5% level of probability as per the procedure given by Panse and Sukhatme (1967). Microsoft Excel 2000 was used in statistical processing of the data. The least significant difference was calculated (p=0.05).

RESULTS AND DISCUSSIONS

It is evident from the data presented in table 1 & 2 that RSC neutralization of water through gypsum tank and application of gypsum and FYM in soil significantly increased the grain and straw yield of both the crops wheat and pearl millet. Maximum grain and straw yield of pearl millet 19.2 and 43.1 q/ha and of wheat 31.7 and 43.1 q/ha, respectively was recorded with the addition of FYM @ 10 t/ha along with soil application of gypsum @ 5.0 me/l RSC neutralization irrigated with treated water (RSC 8.0 me/l). There was an increase of 54.06 and 39.03 percent in yields of pearl millet and wheat, respectively, in W_2S_4 treatment over control. Data on yield attributes of wheat and pearl millet also indicated maximum plant height,

Table 1. Effect of RSC neutralization of water and soil amendments on yield of pearl millet

Treatment	Grain yield (q/ha)				Stover Yield (q/ha)			
	2006	2007	2008	Mean	2006	2007	2008	Mean
W_1S_1	11.1	14.9	12.1	12.7	24.6	31.8	25.0	27.1
W_1S_2	12.6	16.6	13.3	14.2	27.0	35.3	28.2	30.2
W_1S_3	15.8	19.9	15.9	17.2	31.3	43.1	32.6	35.7
W_1S_4	16.5	21.5	17.0	18.3	35.1	45.8	38.4	39.8
W_2S_1	12.6	16.2	13.3	14.0	28.2	32.7	30.8	30.6
W_2S_2	14.2	17.9	14.2	15.4	31.8	35.7	33.6	33.0
W_2S_3	16.0	20.6	16.7	17.8	36.0	45.1	41.3	40.8
W_2S_4	17.6	22.2	18.0	19.2	37.9	48.5	42.8	43.1
S.Em	0.6	0.7	0.7	0.6	1.2	1.5	1.3	1.3
CD (5%)	1.8	2.2	2.1	2.0	3.7	4.5	3.8	4.0

Table 2. Effect of RSC water and soil amendments on yield attributes of pearl millet

Treatment	Plant height (cm)				Test weight (g)				Ear length (cm)			
	2006	2007	2008	Mean	2006	2007	2008	Mean	2006	2007	2008	Mean
W_1S_1	95.9	134.4	98.3	109.5	4.27	7.59	6.98	6.28	25.0	18.4	17.6	20.3
W_1S_2	105.2	140.5	105.7	117.1	4.83	7.77	7.19	6.59	29.0	23.4	20.3	24.2
W_1S_3	122.2	148.1	133.0	134.4	5.27	8.02	7.35	6.88	32.0	28.3	25.3	28.5
W_1S_4	126.5	152.1	143.0	140.5	5.54	8.24	7.48	7.08	33.0	31.8	28.7	31.2
W_2S_1	110.0	151.7	112.1	124.9	4.76	7.75	7.03	6.50	27.8	24.8	19.4	24.0
W_2S_2	124.0	156.4	122.0	134.1	5.01	7.93	7.21	6.71	31.2	28.2	22.1	27.2
W_2S_3	118.6	163.7	135.0	139.1	5.25	8.49	7.61	7.01	35.1	33.9	28.1	32.4
W_2S_4	136.6	167.8	144.3	149.6	5.42	8.49	7.81	7.24	35.7	36.2	29.3	33.7
S.Em	4.6	5.0	2.6	4.06	0.24	0.19	0.08		1.1	1.5	0.8	
CD (5%)	13.9	15.0	7.9	12.3	0.71	0.57	0.23		3.2	4.5	2.3	

ear length and test weight in treatment W_2S_4 (Table 3 & 4). These results are corroborated with Singhania *et al*. (1991) where superior wheat and pearl millet yields were recorded with gypsum applied @ 50% GR as compared to control whereas crops did not respond to the application of FYM alone @ 25 t/ha. In an another trial a significant increase in wheat yield was recorded with gypsum application alone or in combination with FYM on a soil irrigated with alkali water (EC 1.95 dS/m, RSC 13 me/l and SAR 19.0). That called for the addition of gypsum on recurring basis. Sharma and Manchanda (1989) also reported higher yields of pearl millet and sorghum in presence of gypsum and FYM with sodic water. Manchanda *et al.* (1982) recommended that water containing 4.5 to 13.8 me/l RSC could be used on a loamy sand soil for growing tolerant crops like wheat and barley in areas receiving 400 mm rainfall. In an experiment at Agra, responses of wheat to neutralization of RSC up to 5 me/l with gypsum was reported by Chauhan *et al*. (1988). Verma *et al*. (2003) observed that addition of gypsum to soil @ 50%GR increased grain yields of pearl millet and mustard and there was no further improvement in yield when gypsum was added @ 100% GR. They further reported that pearl millet and mustard can tolerate RSC up to 4.0 me/l. Gupta (1980) reported that irrigation with waters having RSC of 10 me/l can be practiced annually for wheat crop on sandy loam soils, provided the SAR is low and field was kept fallow during monsoon season which received 500-550 mm rainfall. This rainfall prevented sodicity build-up in soil to a level that could adversely affect the wheat yields, which is quite tolerant to sodicity (Ayers and Westcot, 1985). Use of sodic waters in both seasons, on the contrary, leads to faster deterioration of soils. However 15 and 25 percent decline in wheat yields was observed when irrigated with waters having RSC 15 and 20 me/l, respectively. The reduction in the crop yield was mainly due to reduced no. of tillers.

When a soil receives sodic irrigation it experiences reduced infiltration, resulting in salt and Na saturation in the upper layer. This along with evaporation leaves salt concentrated in the surface. Since in the initial stages of plant growth the root zone is limited to a few centimeters below the surface, germination and early seedling establishment are the most critical stages for most of crops for sodic irrigation. The other critical period is during change from vegetative to reproductive phase. The general tolerance of crop to salinity or sodicity increases with its age. (Minhas and Gupta, 1992).

Addition of organic matter and gypsum decreased the pH and ESP of soil from 9.44 to 8.93 and 29.2 to 18.5, respectively. After harvesting of second wheat crop in general pH and ESP of soil started increasing from 8.93 to 9.22 and 18.5 to 24.2, respectively and thereafter in third year there was again increase in the pH and ESP of soil to 9.38 and 29.2, respectively might be due to the remaining 3.0 me/l RSC in irrigation water in both the crops (Fig. 1 & 2). Similar variation in pH and ESP due to gypsum application was also observed by Singhania *et al*. (1991) and Verma *et al.* (2003).

In un command area of western Rajasthan with the availability of electricity more and more tube wells are being installed/dug for last one decade by the farmers to irrigate the crops. However, the

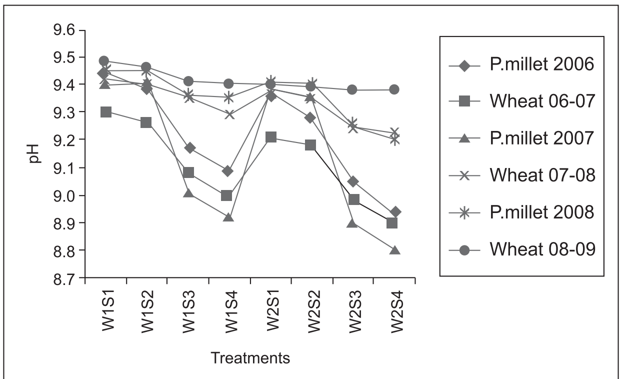


Fig. 1. Effect of RSC neutralization and soil amendments on pH of soil

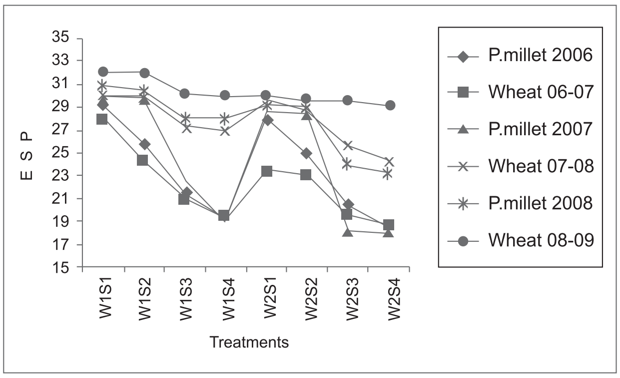


Fig. 2. Effect of RSC neutralization and soil amendments on ESP of soil

water table in these areas is very deep and the quality is also poor. In Bikaner district 16.1% waters have RSC > 2.5 me/l, whereas in Jaisalmer, Fatehgarh and Pokran tehsils of Jaisalmer district the high RSC water is 42.9%, 36.2% and 14.1%, respectively. Likewise in Sardar shahar, Sujangarh and Ratangarh tehsil of Churu district the high RSC water is 46.2%, 11.7% and 34.7%, respectively. In agroclimatic zone 1c covering Bikaner, Jaisalmer and three tehsils of Churu district the high RSC waters covers an area of 28.1%.

Due to undulated topography and high infiltration rate in sandy desert soils the only efficient method of irrigation is the sprinkler irrigation system. Further, due to high temperatures and high wind velocity in the desert, irrigation with these poor quality saline and alkali waters under sprinkler irrigation causes scorching of leaves particularly in day times.

High RSC water is characterized by low total salts concentration. The relative proportion of calcium and magnesium is much smaller as compared to sodium. Such waters have carbonates and bicarbonates predominant anions. The prolonged use of such water immobilizes soluble calcium and magnesium in soil by precipitating them as carbonates, consequently the concentration of sodium in soil solution and exchangeable complex increases and leads to development of alkali or sodic condition. The magnitude of adverse effect is variable depending upon the content of RSC in irrigation water, soil texture, calcium carbonate and calcium sulphate in the soil, SAR of water, source of RSC and effect of leaching and mean annual rainfall. High sodicity in soil induced by irrigation with alkali water reduced soil water availability to plants, not for osmotic reasons but due to lack of infiltration of water into the root zone. Additionally, high pH leads to reduction in availability of micro-nutrients and some macro nutrients viz. Calcium and potassium. Irrigation with water containing more than 2.5 mel^{-1} RSC is considered hazardous.

Role of sypsum in reclaiming RSC of water & sodicity of soil

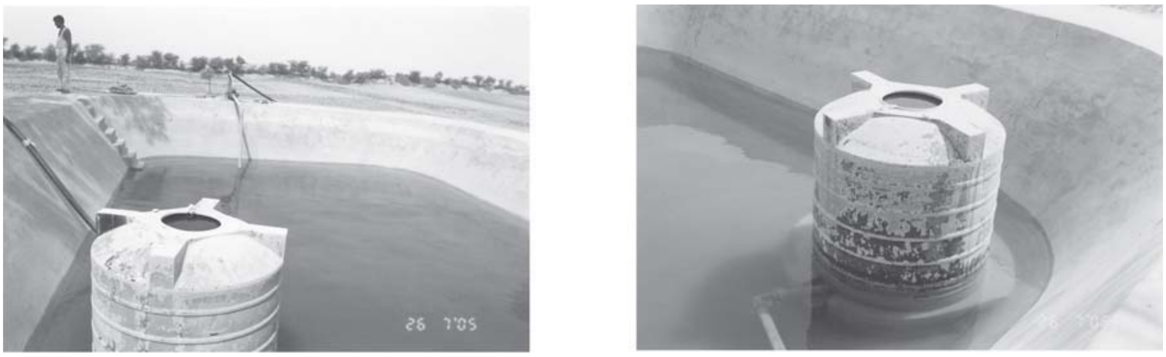
Properties of sodic soils are dominated by excessive exchangeable Na. Ca from gypsum replace exchangeable Na. It decreases pH of sodic soils, reduces soil crusting, improves water infiltration and percolation. It is a salt to maintain electrolyte concentration at soil surface, thereby, reduces clay dispersion and swelling. It is a source of Ca and S for plant nutrition. Its solubility

Table 3. Effect of RSC neutralization of water and soil amendments on yield of wheat

Treatment	Grain yield (q/ha)				Straw Yield (q/ha)			
	2006-07	2007-08	2008-09	Mean	2006-07	2007-08	2008-09	Mean
W_1S_1	20.4	23.2	24.8	22.8	29.3	31.6	32.8	31.2
W_1S_2	23.7	25.9	27.6	25.7	33.1	34.4	36.6	34.7
W_1S_3	26.8	29.0	29.0	28.3	36.1	37.1	38.0	37.1
W_1S_4	29.1	30.6	30.2	29.9	38.0	38.8	40.8	39.2
W_2S_1	22.6	24.4	25.2	24.1	31.3	34.5	34.0	33.2
W_2S_2	25.4	27.8	28.6	27.3	34.4	36.4	35.8	35.5
W_2S_3	28.5	30.2	30.7	29.8	37.2	41.5	41.8	40.2
W_2S_4	30.9	32.6	31.8	31.7	41.1	44.7	43.7	43.1
S.Em	1.0	0.9	0.8	0.9	1.6	1.1	1.3	1.3
CD (5%)	2.9	2.9	2.6	2.8	5.0	3.3	4.0	4.1

Table 4. Effect of RSC water and soil amendments on yield attributes of wheat

Treatment	Plant height (cm)				Test weight (g)				Ear length (cm)			
	2006-07	2007-08	2008-09	Mean	2006-07	2007-08	2008-09	Mean	2006-07	2007-08	2008-09	Mean
W_1S_1	55.8	70.6	72.0	66.1	33.13	33.87	35.3	34.1	6.3	7.5	8.0	7.3
W_1S_2	58.8	74.9	76.0	69.9	36.60	36.62	37.4	36.9	6.9	8.1	8.1	7.7
W_1S_3	60.1	80.2	79.6	73.3	38.03	38.75	38.8	38.5	7.0	8.3	8.6	8.0
W_1S_4	64.2	82.8	81.8	76.3	39.20	39.94	40.8	40.0	7.5	8.7	8.7	8.3
W_2S_1	59.7	74.7	74.0	69.4	35.80	35.97	36.3	36.0	6.8	8.0	8.2	7.7
W_2S_2	62.4	78.2	78.1	72.9	38.50	38.63	38.1	38.4	7.3	8.4	8.6	8.1
W_2S_3	67.0	85.3	86.2	79.5	39.60	40.07	41.5	40.4	7.6	8.9	9.1	8.5
W_2S_4	70.2	89.8	87.8	82.6	39.80	40.34	42.0	40.78	7.6	9.1	9.4	8.7
S.Em	2.4	2.2	2.41		1.26	1.00	1.16		0.4	0.3	0.27	
CD (5%)	7.3	6.7	7.30		3.83	3.02	3.53		1.1	0.8	0.83	



Neutralization of RSC water through gypsum tank for sprinkler irrigation

Poor pearl millet crop with high RSC water

Good pearl millet crop with neutralized RSC water

Table 5. Chemical characteristics of soil after harvest

Treatments	Pearl millet		Wheat		Pearl millet		Wheat		Pearl millet		Wheat	
	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)
W_1S_1	9.44	0.24	9.30	0.17	9.44	0.18	9.42	0.22	9.45	0.14	9.46	0.26
W_1S_2	9.37	0.25	9.26	0.18	9.41	0.20	9.40	0.24	9.45	0.14	9.45	0.24
W_1S_3	9.17	0.31	9.08	0.21	9.01	0.20	9.35	0.25	9.36	0.18	9.41	0.23
W_1S_4	9.09	0.30	8.99	0.22	8.92	0.20	9.29	0.27	9.35	0.19	9.40	0.23
W_2S_1	9.37	0.28	9.21	0.20	9.38	0.19	9.38	0.24	9.41	0.15	9.40	0.28
W_2S_2	9.28	0.30	9.18	0.21	9.35	0.20	9.35	0.26	9.4	0.16	9.39	0.27
W_2S_3	9.05	0.35	8.98	0.25	8.90	0.22	9.24	0.28	9.25	0.20	9.38	0.26
W_2S_4	8.93	0.37	8.90	0.25	8.80	0.23	9.22	0.30	9.20	0.20	9.38	0.24

Table 6. Effect of amendments on soil characteristics and yield of wheat

Treatments	ECe (dS/m)		pH_s		ESP		Yield (t/ha)		Nutrient uptake (kg/ ha)	
	A*	B	A	B	A	B	A	B	N	P
Control	4.75	5.59	9.3	9.2	30.0	28.9	1.86	2.07	65.3	12.5
FYM @ 25t/ha)	4.53	5.35	8.9	8.9	25.0	23.7	2.31	2.50	73.3	16.3
Gypsum @ 25% GR	4.51	5.30	8.8	8.9	23.4	22.9	2.37	2.45	73.0	16.1
Gypsum @ 50%GR	4.55	5.20	8.7	8.8	21.3	20.4	2.71	2.83	79.5	19.3
Pyrites @ 25% GR	4.56	5.26	8.9	8.9	24.4	24.3	2.10	2.29	69.6	15.5
Pyrites @ 50%GR	4.55	5.28	8.8	8.9	23.4	22.7	2.43	2.51	73.9	16.9
LSD (p= 0.05)	NS	NS	0.35	0.23	2.5	1.8	0.23	0.25	6.0	1.6

* A :1983-84 B : 1984-85

is 2.5g/l, hence, contributes to ionic strength of soil solution.

Gypsum availability in western Rajasthan

In western Rajasthan huge natural gypsum deposits are found in large areas. Therefore it is the cheapest source of soil amendment for alkali soils in the region. The Government is also providing subsidies on the transportation of the gypsum to the farmer's fields.

For sustainable production of Pearl millet-wheat crop rotation in sandy coarse textured soils with high RSC water through sprinkler irrigation experiments were under taken during 2006-09 at farmers field in Dheerdesar village of Bikaner district of Rajasthan having pH_2 9.4, EC_2 0.25 dS/m and ESP 29.2, irrigated with water having pH 8.8, EC 1.44 dS/m and RSC 10.2 me/l.

Technology developed

For neutralization of high RSC of irrigation water under sprinkler irrigation system a plastic tank filled with gypsum lumps is put into the diggi itself connected directly with the tube well and water is stored in the diggi after passing through gypsum tank, before lifting for irrigation through sprinklers. Further, for remaining RSC of water, not neutralized through gypsum tank, agriculture grade (about 70% pure) gypsum is mixed in the soil before sowing at the rate of 73.7 kg for each me/l RSC for 6 cm irrigation. The benefit of neutralization of RSC through gypsum tank is that it reduces the harmful effects of RSC water on foliage of the crops.

CONCLUSIONS

There was significant effect of neutralization of RSC of water and addition of soil amendments on grain yield of pearl millet and wheat. Maximum grain yield of both the crops were recorded with the application of gypsum @ equivalent to 5.0 me/l RSC neutralization of each irrigation along with FYM @ 10 t/ha with treated water (2.0-2.2 me/l RSC neutralization through gypsum tank). Addition of gypsum and organic matter decreased the pH and ESP of soil. Gypsum as per GR, if any, should also be added before sowing. Further, a periodical monitoring of the GR of soil is necessary while using such type of high RSC water for irrigation.

It can be also inferred that comparatively good yields of pearl millet and wheat crops can be taken with RSC water under sprinkler irrigation up to 3.0 me/l in sandy coarse textured soils.

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REFERENCES

Ayers, R.S and Westcot, D.W. 1985. Water quality for Agriculture, Irrigation and Drainage, 174 pp, paper 29. Rev. 1, FAO, Rome.

Bajwa, M. S., Hira, G.S. and Singh, N.T 1983. Effect of sodium and bicarbonate of irrigation on water on sodium accumulation and maize and wheat yield in northern India. *Irrigation Sci.* 4: 91-99.

Chauhan, R.P.S., Bhu-Dayal and Chauhan, C.P.S. (1988). Effect of residual sodium carbonate in irrigation water on soil and bread wheat. *Indian J. Agric. Sci.* 58: 454-58

Eaton, F.M., 1950. Significance ofd carbonates in irrigation water. Soil Sci. 69:123-33.

Gupta, I.C., 1980. Effect of irrigation with high sodium waters on soil properties and growth of wheat. *Proceedings of International Symposium on Salt Affected Soils,* pp. 382-388, CSSRI, Karnal.

Gupta, R.K. and Abrol, I.P., 1990. Salt- affected soils – their reclamation and management for crop production . Advance Soil Sci. 12 :223-75.

Gupta, R.K., Bhumbala, D.R. and Abrol, I.P., 1984. Effect of soil pH, organic matter and calcium carbonate on the dispersion behavior of alkali soils. *Soil Sci.* 137: 245-51.

Joshi, D.C. and Dhir, R.P. 1989. Mangement of loamy sand soils irrigated with high RSC water. Abstract II. Ppp 473-78. In International Symposium Managing Sandy Soils. CAZRI, Jodhpur, India.

Handa, , B.K., 1983. Hydro-geochemical zones of India. Proc. Symp. On ground water development- A prospective of 2000 A.D., pp. 439-50. Vol.1. Indian water Resource Society. Roorkee, U.P., India.

Lal, P., Verma, B.L., Singhania R.A. and Sharma, Yogesh, 1998. Quality of Underground Water of Bikaner district of Rajasthan and their effect on Soil Properties. *J. Indian Soc. Soil Sci.* 46 (1): 119-123.

Manchanda, H.R., Verma, S.L. and Khanna, S.S., 1982. Identification of some factors for use of sodic waters with high residual carbonate. *J. Indian Soc. Soil Sci.* 30: 353-60.

Minhas, P.S. and Gupta, Raj K, 1992. *Quality of irrigation water: assessment and management*, p.123, ICAR, New Delhi.

Minhas , P.S. , Sharma, D.R. and Singh Y.P, 1995. Response of rice and wheat to applied gypsum and Farm yard manure on alkali water irrigated soil. *J. Indian Soc. Soil Sci.* **43**:452-55.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers. ICAR, New Delhi.

Poonia, S.R., Mehta, S.C and Pal, R., 1980. Calcium-sodium, magnesium-sodium exchange equilibrium in relation to organic matter in soils. Proc. Intrn. Symp. Salt affected soils, pp 134-42. CSSRI, Karnal.

Puntamkar, S.S., Mehta, P.C. and Seth, S.P., 1972. Effect of gypsum and manure on growth of wheat irrigated with bicarbonate rich waters. *J. Indian Soc. Soil Sci.* 20: 281-85.

Richards, L.A., 1954. Diagnosis and Improvement of saline alkali soils. U.S.D.A. Hand book No. 60

Sharma, D.R. and Mandal, R.C., 1982. Irrigation of sodic water and gypsum application on soil properties and crop yields. **12th** International Congress on Soil Science, Feb 8-12, 1982 New Delhi.

Sharma, S.K. and Manchanda, H.R., 1989. Irrigation of pearl millet and sorghum with sodic water in presence of gypsum and FYM. *Indian Journal of Agricultural Science* 59: 118-119.

Sehgal, J.L., Bajawa, M.S. and Sharma, P.K., 1985. Soils of Punjab and their management. (In) Soils of India, pp 316-42; FAI, New Delhi.

Singhania,R.A., Vyas, K.K. and Singh, G.D., 1991. Minimizing the adverse effect of high RSC water in plant growth and soil properties. *Trans. Indian Soc. Desert Technology.* **10** : 39-43.

Tripathi and Sharma, 1995. Eefect of gypsum and pyrites on yield and quality of mustard in salt affected soils of western Uttar Pradesh. *Journal Indian Society Soil Science* **43**: 291-92.

Verma, B.L., Babel, A.L.,Sharma, Yogesh and Singhania, R.A., 2003. Effect of mitigating the adverse effects of soil salinity and high RSC water on yield of peal millet and mustard. *Research on Crops*. **4**: 199-205.

Verma, B.L., Sharma, Yogesh and Singhania, R.A., 2003. Quality of underground waters of Churu district in Rajasthan. *J. Indian Soc. Soil Sci.* **51**: 214-216

Wilcox, L.V., Blair, G.Y. and Bower, C.A., 1954. Effect of bicarbonates on suitability of waters for irrigation. Soil Sci. 77:259-66.

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Water balance study of upper kolab command of Odisha for effective crop planning

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ABSTRACT

A study was carried out to assess the potential and utilization of water resource of the upper Kolab Command of District Koraput, Odisha, India. The total cultivable command area of the study site is about 44,500 ha. The total water resource available through rainwater and canal are estimated. Irrigation water requirements of major crops grown in the command are also calculated. The results of the study reveal that the total water available from rainfall and canal in the command is 719.11 x 10^6 m^3 whereas as per the existing cropping pattern, the actual water requirement is 729.44 x 10^6 m^3. Thus, the study shows there is a net deficit of 10.33 x 10^6 m^3. But, computation on monthly basis indicates that there is surplus in the month of May to September and deficit in the month of October to April. The surplus months are mostly in the monsoon *(kharif)* season when there is high amount of rainfall (total rainfall in monsoon season is 1423 mm) causing large share of rainwater to the total water availability. On the other hand deficit in the *rabi* season is caused due to intensive cultivation of paddy and scanty rainfall which causes less availability. The study suggests harvesting of surplus rainwater during monsoon *(kharif)* season through various water harvesting structures including soil and water conservation measures in the catchment area/command area which can be utilised in the post monsoon (*rabi)* season.

Key words: Command area, Water availability, Water demand, Crop water requirement

INTRODUCTION

Assessment of water availability and demand in any command area can be done through water balance application which is based on the principle of conservation of mass. In the Hirakud irrigation project, Odisha (India, which is designed both for *kharif* and *rabi*, estimation of irrigation water supply and demand reveals that at the present level of rice-based cropping, canal water availability during the monsoon (rainy season) is just sufficient to meet the irrigation requirements of crops at only 10% probability of exceedance (PE) and at higher PE levels, the water availability is less than the crop water requirement. But during *rabi* (non-monsoon season), irrigation water requirement is more than the canal water availability at all PE levels. At 10% PE level, irrigation water requirement exceeds canal water availability by more than 1050 M m^3 (Raul *et al*, 2008). The present study was carried out to assess the total water availability and present utilization status of water resource of Upper Kolab command area to provide a frame work for sustainable use of water resources in this command.

Water available in the Upper Kolab command area is mainly from two sources namely, (i) rainfall and (ii) canal system. The study area has hard rock terrain where well drilling is very difficult and not economical. Ground water in the area lies at more than 50 m depth and is uneconomical for exploitation. Therefore ground water is hardly used in the command and hence, in this study it is not considered as a potential source.

In any command area, farmers grow crop as per their choice, regional demand and suitability to the climate. In Odisha, rice is the staple food of people and the climate is suitable for growing rice. Farmers prefer to grow rice in both *kharif* as well as in *rabi* season leading to higher demand for irrigation water.

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In addition to crop planning, water balance study in an irrigation command area is also used for developing the strategy of canal operation, which is linked with the rain water availability. In this paper, a study is conducted to assess the water supply from different sources in the command and water demand of various crops grown in the command and ultimately to estimate the water surplus-deficit pattern in the command.

Physical characteristics of Upper Kolab Command

Location

The Upper Kolab Command is situated in Koraput district of Odisha, India at 18^0 47′ North Latitude, 82^0 37′ East Longitude and 1372 m above mean sea level. It comprises four blocks of Koraput district namely Jeypore, Kundra, Kotpad and Boriguma. The reservoir is constructed on river Kolab which is a tributary of river Godavari. The command area comes under South Eastern Ghat Zone of Agro climatic zone. Jeypore, Boriguma and Kundra blocks comes under medium rainfall and high elevation Agro Ecological situations where as Kotpad block comes under medium rainfall and low elevation Agro Ecological situation. (Anonymous, 2001). Location map of Upper Kolab command is given in Fig. 1.

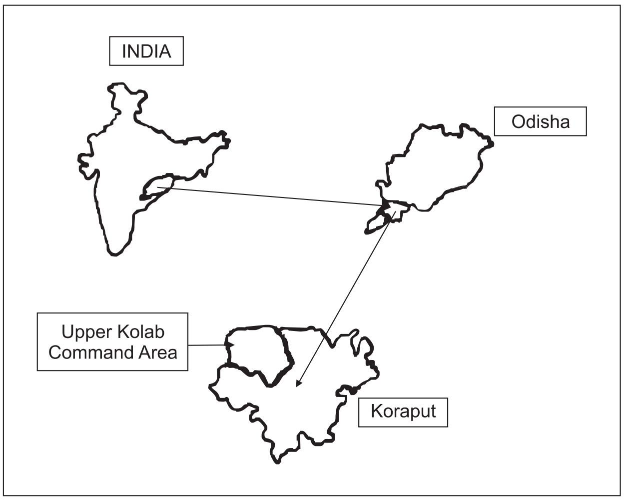

Fig.1. Location of Upper Kolab Command

Climate

The climate of the command area is sub-tropical, humid to semi humid and is characterized by hot summer. The average annual rainfall of last ten years (2000 – 2009) is 1645 mm. More than 87.5% annual rainfall occurs during June to September by the south west monsoon and rest of the rainfall occurs during October to May. Maximum monthly average pan evaporation occurs during May and is 195.02 mm and minimum occurs in August that is 63.81 mm.

Soil

The soil in Upper Kolab command is mostly red, mixed red and yellow (70.34 x 10^3 ha) and 21.17 x 10^3 ha alluvial soil. The texture is sandy loam to sandy clay loam. Soil is poor in fertility and slightly acidic. It is highly eroded, rich in aluminium and iron and is usually deficient in boron and molybdenum. Iron toxicity amounts to 14.502 x 10^3 ha (Anonymous, 2001).

Topography

The land topography of the command area is undulating-with general slope running from south east to north west direction. The hill slopes, locally called as Dongar land, is suitable for cultivation of niger and ragi cros. Medium land is suitable for varieties of crop, but farmers mainly grow paddy. In the low land, paddy is mostly cultivated. Water logging problem of the command area is not significant. A number of streams originated from nearby hills pass through the command and ultimately join the river Kolab, which is a tributary of Godavari river (Anonymous, 2004).

Canal network with irrigation scenario

The Upper Kolab irrigation project became functional during 1987-88. The project has left and right canal system. Right canal is named as Jeypore main canal having length 58.83 km and left canal is called Padampur distribury having length 12.27 km. Total 19 numbers of distributaries having total length 236.68 km and 250 numbers of minor/sub minors having length 575.298 km irrigate the entire command. Design flow in Jeypore main canal and Padampur distributarys of Upper Kolab irrigation project are 98.1 and 2.7 cumecs, respectively (Anonymous, 2004).

Cropping pattern

The cultivable command area of Upper Kolab Command in *kharif* season is 44,500 ha, out of which the command area of Jeypore Main canal is 43,030 ha and Padmapur distributory is 1,470 ha. In *rabi* season, the design cultivable command area of the whole is 26,700 ha which constitutes 60% cultivable command area of *kharif* season. On an average paddy is cultivated in more than 93% area in *kharif* season and in more than 84% area in *rabi* season.

Paddy-paddy cropping pattern is predominant in the command. Maize and ragi are also cultivated in some parts of the command area in small patches. Vegetables and sugarcane are the two important crops after paddy in the *rabi* season. Among the vegetables in *kharif* season mainly tomato and brinjal are cultivated. Tomato, brinjal, cauliflower, cabbage etc are grown in the *rabi* season. Among the oil seeds, sunflower is cultivated in small patches in the command area. Pulses are mainly grown in *rabi* season in a very limited area. In addition to the above mentioned crops, some other crops are also grown in small patches. Figs. 2 and 3 represent the area coverage by the different type of crops in existing cropping pattern in *kharif* and *rabi* season, respectively.

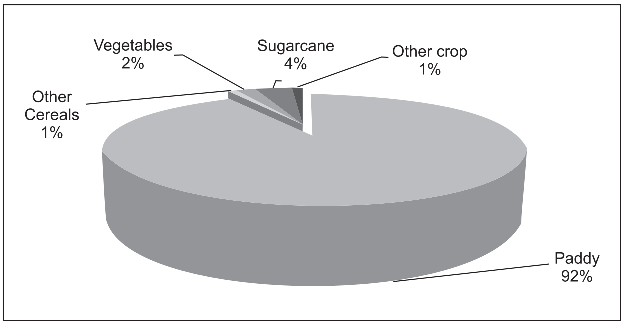

Fig. 2. Area of crop (%) in existing cropping pattern in *kharif* season

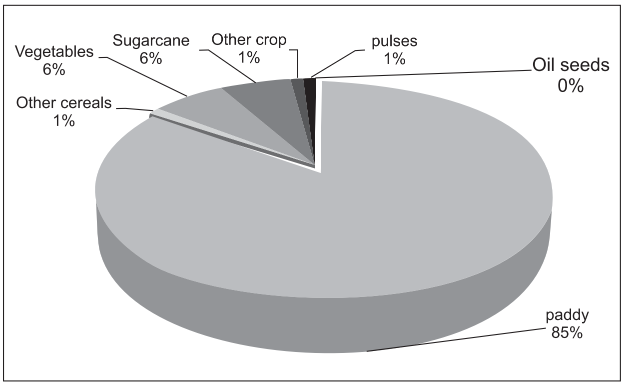

Fig. 3. Area of crop (%) in existing cropping pattern in *rabi* season

MATERIALS AND METHODS

The basic objective of water balance study is to estimate the surplus and deficit of water in any area. Following are the important parameter used for computing water balance study in this paper :(i) Estimation of water availability in the command both from rainfall and canal, (ii) Estimation of water requirement of different crops as grown presently in the command, and (iii) Estimation of excess/deficit of water supply.

Estimation of water availability

The two main source of water available in the command are rainfall and canal. As discussed earlier, ground-water is hardly used in the command and so is not included in the estimation of water supply. Before estimating the water supply due to rainfall and canal, it is important to carry out the hydrological analysis of the stochastic variable like rainfall and canal water and predict the variable at certain probability level.

Analysis of rainfall and evaporation data

There are four numbers of non-recording rain gauge stations situated in the four blocks of command. Daily rainfall data of ten years (2000 - 2009) for the four blocks have been collected from the District Agriculture Office, Jeypore, Odisha, India. From the daily rainfall data, weekly rainfall of command is computed taking average of the four blocks. Daily pan evaporation from the nearest meteorological station of Central Soil and Water Conservation Research and Training Institute, Research centre, Koraput, Odisha of last ten years (2000-2009) have been used for analysis purpose. Like rainfall, weekly evaporation has been calculated from the daily values for each year.

Values of rainfall and evaporation at different probability levels for each standard week were predicted by the best fit model. In the present study five models *i.e* linear, logarithmic, power, polynomial and exponential were tested. The model which gave maximum value of coefficient of determination (R^2) was considered the best fit model. Rainfall and evaporation at different probability levels ranging from 10 to 90 percent were computed for each week using the best fit model. Irrigation planning is generally done considering lower but assured value of water availability and higher value of crop water requirement so that the estimation of the irrigation requirement of crops is at the higher side. This will ensure the availability of irrigation water to the crops at maximum time in the command. To get lower but assured value of water availability, rainfall at 70 percent PE level and to get higher value of crop water requirement, evaporation at 30 percent PE level are considered in irrigation planning (Doorenbos and Pruitt, 1977; Senapati, 1988; Panigrahi *et al*.,1999). Hence, in the present study, availability of rainwater at 70 percent probability level of exceedence (PE) for each week was considered as dependable value and for computation of crop water requirement, evaporation at 30 percent PE of each standard week was considered.

Analysis of canal discharge data

Daily canal discharge data both for the Left canal and Right canal for 10 years (2000-2009) have been collected from the office of the Chief Construction Engineer, Irrigation Division, Upper Kolab Hydro Power Corporation, Jeypore. From the daily discharge data weekly canal flow computed. Using the best fit model (like analysis of rainfall and evaporation), values of canal discharge at different probability levels was computed. For irrigation planning in Upper Kolab command of Odisha, average value of discharge are considered towards computation of the canal water availability (Anonymous, 2004; Senapati, 1988; Panigrahi *et al.*, 1999). The average values of discharge are obtained at 50% PE level and so in this study, we have considered the discharge data at 50% PE level for deciding the canal water availability.

Assessment of water availability

As discussed above, rainwater at an average value of 70% PE for each week was considered for computing available rain water resource. Weekly and monthly predicted data of rainfall and evaporation at 70 and 30% PE levels along with the canal flow at head regulator predicted at 50% PE level by the best fit models were taken for estimation of total water availability and crop water requirement. Considering the above mentioned predicted flow at the head regulator and assuming the conveyance losses (45%) in various canal systems including water course , availability of canal water at the field level in the command has been estimated on weekly and monthly basis (Michael, 2008). It is obvious that all the water available from rainfall is not used effectively by the crops. So the effective rainfall from the predicted rainfall (predicted at 70% PE level by the best fit model) for different weeks were computed by the methods as suggested by Doorenbos and Pruitt (1977). From the weekly values, monthly and seasonally values of effective rainfall were computed.

Crop water requirement

Estimation of crop water requirement is one of the prime factors for crop planning as well as irrigation management in any command area. Crop water requirement varies from crop to crop, stages of crop growth and climate of location of crop area. Here weekly crop water requirement was calculated by multiplying crop coefficient with weekly potential evapotranspiration. Crop water requirement (ET_c) was estimated as:

$$ET_c = Kc \times PET \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, Kc = Crop coefficient and PET = Potential evapo-transpiration mm/day

Values of PET of each standard week were computed from the weekly pan evaporation data at 30% probability level (E_{30}) (calculated by the best fit model). The equation used to compute the above mentioned values of PET is (Michael, 2008):

$$PET = Kp \times E_{30} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where, Kp = Pan evaporation coefficient assumed as 0.8 (Michael, 2008) and E_{30} = Pan evaporation at a level of 30% PE for the week, mm (predicted by the best fit model). The values of crop coefficient for different crops grown in the command were obtained from F.A.O publication No-56 (Allen *et al*, 1998).

Estimation of water excess and deficit

The canal water available in command was computed by taking the canal water at 50% probability level as dependable canal water availability at field level. Conveyance loss has been considered (45 percent) while estimating the canal water availability at the field level. The rain water at 70% probability level was taken as dependable rainfall. Effective rainfall was computed for each week from the dependable rainfall as reported earlier. The crop area was multiplied with the effective rain fall to estimate the rain water availability. So total water available in the command was the sum of availability of effective rain water and canal water at field level. Total water requirement in command was calculated by multiplying the area under each crop and water required by the crop in that month and accordingly surplus and deficit was computed.

RESULTS AND DISCUSSIONS

Climatic data analysis

Rainfall

The best fit model for prediction of rainfall at different PE level was found to be polynomial of order two with R^2=0.98. The study reveals that there is a large difference in weekly rainfall at different level of probability. The rainfall analysis at 70% probability level shows that the annual rainfall in the command is 1322.1 mm. The rainfall analysis shows that at 70% probability level there is no rainfall in the month of January and December and less than 2 mm in the month of February, March and November and less than total 60 mm rainfall in the month from April, May and October. Also from weekly data it can be seen that there is almost no rainfall at 70% probability, in the week number 1 to 13 and 43 to 52. Maximum rainfall is found to occur in the standard week number 32 (in the month of August). Monthly analysis also shows that at 70% probability, maximum rainfall occurs in the month of August which is 440.30 mm. The total annual effective rainfall computed from rainfall at 70% PE level is 1322.1 mm.

Evaporation

For pan evaporation, the data were subjected to probability analysis and weekly values at 10 to 90% probability level were predicted. The best fit model for prediction at different PE level was a polynomial of order two with R^2=0.96. At 30% probability, annual evaporation (sum of 52 weeks data) is found to be 1291.55 mm. Maximum monthly evaporation at 30% probability is found to occur in the month of May which is 175.4 mm and minimum in the month of August *i.e.* 61.82 mm. The maximum weekly evaporation is obtained in the standard week number 17 which is 41.38 mm and minimum is obtained in the week number 31 *i.e.* 11.39 mm. Fig 4 represent the monthly values of rainfall and evaporation at 70 and 30% probability level respectively.

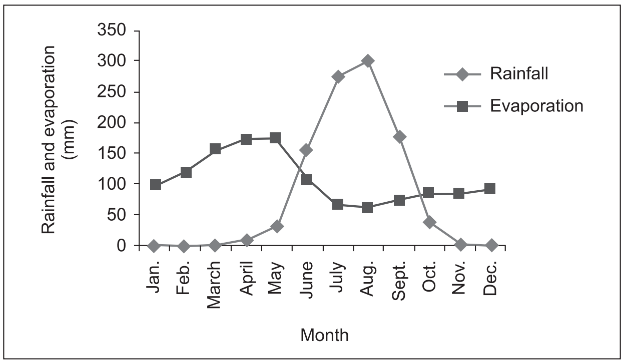

Fig. 4. Rainfall and evaporation at 70 and 30% probability level, respectively

Rain water availability

The rainwater at 70% PE level was taken as dependable value. Effective rainfall was computed from 70% PE level predicted rainfall as suggested earlier. Effective rainfall volume available in a particular month is calculated by multiplying the effective rainfall with command area occupied by the crop. From the analysis, it was found that there was no rain water available in the command in the month of January and December. In the month of February, March and November rainwater availability are 0.07 x 10^6 cum, 0.22 x 10^6 cum and 0.43 x 10^6 cum, respectively. Maximum rainwater available is during the month August i.e 133.85 x 10^6 cum.

Canal water availability

The best fit model for prediction of canal water availability was also a polynomial of order two with R^2= 0.94. Weekly canal water released at head regulator was subjected to probability analysis and values at 50% were taken as dependable value of canal water available at head regulator. Weekly canal flow at 50% probability level shows that maximum canal discharge occurs in the week number 5 and minimum in the week number 23. There is no canal water availability in the weeks number 22, 24 to 26 and 46 to 51. The monthly canal discharge calculated from the standard week shows that maximum water availability from canal network is in the month of March and minimum in June. The annual canal water availability at 50% probability is 322.23 x 10^6 cum. Total water availability on annual basis was found 719.11 x 10^6 cum.

Crop water requirement

Crop water requirement (ET_c) of each crop was estimated and shown in Table 1. It is seen from the analysis that maximum water is required for paddy crop in the month of July for *kharif* season which is 277.62 mm and in the month of April (309.09 mm) for *rabi* season.

Analysis of surplus and deficit water for crop planning

Table 2 presents the water availability and demand for the existing cropping system with the existing area under each crop. Fig.5 shows the water available and demand in the existing

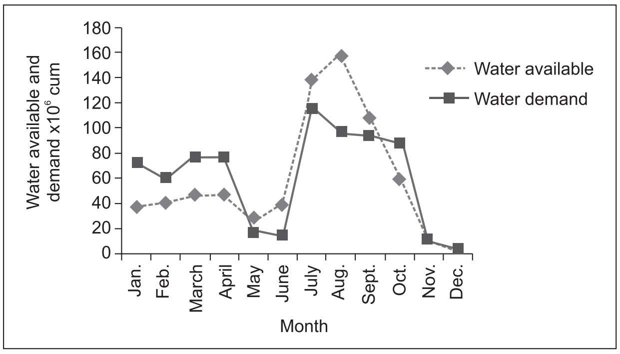

Fig. 5. Water available and demand in existing cropping pattern

Table 1. Monthly crop water requirement, mm of different crops grown in command

Month / Name of crop	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Paddy, *Kharif*						30.00	277.62	228.71	220.94	209.01	24.17	
Paddy, *rabi*	302.9	242.06	308.99	309.69	64.42							10
Ragi						36.87	51.45	69.02	82.21	54.4		
Sugarcane	88.92	106.03	144.44	163.38	166.63	103.29	67.77	61.82	70.38	76.52	76.34	111.69
Tomato*Kharif*								61.94	74.56	83.61	25.73	
Brinjal *kharif*							30.0	46.01	74.22	81.63	7.54	
Maize *kharif*						48.22	45.33	66.62	43.27			
Maize *rabi*	75.65	96.44	146.80	67.72								
Tomato *rabi*	75.07	107.81	155.86	71.87								
Brinjal *rabi*	38.10	106.00	156.40	151.89								
Cauliflower *rabi*	38.05	106.00	156.39	153.02								
Cabbage *rabi*	38.05	106.00	156.39	153.02								
Chilly *rabi*	38.05	105.88	156.21	151.62								
Sunflower *rabi*	82.60	102.54	143.49	63.27								
Greengram *kharif*						36.76	53.22	52.63	10.84			
Blackgram *kharif*						36.76	53.22	52.63	10.84			
Green gram *rabi*	81.95	104.87	25.498									
Blackgram *rabi*	81.95	107.87	25.498									
Field pea *rabi*	77.91	108.23	128.93	24.96								

Table 2. Water surplus and deficit in existing cropping pattern, x 10^6 cum

Season	Name of crop	Month												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Kharif	Paddy						12.42	114.94	94.69	91.47	86.53	10.00		
	Ragi						0.07	0.11	0.14	0.17	0.11			
	Vegetable								0.62	0.74	0.83	0.25		
	Maize						0.09	0.09	0.13	0.08				
Rabi	Paddy	69.66	55.68	71.07	71.23	14.81							2.30	
	Maize	0.19	0.24	0.37	0.17									
	Vegetables	0.65	1.82	2.68	2.61									
	Chilly	0.10	0.29	0.43	0.42									
	Sunflower	0.02	0.02	0.02	0.01									
	Greengram	0.11	0.14	0.03										
	Blackgram	0.06	0.09	0.02										
	Field pea	0.01	0.02	0.03	0.005									
Annual crop	Sugarcane	1.49	1.77	2.41	2.73	2.79	1.72	1.13	1.03	1.18	1.28	1.27	1.87	
Total demand		72.29	60.07	77.06	77.18	17.60	14.30	116.27	96.61	93.64	88.75	11.52	4.17	729.44
Available	Canal water	37.81	41.22	47.66	45.78	26.01	0.11	16.50	24.06	27.94	43.21	8.78	3.15	322.23
	Rain water	0.00	0.07	0.22	2.54	2.80	39.17	120.90	133.85	79.80	17.10	0.43	0.00	396.88
Total water available		37.81	41.29	47.88	48.32	28.81	39.28	137.40	157.91	107.74	60.31	9.21	3.15	719.11
Surplus					11.21	24.98	21.13	61.30	14.10				132.72	
Deficit		34.48	18.78	29.18	28.86						28.44	2.31	1.02	143.05
Net deficit														10.33

cropping pattern. From the above table it is seen that the total water available from rainfall and canal is 719.11 x 10^6 cum and water required in the existing cropping pattern is 729.44 x 10^6 cum and thus there is net deficit 10.33 x 10^6 cum. However, computation of monthly basis indicates that there is surplus in the month of May to September and deficit in the month of October to April. The surplus months are mostly in the monsoon season when there is high amount of rainfall causing large share of rainwater to total water availability. On the other hand in *rabi* season deficit is caused due to scanty rainfall which causes less availability and other hand there is intensive cultivation of paddy in *rabi* (approximately 23,000 ha).

CONCLUSIONS

Water balance study of Upper Kolab Command reveals that there is total available water both from rainfall and canal is 719.11 x 10^6 cubic meter (From canal 322.23 x 10^6 cubic meter and from rain water 396.88 x 10^6 cubic meter) and water required in the existing cropping pattern is 729.44 x 10^6 cubic meter and thus there is net deficit 10.33 x 10^6 cubic meter on annual basis. On monthly basis, surplus water available from May to September and deficit in the month of October to April. The surplus months are mostly in the monsoon season when there is high amount of rainfall causing large share of rainwater to total water availability. However, there is scarcity of water in the month of October of 28.44 x 10^6 cubic metre. The total water required in the *kharif* season by the paddy crop is 410.05 x 10^6 cubic meter and *rabi* season is 284.75 x 10^6 cubic meter. Total water required by the paddy crop in both the season is 694.8 x 10^6 cubic meter which is 95.25% of total water demand of the command. So paddy crop area may be reduced and other low water requirement crop like vegetables and maize which is already grown in the command area should be replaced with paddy in the *kharif* season. On the other hand in *rabi* season deficit is caused due to intensive cultivation of paddy in *rabi* and scanty rainfall which causes less availability. Deficit is maximum in the month of January *i.e.* 34.48 x 10^6 cubic meter followed by March and April *i.e.* 29.18 x 10^6 and 28.86 x 10^6 cubic meter respectively. So there is need of change of existing cropping pattern as per the availability of water resource and need of crop diversification mainly in the *rabi* season. The area grown in the paddy crop in *rabi* may be reduced and less water requiring crop like pulses, oil seeds and vegetables may be grown.

The current irrigation water management practice which is now followed in the command need to be changed from plot to plot method of irrigation to irrigation through the field channels. Field channels equipped with volumetric measuring devices will help to meet the exact water requirement of the crops and thereby saving a lot of costly irrigation water besides enabling crop diversification possible. The present practice of continuous flow of water in the canals should also be changed to rotational irrigation system. Furthermore, the paddy crop should be irrigated with water saving irrigation technique like intermittent irrigation technique instead of continuous submergence which will reduce the gap between the water availability and demand. Proper land levelling and grading will also ensure quick and equitable distribution of water and will save a lot of precious irrigation water.

REFERENCES

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. 1998. Crop evapotranspiration. Guidelines for computing water requirement. *FAO Irrigation and Drainage Paper*. 56, FAO, Rome

Anonymous, 2001. Strategic Research and Extension Plan of Koraput district, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India.

Anonymous, 2004. Detailed Project Report on Command Area Development and Water Management works in Upper Kolab Irrigation Project, Jeypore. Directorate of Command Area Development , Bhubaneswar, Orissa.

Doorenbos, J. and Pruitt, W.O. 1977. Crop water requirement. *Irrigation and Drainage paper No. 24 (revised)*, FAO, United Nations, Rome, Italy.

Michael, A. M. 2008. Irrigation Theory and Practice. Vikas Publishing House Pvt. Ltd., U.P, India

Panigrahi, B; Panda, S.N. and Mull, R. 1999. Dry and Wet Spell Analysis for Planning Supplemental Irrigation. Civil and Environmental Engineering Conference - New Frontiers and Challenges, Vol. 5(2), Bangkok, Thailand, pp. IV 53-62.

Raul, S. K., Panda, S. N., Hollaender, H. and Billib, M. 2008. Sustainability of rice-dominated cropping system in the Hirakud canal command, Orissa, India. *Irrigation & Drainage*, 57(1): 97-104.

Senapati, P.C. 1988. Integrated Water Resources Planning in Canal Command Areas of Orissa. Ph.D thesis submitted to Orissa University of Agriculture and Technology, Bhubaneswar.

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Status of major nutrient in relation to soil properties of Jaipur district of Rajasthan under groundnut cultivation

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ABSTRACT

Fifty nine surface (0-15 cm) soil samples from Jaipur district of Rajasthan were collected from five tehsils (Amber, Chomu, Dudu, Jaipur and Phulera) from the Groundnut cultivated farmer's fields, and were analyzed for different physico-chemical properties, the soil texture were determined loamy sand to fine sand; and determined its fertility status. A area is deficient with respect to O.C., available N and S, the fertility status in terms of available P_2O_5, K_2O, Ca and Mg is medium. Correlations among the soil properties and major nutrients are significantly negative and positive. Thus, the constraints of the soil of Jaipur district are low fertility status due to consistency of soil particles. This information can be useful in developing management practices for the soils of groundnut cultivated farmer's field of Jaipur district.

Key words: Macronutrients, Correlation, Physico-chemical propertis

INTRODUCTION

The major nutrients govern the fertility of the soils and control the yields of the crops. Soil fertility evaluation of an area or region is an important aspect in context of sustainable agricultural production, particularly for arid region where, sparse and highly variable precipitation, extreme variation in diurnal temperature, high evaporation and low humidity, the alluvial and aeolian landforms have given rise to the variability in soils. Besides, acute moisture deficit, wind erosion is most serious limiting factor limiting biological productivity. The region had extreme fallowing in past even during the good rainfall years. But because of increase in population and its activities, lot of area is being brought under cultivation; even dunes of several meters heights are also cultivated. In present era of technological advancement in agriculture, it is of immense interest to study the fertility status of soils. Although the widespread deficiency of major nutrients in arid Rajasthan have been reported by Joshi *et al.* (1989) and Gupta *et al*. (2000), the information on availability of major and micronutrients of the study area is meager and mainly based on the widely scattered sampling that is hardly sufficient to bring the inherent variability in the soils of the area. Therefore, a comprehensive study was undertaken to know the fertility status of soils occurring in the district and an attempt was also made to correlate micronutrient content of the soils with other soil properties.

MATERIALS AND METHODS

The study covers five tehsil (Amber, Chomu, Dudu, Jaipur and Phulera) of Jaipur district in semi-arid region of Rajasthan. The soils of Jaipur district are characterized by light textured, moderate to high pH and low organic matter content. Soil samples (0-15 cm) were collected from 59 sites covering 59 villages, Jaipur district falling under agro-climatic zone III-A (semi-arid eastern plain) of Rajasthan, situated between 26º 33' to 27º 51' N and 74º55' to 75º50' E. It is surrounded by Sawai-Madhopur, Dausa, Alwar, Sikar, Nagour, Ajmer and Tonk districts of Rajasthan. Soil sampling sites are depicted in Map 1, for which an inventory survey of the area was conducted.

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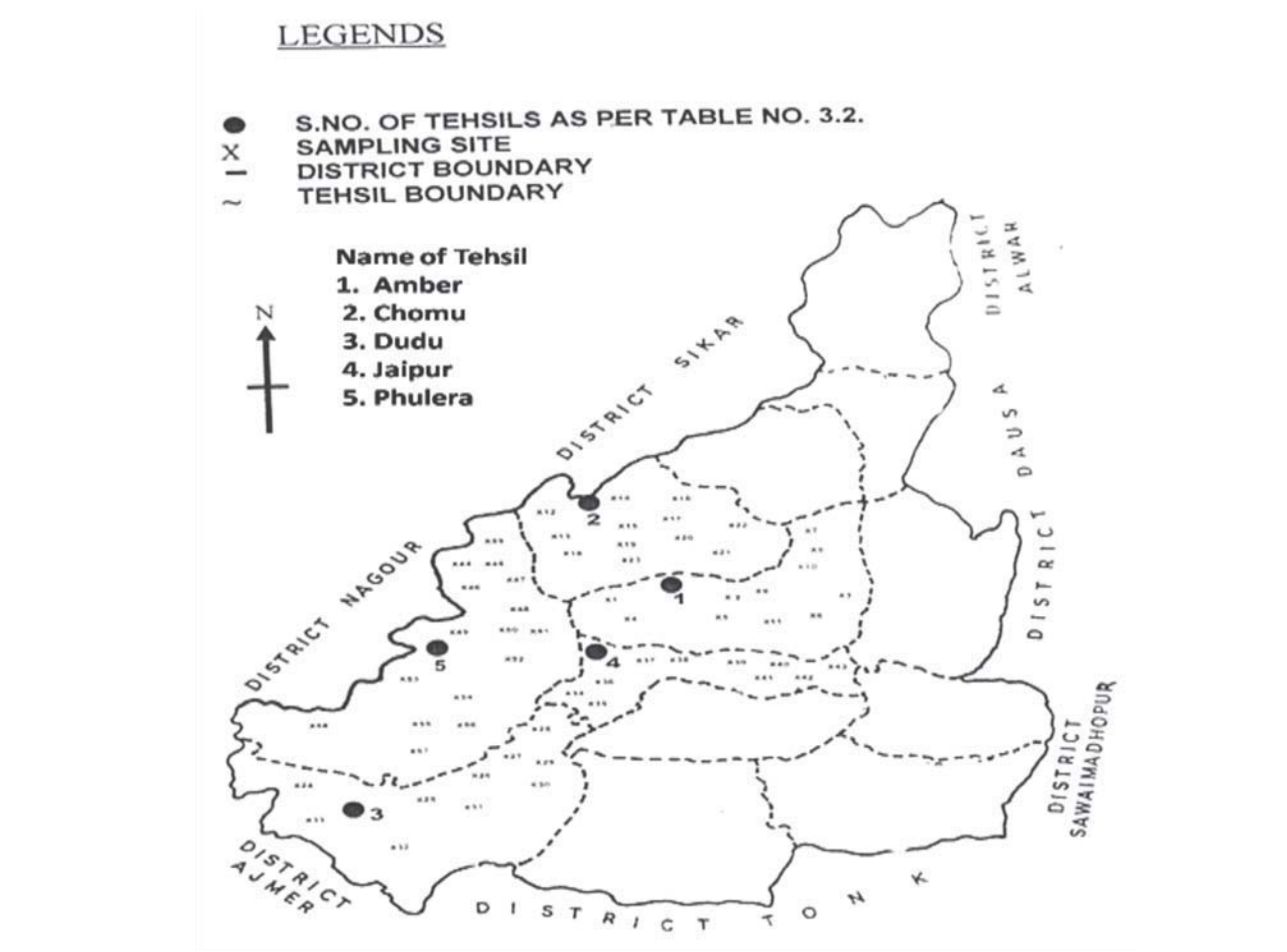

Map 1. Sampling site with locations

The samples were drawn where the land has been put under represent groundnut cultivation for more than 5 years, and where surface soils samples (0-15 cm) were collected from 59 villages located at different locations of Jaipur district. Samples were completely air dried and passed through 2 mm sieve and stored in properly labeled plastic bags for analysis. A list of villages of sampling of Jaipur district site given in Map 1.

Soil pH was measured in 1:2 soil water suspensions using pH meter systemic model 322-1 as described in USDA Handbook No. 60. Electrical conductivity was measured in 1:2 soil water suspension with help of EC meter as per method (4b) USDA Handbook No. 60. (Jackson, 1973) and CEC was determined by method 19 USDA Handbook No. 60 (Richards 1954), and the soil samples were analyzed for particle size distribution (Piper, 1950). The organic carbon was determined by rapid titration method (Walkley and Black 1934) and $CaCO_3$ by rapid titration method (Piper 1950).

Available N was determined by alkaline $KMnO_4$ method (Subbaih and Asija 1956), available P_2O_5 by extraction of soil with 0.5M $NaHCO_3$ at pH 8.5, developed colour by $SnCl_2$ and measured coloured intensity on spectrophotometer (Olsen *et al,* 1954), and K_2O using 1N neutral normal ammonium acetate solution, and Ca and Mg estimated by using EDTA solution (Richards, 1954) and available S by heat soluble method (Williams and Stainbergs 1959). Simple correlation coefficient equations were computed relating macronutrient content with other physic-chemical properties of the soils as suggested by Panse and Sukhatme (1961).

RESULTS AND DISCUSSIONS

Data on soil properties showed that the sand content ranged between 79.0-85.3% with mean value of 82.6%, silt content varied from 7.9-11.4% with mean value of 9.4% and clay content varied from 6.3 to 9.1% with mean value 7.5% (Table 1). The soils are neutral to alkaline in reaction (pH 7.8-8.7). The electrical conductivity (EC_2) ranged from 1.03-4.33 dS m^{-1}, the highest mean (2.95 dS m^{-1}) and lowest mean (2.65 dS m^{-1}) value of soil was found in Chomu and Phulera tehsil, respectively. Organic carbon content varied from 0.12-0.40%. The low organic carbon content in the sandy soils might be due to absence of stable aggregate (Jolivet *et al*, 1997), severe wind erosion (Wu and Tiessen, 2002), high microbial decay and high temperature of the region. The $CaCO_3$ content in soil, which varied from 1.00 to 5.30% with mean value of 2.70% in arid and semi-arid regions, rainfall is less compared to annual evapotranspiration, hence, less water in available for the leaching of insoluble carbonates and available for the leaching of carbonates and bicarbonates of calcium. This may have facilitated the accumulation of $CaCO_3$ in these soils. The CEC of soils varied between 2.00 to 6.80 cmol(p^+)kg^{-1} of soil. The highest (4.66 cmol(p^+) kg^{-1} and lowest (4.27 cmol(p^+) kg^{-1}) mean CEC of soils was found in Phulera and Jaipur tehsil, respectively. Rather low CEC of these soils might be due to their coarse texture, low organic matter content, presence of high amount of $CaCO_3$ and predominance of 1:1 type clay minerals (Yadav and Meena, 2009).

The content of available N in soils varied from 110.8 to 140.0 kg ha^{-1} with an average value of 127.0 kg ha^{-1} (Table 2). Data on available N in soil samples indicated that all the soil samples were deficient in available N content, considering <280 kg ha^{-1} as critical limit for N deficiency (Muhr *et al*, 1965). The maximum (129.1 kg ha^{-1}) and minimum mean available N (124.8 kg ha^{-1}) in soils was found in Jaipur and Dudu tehsils, respectively. The nutrient index value of available N was (1.00) low as critical limit.

The availability of N increased significantly with an increase in CEC (0.557**), organic carbon (0.830**) silt (0.717**) and clay (0.767**) whereas, the same decreased with increase in sand content (-0.743**) of soil (Table 3). The positive relationship between available N and organic carbon is due to the presence of soil nitrogen in the organic forms (Verma *et al.* 1980) and be due to increased rate of determination at lower pH values. Similar results were also reported by Meena *et al*, (2006).

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Available P_2O_5 in the soils samples varied from 12.60 to 30.11 kg ha^{-1} (Table 2). Considering 20 kg ha^{-1} as critical limit for P_2O_5 deficient (Muhr *et al*, 1995), 66% samples were deficient in phosphorus. The available P in these soil samples was significantly and positively correlated with $CaCO_3$ (r = 0.340**), organic carbon (r = 0.610**), silt (r = 0.722**) and clay (r = 0.699**) content of soils whereas, it was significantly reduced with increase in sand (r = -0.714**) content. Availability of

Table 1. Physico-chemical properties of the soils of Jaipur district

Tehsils	pH (1:2)	EC (1:2)	OC (g kg^{-1})	$CaCO_3$ (%)	CEC cmol(p^+) kg^{-1}	Sand (%)	Silt (%)	Clay (%)
Amber	8.2-8.7 (8.5)	1.80-3.64 (2.73)	0.18-0.31 (0.25)	1.30-3.0 0(2.26)	3.70-6.80 (4.57)	80.6-85.3 (83.3)	7.9-10.5 (9.0)	6.3-8.6 (7.3)
Chomu	8.2-8.6 (8.4)	2.48-3.50 (2.95)	0.17-0.40 (0.27)	1.80-4.50 (2.71)	3.40-5.70 (4.45)	79.0-85.1 (82.4)	8.0-11.4 (9.48)	6.4-9.0 (7.5)
Dudu	8.2-8.7 (8.4)	1.65-3.48 (2.80)	0.19-0.31 (0.23)	1.30-3.80 (2.76)	3.70-5.00 (4.29)	81.4-84.2 (83.1)	8.5-10.1 (9.1)	6.8-8.0 (7.3)
Jaipur	8.3-8.6 (8.4)	2.54-3.45 (2.90)	0.22-0.30 (0.26)	2.50-4.50 (3.33)	2.00-5.00 (4.27)	81.3-82.3 (81.8)	9.6-10.1 (9.9)	7.7-8.1 (7.9)
Phulera	7.8-8.7 (8.3)	1.03-4.33 (2.65)	0.12-0.31 (0.25)	1.00-5.30 (2.58)	3.00-5.40 (4.66)	81.3-84.9 (82.3)	9.1-10.2 (9.6)	7.0-8.1 (7.6)
Overall	7.8-8.7 (8.4)	1.03-4.33 (2.80)	0.12-0.40 (0.25)	1.00-5.30 (2.70)	2.00-6.80 (4.46)	79.0-85.3 (82.6)	7.9-11.4 (9.4)	6.3-9.1 (7.5)

*Figures in parenthesis indicate the mean values

Table 2. Tehsilwise range and mean of available macronutrients in soils of Jaipur district

Teshils	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})	Ca(mg kg^{-1})	Mg(mg kg^{-1})	S(mg kg^{-1})
Amber	120.0-136.8 (127.6)	12.6-25.8 (18.0)	200.0-230.5 (212.0)	340.0-616.0 (426.0)	124.0-166.0 (141.8)	5.5-8.8 (7.68)
Chomu	118.5-140.0 (128.6)	15.2-25.8 (20.1)	199.0-230.8 (217.71)	340.0-566.0 (440.0)	124.0-152.8 (140.0)	5.5012.5 (8.38)
Dudu	120.0-138.1 (124.8)	16.5-26.4 (19.7)	202.6-285.2 (221.3)	370.0-504.0 (426.0)	124.0-148.0 (135.3)	5.60-9.00 (7.20)
Jaipur	124.0-135.6 (129.1)	21.2-28.2 (24.3)	202.4-285.0 (211.3)	400.0-500.0 (448.0)	130.0-156.4 (137.7)	7.00-9.50 (7.83)
Phulera	110.8-135.6 (125.4)	14.8-30.1 (23.6)	190.8-230.6 (215.4)	370.0-530.0 (462.0)	124.0-152.8 (141.4)	5.30-9.50 (7.80)
Overall	110-140.0 (127.0)	12.6-30.1 (21.3)	190.0-285.2 (203.7)	340.0-616 (442.0)	124.0-166.0 (139.5)	5.30-12.5 (7.80)

*Figures in parenthesis indicate the mean values

phosphorous reduced with increased in salinity hazards of soils on account of the accumulation of soluble salts resulting into precipitation of phosphorus as Ca-phosphate thereby reduction in P availability . Further more, the availability of phosphorus also increased with increase in organic carbon due to (i) formation of phosphorus humic complexes which are easily assimilated by plants. (ii) anion replacement of phosphorus by humation and (iii) the coating of sesquioxide by particles of humus form a protective cover and thus reduced the phosphorus fixing capacity of the soils (Gharu and Tarafdar 2004).

Available K_2O content in soil samples varied from 190.8 to 285.2 kg ha^{-1}. None of the samples come under the deficient category of K with 125 kg ha^{-1}, as critical limit (Muhr *at al*, 1965). The available K increased significantly with increase in CEC (r = 0.308*), organic carbon (r = 0.342), silt (r = 0.314*) and clay (r = 0.308**). On the other hand, the availability of K_2O reduced significantly with sand (r = -0.330*) content. This might be due to the presence of most of mica in finer fraction (Singh *et al*, 1985).

The content of Ca in soil varied from 340.0 to 616.0 mg kg^{-1} with mean value of 442.0 mg kg^{-1}. Considering 300 mg kg^{-1} as critical limit for Ca deficiency (Tandon 1992), none of the sample was deficient in Ca. The available Ca in these soils samples was significantly and positively correlated with CEC (r = 0.698**), organic carbon (r = 0.735**), silt (r = 0.737**) and clay (r = 0.723**) content of soils. Whereas, it was negatively related with sand (r = 0.725**) and soil pH (r = -0.017). The results are in close proximity of Gathala *et al,* (2004) and Hundal *et al,* (2006).

Available Mg content in soil samples varied from 124.0 to 166.0 mg kg^{-1} with an average value of 139.5 mg kg^{-1}. None of the sample was deficient in available Mg with 120.0 mg kg^{-1} as critical limit (Tandon, 1992). The available Mg increased significantly with increase in CEC (r = 0.606**), organic carbon (r = 0.286**), silt (r = 0.504**) and clay (r = 0.515**) whereas, the same decreased significantly with increase in sand content (r = -0.512**). The results are in close proximity of Gathala *et al,* (2004) and Hundal *et al,* (2006).

The S content in soil sample varied from 5.3 to

Table 3. Correlation between soil properties and major nutrients

Soil properties/ Major nutrient	N	P_2O_5	K_2O	Ca	Mg	S
pH	0.121	0.054	-0.029	-0.017	0.016	-0.030
EC	0.104	-0.084	0.026	0.028	-0.074	0.126
$CaCO_3$	0.221	0.340**	0.034	0.114	-0.008	0.096
CEC	0.557**	0.487**	0.308*	0.698**	0.606**	0.529**
OC	0.830	0.610**	0.342*	0.725**	0.286**	0.943**
Sand	-0.743**	-0.714**	-0.330*	-0.735**	-0.512**	0.777**
Silt	0.717**	0.722**	0.314*	0.737**	0.504**	0.757**
Clay	0.767**	0.699**	0.348**	0.723**	0.515**	0.793**

*significant at 5%, **significant at 1%

12.5 mg kg^{-1} with mean value 7.80 mg kg^{-1}. Ninety six per cent samples were sufficient and only 4% were deficient in available S, with critical limit deficiency of 10 mg kg^{-1} available S (Tandon 1992). The availability of S increased significantly with an increase in CEC (r = 0.529**), organic carbon (r = 0.943**), clay (r = 0.793**) whereas, the same decreased with increase in sand content (r = 0.777**) of soil. The negative correlation of available S with sand content indicates that soils dominant in sand fraction are devoid of S which is in accordance with the observation of Jat and Yadav (2006). Organic carbon content and clay content were positively correlated with available S content of soil because organic matter could be a good reservoir or source of sulphur. Similar results were also reported by Jat and Yadav (2006), Sarkar *et al,* (2007) and Kaur and Jalali (2008).

It is apparent from the study that the majority of soils are low in organic carbon, available nitrogen, phosphorus and sulphur and medium in potassium, calcium and magnesium. Among soil properties, CEC, organic carbon, silt and clay content had a positive influence on the availability of nutrients whereas sand content had negative influence on availability of these nutrients.

REFERENCES

Gathala, M.K., Yadav, B.L. and Singh, S.D. 2004. Mineral nutrient status of Pomegrenate orchard in Jaipur district of Rajasthan. *Journal of the Indian Society of Soil Science* **52**: 206-208.

Gharu, Amita and Tarafdar, J.C. 2004. Influence of organic acids on mobilization of inorganic and oranic phosphorus in soil. *Journal of the Indian Society of Soil Science* **24**: 248-253.

Gupta, J.P., Joshi, D.C. and Singh, G.B. 2000. Management of arid agro-ecosystem. In *Natural Resources Management for Agricultural Production in India*. (J.S.P. Yadav and G.B. Singh, Eds.), pp. 557-668, New Delhi, India.

Hundal, H.L., Kumar, R., Singh, D. and Manchandra, J.S. 2006. Available nutrient and heavy metal status of soils of Punjab, Nourth-West India, *Journal of the Indian Society of Soil Science* **54**: 50-56.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Jat, J.R. and Yadav, B.L. 2006. Different forms of S and their relationship with properties of Entisols of Jaipur district (Rajasthan) under Mustard cultivation. *Journal of the Indian Society of Soil Science* **54**: 208-212.

Jolivet, C., Arrouays, D., Andreux, F. and Leveque, J. 1997. Soil organic carbon dynamics in cleared temperate forest Spodosols converted to maize cropping. *Plant and Soil* **191**: 225-231.

Joshi, D.C., Arora, B.R., Aggarwal, R.K., Ruhal, D.S. and Sharma, B. K. 1989. Forms and content of nutrient elements. In *Review of Research on Sandy Soils in India*, pp. 85-112. CAZRI, Jodhpur.

Kaur, J. and Jalali, V.K. 2008. Forms of sulphur and their relationship in soil of different Agro-climatic zone of Jambu region. *Journal of the Indian Society of Soil Science* **56**: 309-312.

Meena, H.B., Sharma, P.R. and Rawat, U.S. 2006. Status of macronutirent in some soils of Tonk district of Rajasthan. *Journal of the Indian Society of Soil Science* **54**: 205-512.

Muhr, G.R., Datta, N.P., Shanjkara, S.H., Laley, V.K. and Danahue. R.L. 1965. Soil testing in India, USDA publication, pp 120.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture Circular, 939.

Panse, V.G. and Sukhatme, P.V. 1961. Statistical Methods for Agricultural Workers, ICAR, New Delhi.

Piper, C.S. 1950. Soil and Plant Analysis. The university of Aledade, Australia.

Richards, L.A. (1954) *Diagnosis and Improvement of Saline and Alkali Soils*. Hand Book No. 60, Oxford and IBH Pub. Co., Calcutta-16.

Sarkar, M., Ghosh, S.K., Mukhopadhyay, P. and Pal, S.K., 2007. Distribution of sulphur and its relationship with soil properties in some soil series (Alfisols) of West Bengal. *Agropedology* **17**: 113-117.

Singh, Y.P., Singh, M. and Singh, R. 1985. Forms of soil potassium in Western part of Haryana, *Journal of the Indian Society of Soil Science* **33**: 285-291.

Subbiah, B.R. and Asija, G.L. 1956. A rapid procedure for estimation of available N in soils. *Current Science* **25**: 259-260.

Tandon. H.L.S. 1992. Fertilizer Guide Fertilizer Development and Consultation Organization, New Delhi.

Verma, L.P., Tripathi, B.R. and Sharma, D.P. 1980. Organics as an index to assess the nitrogen status of soils. *Journal of the Indian Society of Soil Science* **28**:138-140.

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

Williams, C.H. and Stainbergs, 1959. Soil sulphur interaction as chemical indices of available sulphur in some Australian soils. *Australia Journal of Agricultural Research* **10**: 340-231.

Wu, R. and Tissen, H. 2002. Effect of land use on soil degradation in alpine grassland soil of China. *Soil Society of American Journal* **66**: 1648-1656.

Yadav R.L. and Meena, S.C. 2009. Available micronutrient status and their relationship with soil properties of Degana soil series of Rajasthan. *Journal of the Indian Society of Soil Science* **56**: 309-312.

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Evaluation of rice establishment methods with nutrient and weed management options under rainfed farming situations of Bastar plateau

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ABSTRACT

This study was conducted during 2006-2009 at Shaheed Gundadhoor College of Agriculture and Research Station, Kumhrawand, Jagdalpur district Bastar (Chhattisgarh) under different rainfed farming situations. In upland farming situation, broadcasting (dry aerobic) + biasi + recommended fertilizer (80-50-30 kg ha^{-1} of NPK) + *In-situ* green manuring with sunhemp was found efficient with respect to significantly higher mean grain yield (1.83 t ha^{-1}), highest benefit cost (B:C) ratio (1.52 Rs. per Re.) and maximum rain water use efficiency (RWUE) of 1.59 kg/ha-mm. Under medium land situation, line seeding (dry aerobic) + recommended fertilizer (80-50-30 kg ha^{-1} of NPK) + *in situ* green manure incorporation by paddy weeder and weed control was found effective with significantly higher mean grain yield (3.08 t ha^{-1}), highest B:C ratio (2.28) and maximum RWUE (2.51 kg/ha-mm). However, under lowland situation broadcasting + biasi (dry aerobic) + RDF 80:50:30 kg ha^{-1} of NPK + *in-situ* green manuring with sunhemp was recorded efficient with a mean maximum grain yield of 5.76 t ha^{-1}, followed by line seeding (dry aerobic) + RDF 80:50:30 kg ha^{-1} of NPK + Post E weedicide with mean grain yield of 5.74 q ha^{-1} and line seedling (Dry aerobic)+ RDF 80:50:30 kg ha^{-1} of NPK + in-situ GM incorporation by paddy weeder & weed control with a marginally lower yield of 5.69 t ha^{-1}. The highest B:C ratio was found in Line seedling (Dry aerobic)+ RDF 80:50:30 kg ha^{-1} of NPK + In-situ GM incorporation by paddy weeder & weed control. The rice crop establishment methods did not gave any effect on relay crops because the sowing of relay crops is done as soon as the free water disappears. This time is almost same for all the treatments. However, field pea and lathyrus was recorded comparatively higher yields indicating their effectiveness in soil moisture utilization. Field pea was superior with a yield of 1.47 t ha^{-1} and B: C ratio of 6.16.

Key words: Rice establishment methods, nutrient and weed management options, dry aerobic rice seeding, rainfed farming situations of Bastar plateau

INTRODUCTION

Rainfed agriculture constitutes 80% of global agriculture and plays a vital role in achieving food security. These rainfed areas are vulnerable to poverty, malnutrition, water scarcity, severe land degradation and poor physical and social infrastructure. To eliminate all these severe problems, it is very important to conduct basic and applied research that will contribute to the development of sustainable rainfed farming systems dedicated for every agro climate zones separately. The production of rainfed rice (Oryza sativa L.) in drought-prone areas such as eastern India is highly variable and risky due to temporal and spatial variability in rainfall. Rice yields in eastern India only average 1.0–2.4 t ha^{-1} (Tomar, 2002). Water deficit is however not the only factor limiting crop production in rainfed lowlands. The

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low nutrient supplying capacity of soils and low fertilizer use also contribute to the large gap between potentially attainable yields and current yields of farmers (Dobermann and White, 1999).. Farmers' use of nutrient inputs is constrained by their limited financial resources and risk avoiding management strategies. Crop management options that efficiently use soil nutrients and moderate amounts of nutrient inputs while simultaneously reducing risk are essential for stabilizing and increasing rice yields in these areas (Pandey, 1998).

Rice is grown in about 3.8 million hectares in Chhattisgarh state out of which 80% area is rainfed (20 % area is under protective irrigation) Rainfed rice suffers due to drought either at early stage of crop growth or at terminal growth stage (at reproductive and maturity). Drought is a recurring phenomenon in rainfed lowland rice ecosystem in the state and due to this the average productivity is low and ranges between 1.2 to 1.4 t/ha. The average fertilizer (N, P, K) use (kg/ha) in all the three agro climatic zones is very low, especially in Bastar plateau and northern hills zones of Chhattisgarh. The ratio of fertilizer N:P:K is not balanced. It is envisaged from the study that, the rice yield potential under the rainfed upland condition is quite high as compared to the current production levels. The nutrients are most limiting factor for high productivity. Rice yield of 3 to 3.5 t/ha which is half of yield potential can be achieved simply by applying 60:40:20 kg/ha of NPK. Slight increase in fertilizer use can pay big dividends.

Aerobic rice is the most promising one in terms of water-saving (Anwar *et al.*, 2010). In precise, aerobic rice system refers to growing direct seeded rice on non-puddled aerobic soil without standing water (Bouman, 2003) and rice is managed intensively as an upland crop like wheat or maize. Aerobic rice is either rainfed or irrigated and soil water is maintained around field capacity in the root zone. This system eliminates surface runoff, percolation and evaporation losses (Singh and Chinnusamy, 2006) resulting in twice the water productivity of flood irrigated rice (Bouman *et al.*, 2002). Apart from lower yield, aerobic rice experiences higher weed pressure (Balasubramanian and Hill, 2002) compared with flood irrigated rice mostly due to lack of 'head start' over weeds and absence of standing water layer to suppress weeds. Weed is the major constraint in aerobic system and thus, yield losses is much higher in aerobic rice compared with other production systems (Balasubramanian and Hill, 2002). Therefore, developing a sustainable weed management approach has been a challenge for widespread adoption of aerobic rice technology. Now a day, people are much bothered about the negative impact of using herbicides on environment and public health (Phuong *et al.*, 2005). Even no herbicidal control has been found so effective against some vegetatively propagated weeds like purple nutsedge (Cyperus rotundus L.) (Juraimi *et al.*, 2009b). On the contrary, hand weeding is highly labor-intensive (as much as 190 person-days/ ha) (Roder, 2001). Due to high wages as well as unavailability of labor during peak season, hand weeding is not an economically viable option for the farmers. Therefore, what is needed that adoption of all possible cultural practices in an integrated way to suppress weeds and reduce chemical dependence.

MATERIALS AND METHODS

Bastar Plateau agro-climatic Zone in Chhattisgarh state comprises of large plateau having elevation ranging from 550 m to 760 m from mean sea level in between 17°46′ N and 20°34′ N latitudes and 80°15′ and 82°15′ E longitudes. Almost entire plateau ACZ makes a part of the large watershed area, receiving annual rainfall varying from 1400 mm to 1600 mm. On the basis of land topography, soil types and its physico-chemical properties, three major farming situations viz. upland (*Marhan and Tikra*), medium land (*Mal)* and lowland (*Gabhar*) have been identified in this region. Uplands are sloppy and eroded having low organic matter, fertility and productivity and poor water retention capacity, however, medium land and lowlands have moderate to good water retention and other physicochemical properties. Texturally soils are clay loam to loamy sand having low pH values ranging from 4.2 to 5.6. This study was conducted at block Tokapal, District Bastar in upland, medium land and lowland farming situations with same set of treatments during 2006-2009. In this study following eight treatments were tested in Randomized Complete Block Design with three replications. In lowland situations, four post-rice legume crops were also tested in sequence.

T1- Broadcasting (dry aerobic) + beushening + RDF (N_{80}:P_{50}:K_{30}) kg NPK/ha.

T2- T_1 + *In - situ* green manure (sunhemp)

T3- Line seeding (dry aerobic) + RDF (N_{80}:P_{50}:K_{30}) + Post emergence weedicide

T4- Line seeding (dry aerobic) + RDF (N_{80}:P_{50}:K_{30}) + *in-situ* green manure (sunhemp) incorporation by paddy weeder and weed control

T5- Broadcasting (moist aerobic) + beushening + RDF (N_{80}:P_{50}:K_{30})

T6- T_5 + *In - situ* green manure (Sunhemp)

T7- Line seedling (moist aerobic) + RDF (N_{80}:P_{50}:K_{30}) + Post emergence weedicide.

T8- Line seeding (moist aerobic) + RDF (N_{80}:P_{50}:K_{30}) + *In–situ* green manure (Sunhemp) incorporation by paddy weeder & weed control

The benefit : cost ratio was calculated as a ratio of gross returns / cost of cultivation; while the rain water use efficiency (kg ha^{-1} mm^{-1}) was calculated as a ratio of grain yield (kg ha^{-1}) and crop seasonal rainfall (mm).

RESULTS AND DISCUSSIONS

In upland condition (Table 1) T_1+ *in-situ* green manure (Sunhemp) was efficient with significantly higher mean yield 1.83 t ha^{-1} and highest B: C ratio (1.52) and maximum RWUE (1.59 kg ha^{-1} mm^{-1}) was found to be superior followed by line seeding (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + Post emergence weedicide (T3) while broadcasting (dry aerobic) – Biasi + RDF (80:50:30 kg NPK ha^{-1}) gave lowest grain yield of 1.00 t ha^{-1}. The upland rice response to management is poor and there is no consistency in the results. Further the B: C ratio is also low. It seems that more remunerative crops like maize, pigeonpea etc or low input crops like millets (finger millets, kodo millets etc.) should be targeted in upland.

Under midland farming situation (Table 2) line seeding (dry aerobic) + recommended fertilizer (80-50-30 kg/ha of NPK) + *in situ* green manure incorporation by paddy weeder and weed control was found to be effective with significantly higher mean yield of 3.08 t ha^{-1} and highest B: C (2.28) and maximum RWUE (2.51 kg ha^{-1} mm^{-1}) followed by treatment T1, T2, and T3, while Broadcasting – beushening (moist aerobic) + RDF (80:50:30 kg NPK ha^{-1}) gave lowest yield of 1.18 t ha^{-1}. The above experiment concluded that dry aerobic sowing has its advantage of better moisture utilization and conservation for second cropping under rainfed cropping system. Dickmann *et al* 1996 reported that green manure increased grain yield of rice significantly over the untreated control, by 1.3–1.7 t ha^{-1}. The yields were comparable to those obtained with 60 kg N ha^{-1} of urea fertilizer. The apparent release of exchangeable NH_4^+ - N in the soils after green manuring and the rice grain yield response showed that green manure with *S. rostrata* may provide sufficient available N throughout the development of rice crop in the wet season. In the rainfed marginal soil site, green manure with *S. rostrata* produced even higher rice grain yields than urea. Green manure therefore seems particularly attractive for poor farmers on marginally productive soils, at least as a temporary strategy to improve yield and yield sustainability.

Table 1. Effect of establishment method, nutrient and weed management options on grain yield, rain water use and economics of rice in upland condition.

Treatments	Grain Yield of rice (t ha^{-1})			Mean RWUE (Kg ha^{-1} mm^{-1})	Mean B:C ratio (Rs. Re^{-1})
	2006	2007	Mean		
T_1 : Broadcasting (dry aerobic) + Biasi + RDF (N_{80}:P_{50}:K_{30})	1.28	0.71	1.00	0.86	0.52
T_2 : T_1+ *In - situ* green manure (Sunhemp)	2.71	0.95	1.83	1.59	1.52
T_3 : Line seeding (dry aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	2.16	1.12	1.64	1.42	1.40
T_4 : Line seeding (dry aerobic)+ RDF (N_{80} :P_{50}:K_{30}) + *In-situ* GM incorporation by paddy weeder	1.08	1.15	1.11	0.97	0.42
T_5 : Broadcasting (moist aerobic) + beushening + RDF (N_{80}:P_{50}:K_{30})	1.00	1.21	1.11	0.96	0.48
$T_6$$T_5$ + *In - situ* green manure (Sunhemp)	1.36	1.35	1.35	1.17	0.99
T_7Line seeding (moist aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	1.81	1.21	1.51	1.31	1.16
T_8Line seeding (moist aerobic)+ RDF (N_{80} :P_{50}:K_{30}) + *In–situ* GM incorporation by paddy weeder	1.50	0.95	1.22	1.06	0.84
CD at 5%	0.28	0.33			

Table 2. Effect of establishment method, nutrient and weed management options on grain yield, rain water use (RWUE) and economics of rice in medium land condition.

Treatments	Grain Yield of rice (t ha^{-1})				Mean RWUE (Kg ha^{-1} mm^{-1})	Mean B:C ratio
	2006	2007	2008	Mean		
T_1 : Broadcasting (dry aerobic) + Biasi + RDF (N_{80}:P_{50}:K_{30})	2.81	2.44	3.40	2.88	2.35	2.15
T_2 : T_1+ *In - situ* green manure (Sunhemp)	3.20	2.15	3.13	2.83	2.30	2.07
T_3 : Line seeding (dry aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	3.40	2.24	3.06	2.90	2.36	2.28
T_4 : Line seeding (dry aerobic)+ RDF (N_{80} :P_{50}:K_{30}) + *In-situ* GM incorporation by paddy weeder	3.12	2.65	3.48	3.08	2.51	2.28
T_5 : Broadcasting (moist aerobic) + beushening + RDF (N_{80}:P_{50}:K_{30})	0.27	1.43	1.86	1.18	0.96	0.38
$T_6$$T_5$ + *In - situ* green manure (Sunhemp)	0.28	2.10	2.93	1.77	1.43	0.87
T_7Line seeding (moist aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	0.21	2.12	2.23	1.52	1.24	0.66
T_8Line seeding (moist aerobic)+ RDF (N_{80} :P_{50}:K_{30}) + *In–situ* GM incorporation by paddy weeder & weed control	0.74	2.18	2.47	1.79	1.46	0.93
CD at 5%	0.38	0.60	0.56	-		

Dry aerobic seeding (broadcasting or line sowing) is found better as compared to moist aerobic seeding in the three years result of lowland study (Table 3). The earlier establishment of rice with dry aerobic seeding can result in earlier maturity which can reduce risk by escaping drought at flowering (Fukai, 1999) and avoiding negative effects of late season drought common in large regions of eastern India (Sastri and Singh, 2000). This is important because drought around flowering has the most devastating effect on rice yield (Garrity and O'Toole, 1994). The dry aerobic seeding therefore appears to be more efficient in the drought prone and rainfed regions. The earlier maturity of dry aerobic rice could also contribute to earlier establishment and hence greater

Table 3. Effect of establishment method, nutrient and weed management options on grain yield, rain water use and economics of rice in low land condition.

Treatments	Grain Yield of rice (t ha^{-1})				Mean RWUE (Kg/ha-mm)	Mean B:C ratio
	2006	2007	2008	Mean		
T_1 Broadcasting (dry aerobic) + Biasi + RDF (N_{80}:P_{50}:K_{30})	4.89	4.64	6.47	5.33	4.36	4.06
T_2 T_1+ In - situ green manure (Sunhemp)	5.03	5.07	7.19	5.76	4.71	4.27
T_3 Line seeding (Dry aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	4.78	5.36	7.08	5.74	4.69	4.41
T_4 Line seedling (Dry aerobic)+ RDF (N_{80}:P_{50}:K_{30})+ In-situ GM incorporation by paddy weeder & weed control.	4.90	5.40	6.77	5.69	4.65	4.63
T_5 Broadcasting – beushening (Moist aerobic) + RDF (N_{80}:P_{50}:K_{30})	3.18	4.94	7.09	5.07	4.14	4.12
T_6 T_5 + In - situ green manure (Sunhemp)	2.68	5.10	6.17	4.65	3.80	3.64
T_7 Line seedling (moist aerobic) + RDF (N_{80}:P_{50}:K_{30})+ Post E weedicide.	2.32	5.12	5.46	4.30	3.52	3.17
T_8 Line seedling (Moist aerobic) + RDF (N_{80}:P_{50}:K_{30})+ In–situ GM incorporation by paddy weeder & weed control.	3.16	5.08	5.42	4.55	3.72	3.49
CD at 5%	0.89	0.40	0.97	-		

productivity of the post-rice food legume and therefore, increase opportunities for system intensification and diversification (Mazid et al., 2002).

The total rainfall was higher in 2006, however because of better distribution and greater sunshine the yields are higher in 2007 as well as in 2008. The yields of this study were higher as compared to medium land experiment. Broadcasting – Biasi (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) with *in situ* green manure (Sunhemp) was efficient with a mean maximum grain yield of 5.76 t ha^{-1}, while line seeding (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + post emergence weedicide was the 2nd best with mean grain yield of 5.74 t ha^{-1} closely followed by line seedling (dry aerobic)+ RDF (80:50:30 kg NPK ha^{-1}) + in-situ green manure incorporation by paddy weeder and weed control with a marginally lower yield of 5.69 t ha^{-1}. The lowest yield of 4.30 t ha^{-1} were attained by line seedling (moist aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + post emergence weedicide. The highest B:C ratio was found in line seedling (dry aerobic)+ RDF (80:50:30 kg NPK ha^{-1} + In-situ green manure incorporation by paddy weeder and weed control than followed by line seeding (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + post emergence weedicide and T_1+ in - situ green manure (Sunhemp). The maximum RWUE was found in line seeding (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + post emergence weedicide (2.69 kg ha^{-1}mm^{-1}) than followed by line seedling (dry aerobic) + RDF (80:50:30 kg NPK ha^{-1}) + in-situ green manure incorporation by paddy weeder and weed control (2.65 kg/ha-mm). Anitha *et al* 2010 reported that two levels of nitrogen (100 and 75% of recommended dose of N i.e. 90 kg) were super imposed over them. Dual cropping of cowpea with dry seeded rice could add about 12 t/ha of organic manure and resulted in a weed suppression of 69-75% and reduction in labour requirement for weeding (40 man-days/ha). This system guarantees 25% nitrogen saving (22.5 kg/ha) with 11% yield enhancement and increase in profitability (Rs 14,562/ha). The study revealed that, cowpea can be effectively incorporated by spraying 2, 4-D with effective weed control. The peak nitrogen release from concurrently grown cowpea coincides with the critical growth stages of rice, the panicle initiation stage, and thereby ensures availability of N at the critical stage. Becker 1995 reported that a quadratic response function between mineral fertilizer equivalence and green manure N indicated that up to 75 kg N/ha, lowland rice uses green manure N more efficiently than urea. Depending on season and establishment method, *S. rostrata* substituted for 35 to 90 kg of split-applied urea N. Benefit-cost ratios indicated that pre-rice green manure use in the wet season under the current fertilizer and labor prices in the Philippines was a less attractive economic option than mineral N fertilizer.

The rice crop establishment methods did not give any effect on relay crops (Table 4). This is because the sowing of relay crops is done as soon as the free water disappears. This time is almost same for all the treatments. However the crop-wise differences are significant. Field pea and Lathyrus gave highest mean grain yields 1.47 and 1.41 t ha^{-1} indicating their effectiveness in soil moisture utilization. The highest B: C ratio was obtained 6.16 for field pea followed by linseed (3.96). Field pea was superior with a yield 1.47 t ha^{-1} and B: C ratio of 6.16, while linseed gave B: C ratio of 3.96 from a yield of 0.31 t ha^{-1}.

Table 4. Grain yield (t ha^{-1}) of relay crops after rice in lowland situations

Treatments	Grain Yield of rice (t ha^{-1})Mean RWUE			Mean B:C ratio	
	2006	2007	Mean	(Kg ha^{-1} mm^{-1})	(Rs. Re^{-1})
Chickpea	650	881.6	765.8	0.63	2.66
Field pea	1565	1366	1465.5	1.21	6.16
Lathyrus	1560	1254.1	1407.05	1.16	3.54
Linseed	331	295.6	313.3	0.26	3.96

REFERENCES

Anwar M P, Juraimi A S, Man A, Puteh A, Selamat A and Begum M. 2010. Weed suppressive ability of rice (Oryza sativa L.) germplasm under aerobic soil conditions. Australian J. Crop Sci. 4(9): 706-717.

Anitha S, Mathew J and Abraham C T. 2010. Dual cropping of rice (Oryza sativa) and green manure crops –A cost effective management alternative for direct seeded semi-dry system of rice cultivation. Ind. J. of Agronomy 55 (3):165-170.

Balasubramanian V and Hill J E. 2002. Direct seeding of rice in Asia: Emerging issues and strategic research needs for the 21 St century. pp.15-39. In: S. Pandey S, Mortimer M, Wade L, Tuong TP, Lopez K, Hardy

B.eds.), Direct Seeding: Res. strategies and opportunities. IRRI, Los Banos, Philippines.

Becker M, Ali M, Ladha J K and Ottow J C G. 1995. Agronomic and economic evaluation of *Sesbania rostrata* green manure establishment in irrigated rice. *Field Crops Research* 40 (3): 135–141.

Bouman B A M. 2003. Examining the water-shortage problem in rice systems: water saving irrigation technologies. In: Proc.Inter. Rice Res. Conference, Beijing, China, 16-19 September (2002). In: Mew TW, Brar DS, Peng S, Dawe D, Hardy B (eds), Rice Sci. Innovation and Impact for Livelihood, pp. 519-535.

Bouman B A M, Wang H, Yang X, Zhao J and Wang C. 2002. Aerobic rice (Han Dao): A new way of growing rice in water-short areas. In: Proc. of the 12 th Inter. Soil Conservation Organization Conference, 26-31 May (2002), Beijing, China. Tsinghua University Press, pp. 175- 181.

Dickmann, K H, Ottow J C G, Diekmann K H and Datta S K. 1996. Yield and nitrogen response of lowland rice (*Oryza sativa* L.) to *Sesbania rostrata* and *Aeschynomene afraspera* green manure in different marginally productive soils in the Philippines. *J. of Bio. and fert. of soils* 21:1-2.

Dobermann, A., White, P F. 1999. Strategies for nutrient management in irrigated and rainfed lowland rice systems. In: Balasubramanian, V., Ladha, J.K., Denning, G.L. (Eds.), Resource Management in Rice Systems: Nutrients. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 1–26.

Fukai, S. 1999. Phenology in rainfed lowland rice. *Field Crops Res.* 64, 51–60.

Garrity, D P and O'Toole, J C. 1994. Screening for drought resistance at the reproductive phase. *Field Crops Res.* 39, 99–110.

Juraimi A S, Begum M, Sherif A M, Rajan A 2009. Effects of sowing date and nut sedge removal time on plant growth and yield of tef [Eragrostis tef (Zucc.)Trotter]. (2009). Afr. J. Biotechnol. **8** (22):6162-6167.

Mazid, M A, Bhuiyan, S I , Mannan, M A. and Wade, L J. 2002. Dry seeded rice for enhancing productivity of rainfed drought-prone lands: lessons from Bangladesh and the Philippines. In: Pandey, S., Mortimer, M., Wade, L., Tuong, T.P., Lopez, K., Hardy, B. (Eds.), Direct Seeding: Research Strategies and Opportunities. International Rice Research Institute, Los Ban˜os, Philippines, pp. 185–200.

Pandey, S. 1998. Nutrient management technologies for rainfed rice in tomorrow's Asia: economics and institutional considerations. In: Ladha, J.K., Wade, L.J., Dobermann, A., Reichardt, W., Kirk, G.J.D., Piggin, C. (Eds.), Rainfed Lowland Rice: Advances in Nutrient Management Research. International Rice Research Institute, Los Ban˜os, Philippines, pp. 3–28.

Phuhong L T, Denich M, Vlek P L G and Balasubramanian V. 2005. Suppressing weeds in direct seeded lowland rice: effects of methods and rates of seeding. J. Agron. Crop Sci. **191**: 185-194.

Roder W 2001. Slash-and-burn rice systems in the hills of northern Lao PDR. In: Description, challenges, and Opportunities, IRRI, Los Banos, Philippines, pp. 201.

Sastri, A S R A S and Singh, V P. 2000. Agroclimatic inventory for environmental characterization of rainfed rice-based cropping systems of eastern India. In: Tuong, T.P., Kam, S.P., Wade, L., Pandey, S., Bouman, B.A.M., Hardy, B. (Eds.), Characterizing and Understanding Rainfed Environments. International Rice Research Institute, Los Ban˜os, Philippines, pp. 215–231.

Singh A K and Chinnusamy V. 2006. Aerobic Rice: Prospects for Enhancing Water Productivity. In: Indian Farming, October (2006). Sinoquet H, Bonhomme R (1992). Modeling radiative transfer in mixed and row intercropping systems. Agric. For. Meteorol. **62**: 219- 240.

Tomar, V S. 2002. The beushening system of rice crop establishment in eastern India. In: Pandey, S., Mortimer, M., Wade, L., Tuong, T.P., Lopez, K., Hardy, B. (Eds.), Direct Seeding: Research Strategies and Opportunities. International Rice Research Institute, Los Ban˜os, Philippines, pp. 53–73.

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Effect of Integrated Nutrient Management (INM) on quality parameters and nutrient balance under rainfed maize-gobhi sarson sequence

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ABSTRACT

A field experiment was conducted to study the effect of integrated nutrient management on quality parameters and nutrient balance under rainfed maize-gobhi sarson sequence at SKUAST-Jammu during *kharif* and *rabi* seasons of 2006-07 and 2007-08, respectively. The experiment consisted of fourteen treatment combinations. Maize crop was fertilized with recommended NPK along with S, Zn and B and 25 percent additional nitrogen through vermicompost (VC) exhibited highest protein content of 7.39 and 7.85 percent during 2006-07 and 2007-08, respectively. Similarly, in gobhi-sarson highest protein content was noted where recommended NPK coupled with S, Zn, B and 25 percent additional nitrogen through VC was applied to preceding crop, exhibiting 21.14 and 21.58 percent protein during 2006-07 and 2007-08, respectively. The highest oil content (41.27 and 41.33 percent) of gobhi- sarson was recorded with the residual effect of treatment NPK+S+Zn+B+VC (50% N replacement) during 2006-07 and 2007-08, respectively. However, the application of NPK+S+Zn+B+VC (25% N additional) in maize resulted in the highest oil yield of gobhi-sarson (5.63 and 5.85 q ha^{-1} during 2006-07 and 2007-08, respectively).

Key words: Maize-Gobhi sarson sequence, rainfed, nutrient balance sheet, protein content, oil content and oil yield

INTRODUCTION

Maize-wheat and oilseed-maize are the predominant cropping systems in the rainfed areas of Jammu Division of Jammu and Kashmir. However, yield of wheat in the existing system is very low due to its complete dependence on rains which is often scanty and erratic during *Rabi* season. Since rapeseed-mustard can withstand moisture deficit better than than wheat and also because of its wider adaptability and suitability for early planting to exploit moisture of rainy (*kharif*) season, it has emerged as a potential replacement for wheat in rainfed situations. Moreover, owing to greater yield potential among cereals with multiple uses for food, feed and industries, maize has become an important crop in our county vis-a-vis in the world. In the present day of intensive agriculture, a plant is unable to use all the applied nutrients in its short life span, therefore fertilizer scheduling is to be done on the basis of cropping sequence rather than individual crop to utilize residual plant nutrients for their efficient, economical and judicious use (Panwar, 2008). The emerging multi-nutrient deficiency has decreased the response of yield to fertilizers. This loss of mustard productivity is attributed to overall deterioration in soil health (Sinsinwar *et al*., 2005). Integrated nutrient management (INM) has been now gaining importance firstly because of the present negative nutrient balance and secondly neither the chemical fertilizers alone nor the potential alternative sources of nutrients exclusively can achieve the production sustainability of soils and crops under intensive cultivation (Bhat *et al*., 2005). Under such situation, integration of indigenously available organic sources of nutrients with inorganic sources is of vital significance for sustaining the productivity and fertility of soil. The adoption of integrated nutrient management practice under the rainfed

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condition not only enhances and sustain the fertility and productivity of soil but also improve the nutrient and water use efficiency besides improving the physical, chemical and biological properties of the soil. Therefore, keeping these facts in view the present study was carried out to evaluate the effects of Integrated Nutrient Management (INM) on quality parameters and nutrient balance under rainfed maize-gobhi sarson sequence.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi* seasons of 2006-07 and 2007-08 at Dryland Research Sub-Station, Dhiansar, SKUAST-Jammu. The experimental soil was sandy loam and contains 0.40 per cent organic carbon, 149.3 kg/ha available N, 14.9 kg/ha available P, 117.7 kg/ha available K, 9.1 mg/kg available S, 0.54 mg/kg available Zn and 0.41 mg/kg available B. The field experiment was laid out in randomized block design (RBD) with fourteen treatment combinations {T_1: NPK; T_2: NPK+S; T_3: NPK+Zn; T_4: NPK+B; T_5: NPK+S+Zn; T_6: NPK+S+B; T_7: NPK+Zn+B; T_8: NPK+S+Zn+B; T_9: NPK+S+Zn+B+FYM (25% N replacement); T_{10}: NPK+S+Zn+B+VC (25% N replacement); T_{11}: NPK+S+Zn+B+FYM (50% N replacement); T_{12}: NPK+S+Zn+B+VC (50 %N replacement); T_{13}: NPK+S+Zn+B+FYM (25% N additional); T_{14}: NPK+S+Zn+B+VC (25% N additional)}. Each treatment was replicated thrice. N, P, K, S, Zn, and B were applied @ 60, 40, 20, 25, 10 and 1 kg ha^{-1} respectively for maize crop. The rate of N, P_2O_5, and K_2O application was 50, 30 & 15 kg ha^{-1} respectively for gobhi-sarson. The sources of nitrogen, phosphorus and potassium were urea, diammonium phosphate and muriate of potash, respectively. Sulphur, zinc and boron were applied through elemental sulphur, zinc oxide and borax. Full amount of P_2O_5, K_2O, farmyard manure and vermicompost along with 50 per cent of nitrogen as per the treatment was applied as basal and remaining 50 per cent of N was top dressed after first rain. Full doses of FYM, phosphorus, potassium, sulphur, zinc oxide, boron and half dose of nitrogen was applied at the time of sowing. Maize *cv.* 'Kanchan-517' and Gobhi-sarson (*B. napus* var. *oleracea*) *cv.* 'DGS-1' was grown during during *kharif* and *rabi* season respectively. Protein content in grain and seeds of maize and gobhi-sarson was calculated by multiplying N content with a constant factor of 6.25 and expressed in per cent. Per cent oil content in gobhi-sarson seeds was calculated with the help of Soxhlet's extraction method taking petroleum ether as a solvent. Available N, P and K were analyzed by Alkaline $KMnO_4$ method (Subbiah and Asija, 1956), Olsen's method (Olsen *et al.*, 1954) and NH_4OAC method (Hanway and Heidel, 1952) respectively. Oil yield of gobhi-sarson was calculated by using the following formula:

RESULTS AND DISCUSSIONS

Protein content in maize and gobhi-sarson

Direct and residual effects of inorganics and organics showed a significant variation in quality studies in terms of per cent protein content in maize and gobhi-sarson during both the years of experimentation (Table 1). Maize crop fertilized with recommended NPK along with S, Zn and B and 25 per cent additional nitrogen through vermicompost (T_{14}) exhibited significantly higher protein content of 7.39 and 7.85 percent during 2006-07 and 2007-08, respectively. Treatment T_{13} {NPK+S+Zn+B+FYM (25% N additional)} and T_8 (NPK+S+Zn+B) were found statistically at par with the (T_{14}) with respect to per cent protein content of maize crop during both the years. The significant enhancement in percent protein content of maize with these nutrient management practices might be due to improvement in LAI of maize which could have resulted in better interception, absorption and utilization of radiant energy leading to higher photosynthetic rate and finally more accumulation of dry matter by the plants (Meena *et al.*, 2012). The higher protein content under above treatment could also be ascribed to more nitrogen, and vital role of zinc in synthesis of protein, indole acetic acid, chlorophyll formation, carbohydrate and auxin metabolism in maize grain. These findings are in agreement with the results obtained by Arya and Singh (2000). A significant and pronounced affect of recommended NPK along with S, Zn and B and 25 percent additional nitrogen through vermicompost applied to preceding maize crop was reflected in per cent protein content of gobhi-sarson (21.14 and 21.58 per cent during 2006-07 and 2007-08, respectively). This combined application of inorganic and organic was significantly followed by treatment T_{13} {NPK+S+Zn+B+FYM (25% N additional)} and T_8 (NPK+S+Zn+B) in affecting the percent protein content in gobhi-sarson. The higher protein content under treatment T_{14}: NPK+S+Zn+B+VC (25% N additional) might be due to more nitrogen content and high seed yield. This was because of higher

Table 1. Direct and residual effect of inorganics and organics on protein content of maize (%) and gobhi-sarson (%) under rainfed maize-gobhi sarson sequence

Treatment	Protein content of Maize (%)		Protein content of Gobhi Sarson (%)	
	2006-07	2007-08	2006-07	2007-08
T_1: NPK	3.27	3.66	16.91	17.33
T_2: NPK+S	3.91	4.08	17.72	18.16
T_3: NPK+Zn	4.27	4.39	17.41	17.85
T_4: NPK+B	3.64	3.91	17.22	17.64
T_5: NPK+S+Zn	5.95	6.41	19.52	20.02
T_6 : NPK+S+B	5.64	5.97	19.22	19.72
T_7: NPK+Zn+B	5.35	5.64	18.91	19.39
T_8: NPK+S+Zn+B	7.04	7.52	20.66	21.16
T_9: NPK+S+Zn+B+FYM (25% N replacement)	5.79	6.60	19.29	19.70
T_{10}: NPK+S+Zn+B+VC (25% N replacement)	5.97	6.66	19.54	20.04
T_{11}: NPK+S+Zn+B+FYM (50% N replacement)	5.41	6.64	18.89	19.60
T_{12}: NPK+S+Zn+B+VC (50 %N replacement)	5.66	6.70	19.20	19.83
T_{13}: NPK+S+Zn+B+FYM (25% N additional)	7.20	7.72	20.85	21.29
T_{14}: NPK+S+Zn+B+VC (25% N additional)	7.39	7.85	21.14	21.58
SEm±	0.30	0.34	0.35	0.36
CD (P=0.05)	0.89	0.99	1.04	1.07

residual availability of nutrients under the treatments receiving organic sources, *viz.* FYM and vermicompost. Similarly positive residual effect of organic sources applied to previous crop was reported by Kumar (2008) on wheat. The vermicompost have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than do organic materials before vermicomposting. Application of vermicompost and its subsequent decomposition in soil released plant nutrients in slow manner throughout the crop growth period causing better nutrient availability and thus it increased the value of yield attributing characters of gobhi-sarson which ultimately reflected in increased yield and quality of gobhi-sarson.

Oil content and oil yield of gobhi-sarson

The different inorganic and organic treatments in combination or alone did not show any significant effect on per cent oil content of gobhi-sarson seeds during both the years (Table 2). However, the highest oil content of gobhi-sarson (41.27 and 41.33 percent during 2006-07 and 2007-08, respectively) was recorded with residual effect of treatment T_{12} {NPK+S+Zn+B+VC (50% N replacement)}. More percent oil content in gobhi-sarson with treatment T_{12} over treatment T_{14} {NPK+S+Zn+B+VC (25% N additional)} might be due to the reason that more available nitrogen with supplementary organics enhance degradation of carbohydrates (tricarboxylic cycle) to acetyl CoA, thereby processes of reductive amination and transamination to produce more amino acids causing increased seed protein content with corresponding decrease in seed oil content (Hussain *et al*., 1998). Premi *et al*. (2012) were also of nearly same opinion after evaluating the effects of mustard straw and green manure on mustard productivity and sustainability. However, the increase in oil content may be attributed to the increased availability of sulphur, zinc and boron which involved in an increased conversion of primary fatty acid metabolites to end products of fatty acids. Shankar *et al.* (2002) and Prasad *et al*. (2003) reported similar results. The oil yield of gobhi-sarson was significantly influenced due to residual effects of organic treatments applied in preceding maize crop. Significantly higher oil yield of gobhi-sarson (5.63 and 5.85 q ha^{-1} during 2006-07 and 2007-08, respectively) was recorded with treatment T_{14} {NPK+S+Zn+B+VC (25% N additional)}. Supplementary addition of 25 per cent nitrogen through vermicompost in combination with recommended NPK along with S, Zn and B in preceding maize crop increased the average mean oil yield of gobhi-sarson by 36.8% over recommended NPK. Since, the oil yield as well as protein yield are the function of seed yield and their respective content in the seed, they increased with the increase in fertility levels and successive addition of supplementary ingredients. The results are in close conformity with the results of Prasad (2000) and Singh and Kumar (1999). According to

Table 2. Residual effect of inorganics and organics on oil content (%) and oil yield (q ha^{-1}) of gobhi-sarson under rainfed maize-gobhi sarson sequence

Treatment	Oil content of Gobhi-Sarson (%)		Oil yield of Gobhi Sarson (q ha^{-1})	
	2006-07	2007-08	2006-07	2007-08
T_1: NPK	40.43	40.46	4.16	4.23
T_2: NPK+S	40.57	40.60	4.36	4.42
T_3: NPK+Zn	40.49	40.51	4.28	4.33
T_4: NPK+B	40.48	40.52	4.21	4.28
T_5: NPK+S+Zn	40.63	40.67	5.01	5.07
T_6 : NPK+S+B	40.61	40.65	4.93	5.00
T_7: NPK+Zn+B	40.50	40.54	4.87	4.97
T_8: NPK+S+Zn+B	40.65	40.68	5.53	5.63
T_9: NPK+S+Zn+B+FYM (25% N replacement)	40.93	40.98	5.04	5.70
T_{10}: NPK+S+Zn+B+VC (25% N replacement)	41.12	41.19	5.09	5.75
T_{11}: NPK+S+Zn+B+FYM (50% N replacement)	41.18	41.25	4.98	5.80
T_{12}: NPK+S+Zn+B+VC (50 %N replacement)	41.27	41.33	5.04	5.84
T_{13}: NPK+S+Zn+B+FYM (25% N additional)	40.76	40.83	5.57	5.80
T_{14}: NPK+S+Zn+B+VC (25% N additional)	40.85	40.93	5.63	5.85
SEm±	0.33	0.34	0.19	0.21
CD (P=0.05)				

Premi *et al*. (2012), oil yield is the function of oil content and seed yield. Since variation in oil content has genetic and biochemical limitations, the oil yield is more influenced by seed yield and thus followed almost similar trend to seed yield.

Soil nutrient balance studies

The result of estimation made to arrive at an appropriate balance sheet of available N, P and K as affected by different treatment applied to maize-gohi-sarson sequence over the two year period are presented in Table 3. A comparison of initial status

Table 3. Balance sheet of available nutrients as influenced by inorganics and organics under maize-gobhi sarson sequence

Treatment	Available N (Kg ha^{-1})			Available P (Kg ha^{-1})			Available K (Kg ha^{-1})		
	Initial status (2006)	Status at the end (2008)	Net gain+)/ (loss (-)	Initial status (2006)	Status at the end (2008)	Net gain+)/ (loss (-)	Initial status (2006)	Status at the end (2008)	Net gain+)/ (loss (-)
T_1: NPK	151.3	146.15	-5.15	16.75	14.45	-2.3	124.82	112.84	-11.98
T_2: NPK+S	151.54	147.43	-4.11	16.92	14.76	-2.16	124.65	114.12	-10.53
T_3: NPK+Zn	151.54	146.78	-4.76	15.75	14.62	-1.63	123.86	112.95	-10.91
T_4: NPK+B	151.45	147.15	-4.30	16.65	14.53	-1.82	123.62	113.18	-10.44
T_5: NPK+S+Zn	151.78	148.27	-3.51	16.55	14.87	-1.68	125.46	115.23	-10.23
T_6 : NPK+S+B	150.77	148.13	-2.64	16.22	14.72	-1.50	125.76	115.85	-9.91
T_7: NPK+Zn+B	150.58	148.35	-2.23	16.42	14.95	-1.47	123.65	117.12	-6.53
T_8: NPK+S+Zn+B	150.74	148.68	-2.06	16.27	15.20	-1.07	123.65	117.27	-6.38
T_9: NPK+S+Zn+B+FYM (25% N replacement)	147.75	153.22	+5.47	15.38	16.85	+1.47	119.15	121.47	+2.32
T_{10}: NPK+S+Zn+B+VC (25% N replacement)	147.55	153.47	+5.92	15.55	17.18	+1.63	119.67	122.55	+2.88
T_{11}: NPK+S+Zn+B+FYM (50% N replacement)	148.30	155.75	+7.45	15.58	17.35	+1.77	121.43	124.67	+3.24
T_{12}: NPK+S+Zn+B+VC (50 %N replacement)	148.13	155.87	+7.74	15.87	17.53	+1.96	120.98	124.85	+3.87
T_{13}: NPK+S+Zn+B+FYM (25% N additional)	147.15	152.13	+4.98	15.28	16.47	+1.19	119.16	120.43	+1.27
T_{14}: NPK+S+Zn+B+VC (25% N additional)	147.34	152.57	+5.23	15.28	16.63	+1.35	119.82	121.37	+1.55

(2006) and status at the end (2008) revealed positive balance of available soil nitrogen, phosphorus and potassium in cropping sequence which received integrated application of inorganic and organic sources of nutrients. A net gain of 7.74 kg N, 1.96 kg P and 3.87 kg K was observed with treatment T_{12} where 50% RDF was applied along with 50 per cent recommended dose of N through vermicompost followed by T_{11} where 50 % RDF was applied along with 50 per cent recommended dose of N through FYM with gain of 7.45, 1.77 and 3.24 kg N, P and K, respectively. However, there was negative balance of available N, P and K in soil when maize gobhi-sarson sequence was fertilized with inorganic nutrients alone. The positive balance of N, P and K was the result of low uptake over total quantity of N, P and K applied to the crops. Vyas *et al.* (2003) and Tolanur and Badanur (2003) also reported similar results.

Hence, it is easily concluded from the present study that application of inorganics in conjugation with organics in dryland not only increased the yield and quality of maize and gobhi-sarson but also depicted a positive balance of available soil nitrogen, phosphorus and potassium which can be judiciously used by the succeeding crop and helps in maintaining soil health. This study further strengthens the role of organic sources of nutrients in maintaining soil health. Whereas, their combination with inorganic sources in appropriate ratios helps to maintain higher yields. Additionally organic sources also improve yields through increased moisture retention in these moisture deficit *kandi* soils.

REFERENCES

Arya, K.C. and Singh, S.N. 2000. Effects of different levels of phosphorus and zinc on yield and nutrient uptake of maize (*Zea mays* L.) with and without irrigation. *Indian Journal of Agronomy 45* (4): 717-721

Bhat, M.A., Singh, R. and Dash, D. 2005. Effect of integrated nutrient management on uptake and use efficiency of nitrogen and sulphur in mustard (*Brassica juncea* J.) on an inceptisol. *Crop Research*. 30(1): 23-25.

Hanway, I.J. and Heidel, H. 1952. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. *Iowa Agric.* 57: 1-31.

Hussain, G., Amanullah, H. and Rashid, A. 1998. Response of sunflower cultivars to different N levels under D.I. Khan conditions. *Sarhad Journal of Agriculture* 14(5): 411-415.

Kumar, A. 2008. Direct and residual effect of nutrient management in maize (*Zea mays*)-Wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* 53(1): 37-41.

Meena, S.R., Kumar, A., Jat, N.K., Meena, B.P., Rana, D.S. and Idnani, L.K. 2012. Influence of nutrient sources on growth, productivity and economics of baby corn (*Zea mays*)-potato (*Solanum tuberosum*)-mungbean (*Vigna radiata*) cropping system. *Indian Journal of Agronomy* 57(3): 217-221.

Olsen, S.R., Cole, V.C., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorous in soil by extension with $NaHCO_3$. USDA. Circ. 939: 19-33.

Panwar, A.S. 2008. Effect of integrated nutrient management in maize (*Zea mays*) mustard-(*Brassica campestris* var toria) cropping system in mid hills attitude. *Indian Journal of Agricultural Sciences*. 78(1): 27-31.

Pathak, S.K., Singh, S.B., Jha, R.N. and Sharma R.P. 2005. Effect of nutrient management on nutrient uptake and changes in soil fertility in maize (*Zea Mays*)-wheat (*Triticum Aestivum*) cropping system. *Indian Journal of Agronomy*. 50(4): 269-273.

Prasad, Baldeo. 2000. Performance of mustard varieties under different fertility levels. *Thesis* M.Sc. G.B. Pant University of Agriculture and Technology, Pantnagar. pp 115.

Prasad, K., Chaudhary, H.P. and Uttam, S.K. 2003. Effect of N, P, S and Zn nutrition on nutrient uptake, quality and yield of rainfed Indian mustard. *Indian Agriculturist.* 47 (1& 2): 45-50.

Premi, O.P., Rathore, S.S., Shekhawat, K., Kandpal, B.K. and Chauhan, J.S. 2012. Sustainability of follow-Indian mustard (*Brassica juncea*) system as influenced by green manure, mustard straw cycling and fertilizer application. *Indian Journal of Agronomy* 57(3): 229-234.

Shankar, G., Verma, L.P. and Singh, R. 2002. Effect of integrated nutrient management on yield and quality of Indian mustard (*Brassica juncea*) and properties of soil. *Indian Journal of Agricultural Sciences.* 72(9): 551-552.

Singh, R.P. and Kumar, A. 1999. New horizons for *Brassica carinata* under resource constraints in northern plains of India. *In* : 10th International Rapeseed Congress, Canberra, Australia September 26-29.

Sinsinwar, B.S., Premi, O.P. and Kumar, A. 2005. Productivity and economics of different Indian mustard, [*Brassica juncea* (L.) Czern & Coss] based cropping systems under irrigated conditions. *Journal of Oilseeds Research* 22(1): 40-41.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in solids. *Current Science* 25: 259-260.

Tolanur, S.L. and Badanur, V.P. 2003. Changes in Organic Carbon, Available N, P and K under Integrated Use of Organic Manure, Green Manure and Fertilizer on Sustaining Productivity of Pearl Millet-Pigeonpea System and Fertility of an Inceptisol. *Journal of the Indian Society of Soil Science.* 51(1): 37-41.

Vyas, M.D., Jain, A.K. and Tiwari, R.J. 2003. Long term Effect of Micronutrients and FYM on Yield and Nutrient Uptake by Soybean on a Typic Chromustert. *Journal of the Indian Society of Soil Science* 51(1): 45-47.

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Assessment of infiltration rates and models under high and low input crop management system in inceptisols of eastern Uttar Pradesh

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ABSTRACT

An infiltration study was carried out in Inceptisols at six locations under two different levels of management *viz.,* high input crop management (HM) and low input crop management (LM). Infiltrometers were setup for taking reading during 2009-10 and its evaluation was calculated in 2010 by different models viz., an empirical infiltration models (Kostiakov, 1932) and two process-based models (Green and Ampt, 1911 and Phillips, 1957) was evaluated to predict instantaneous infiltration rates in Eastern U.P. The model parameters were evaluated for efficiency and precision with respect to effects of management levels. The soil series Nigatpur under HM recorded higher infiltration rates. Infiltration rates were lower in low management at Khetalpur. These models have been evaluated with coefficient of determination (R^2), root mean square error (RMSE) and coefficient of residual mass (CRM) parameters. Phillip (1957) model was the best representation of the infiltration rate and time relationship in Inceptisols at all the locations. Phillips (1957) model had higher value of R^2 (0.97 to 0.99) and lower value of RMSE (0.14 to 1.78) and CRM (-0.598 to -0.143).

Key words: Infiltration rate, Infiltration models, High input and Low input crop management

INTRODUCTION

Infiltration is the process of entry of water into the soil through the soil surface (Hillel 1980). Infiltration is most responsive to conditions near the soil surface and changes with management due to the adoption of various soil and crop management practices (Sarrantonio *et al.* 1996). Moreover, field measurements of infiltration are often time-consuming and cumbersome. Hence, the use of different infiltration models offers viable alternative to assess the infiltration characteristics of the soil. India has geographical area about 329 millions hectare (m ha) and has annual rainfall 1194 mm which contribute total rainfall 400 millions hectare meter (m ha-m). About 215 m ha-m, water infiltrates into the soil and rest 115 m ha-m water flows on the earth surface which produce a hazards runoff and soil erosion and loss of nutrient from the soil surface. About 165 m ha-m soil moisture and 50 m ha-m ground water get recharged by infiltration process (Reddy and Reddi 2010). The infiltration models can be broadly categorized as empirical models (Kostiakov 1932; Empirical USSCS 1964 and Holtan 1961) and process-based models (Green and Ampt 1911; Phillip 1957 and Stroosnijerd 1976). But, the predictive ability of the infiltration models varies with management and cultural practices which influence with the soil properties and consequently the water infiltration into soil (Shukla *et al.* 2003). The coefficients of these models are influenced by soil texture and water transmission parameter, which in turn are functions soil management and land use practices. Infiltration can be measured in field or laboratory using the infiltrometer. infiltrometer is a device to measure the rate of infiltrated water into soil. Generally, it is used as double ring infiltrometer or single ring infiltrometer. The purpose is to create one dimensional flow of water from the inner ring in double ring infiltrometer. If water is flowing in

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one-dimensional at steady state condition and a unit gradient is present in the underlying soil the infiltration rate is approximately equal to the standard saturated hydraulic conductivity (Bouwer 1986). The amount of decayed organic matter found at the soil surface can also enhance infiltration; organic soils are generally more porous than mineral soil, which can hold much greater quantities of water. (Sarrantonio *et al.* 1996*).* Several studies have been conducted to validate these infiltration models under diverse situations (Skaggs *et at.* 1969; Haverkamp *et al.* 1977; Davidoff and Selim 1986; Harverkamp *et al.* 1988; Lal and Doren 1990; Sumathi and Padmakumari 2000 and Shukla *et al.* 2003). In Indian subcontinent, in dryland soils, different land use and crop management practices such as high input management and low input/farmer's management etc. are being followed which may influence the infiltration characteristics of the soils. In India, so far, apart from texture, other inherent properties that affect soil infiltration characteristics and different types of models are tested to predict cumulative infiltration and infiltration rate (Singh, *et al.* 1994). However, information on the extent of changes in soil infiltrati6n characteristics as influenced by management systems and suitability of various infiltration models for a particular soil type is lacking. Therefore, the present study was carried out to study the effect of different land uses and management practices on infiltration characteristics of the Inceptisols of humid sub-tropical (HST) India and to evaluate different infiltration models to predict the infiltration characteristics of these soils.

MATERIAL AND METHODS

The infiltration study was carried out at six locations representing three benchmark sites were: Nigatpur, Majhawa Block, Mirzapur (U.P.) (two spots), Khanpur, Chiraigaon Block, Varanasi (U.P.) (two spots) and Khetalpur, Aurai Block, Sant Ravidas Nagar (U.P.) (two spots). The detailed information on location, soil type, bio-climate and land use systems of the study area is presented in Table 1. The twodifferent levels of management i.e. high input crop management (HM) which is high input agricultural management and low input agricultural management (LM) representing lower input use were chosen for the study. The HM is characterized by application of high dose of NPK (Location specific), regular application of manures, intercropping with legumes; incorporation of residues and adoption of soil moisture conservation practices. The management practices under LM include low application of manure, sole crop, removal of residues and biomass and no soil moisture conservation practices. Some of physical and chemical properties of surface soils (0-30 cm) that influence the infiltration of experimental sites are presented in Table 2. The infiltration study was carried out in using double ring infiltrometer with 27 cm outer diameter and 15 cm inner diameter (Bouwer 1986). Double ring infiltrometers have been setup to observed infiltration rate during *rabi* season 2009-10 only. Three time infiltrometers have been setup for each locations. A constant water head of 8 cm was maintained in the inner ring and free water was kept in the outer ring at all the time. There were used infiltration models viz; an

Table1. Detail of locations, soil classification, land use pattern under high input and low management system

Place and management	Latitude	Longitude	Soil classification	Bio-climate	Land use
Nigatpur (HM)	25^0 10'	82^0 60'	Ustochrepts Order inceptisols	Warm and semiarid to subhumid	Agriculture (Lady's finger-carrot-sunflower)
Nigatpur (LM)	25^0 10'	82^0 60'	Ustochrepts Order inceptisols	Warm and semiarid to subhumid	Agriculture (Paddy-wheat)
Khanpur (HM)	25^0 20'	83^0 00'	Ustochrepts Order inceptisols	Semi-arid and sub-humid	Agriculture (Chilli- bitter guard)
Khanpur (LM)	25^0 20'	83^0 00'	Ustochrepts Order inceptisols	Semi-arid and sub-humid	Agriculture (Paddy-wheat)
Khetalpur (HM)	25^0 24'	82^0 38'	Ustochrepts Order inceptisols	Semi-arid and sub-humid	Agriculture (Sugarcane-moog)
Khetalpur (LM)	25^0 24'	82^0 38'	Ustochrepts Order inceptisols	Semi-arid and sub-humid	Agriculture (Paddy-wheat)

Table 2. Soil physical and chemical properties of different locations.

Place and Management	Sand (%)	Clay (%)	Silt (%)	Bulk Density (Mg m3)	Particle Density (Mg m3)	Porosity (%)	pH	EC dSm^{-1}	Organic Carbon (%)	Calcium Carbonate (%)	Exchangeable Sodium (%)
Nigatpur (HM)	50.12	38.38	11.50	1.260	2.386	47.19	7.40	0.36	0.50	5.00	15.00
Nigatpur (LM)	48.25	41.50	10.25	1.360	2.420	43.80	7.50	0.38	0.41	7.00	15.50
Khanpur (HM)	56.20	30.80	13.00	1.268	2.400	47.16	7.20	0.34	0.58	4.50	17.19
Khanpur (LM)	55.5	25.50	19.00	1.375	2.324	40.83	7.80	0.35	0.40	5.00	17.00
Khetalpur (HM)	52.5	30.00	17.50	1.300	2.321	43.98	7.50	0.26	0.56	4.00	16.54
Khetalpur (LM)	50.00	31.00	19.00	1.380	2.350	41.27	8.20	0.38	0.43	6.20	17.50

empirical models (Kostiakov 1932) and two process based models (Green and Ampt 1911 and Phillip 1957) and its evaluation have been done in 2010. The infiltration rate was determined numerically from the depth of cumulative infiltration and the corresponding time interval data in each location until steady state infiltration rate was reached. The infiltration rate were fitted into an empirical models (Kostiakov 1932) and two process based models (Green and Ampt 1911 and Phillip 1957) as given below:

(1) Kostiakov (1932) model

$$i = Bt^{-(n+1)}$$

Where,
i = instantaneous infiltration rate (cm min^{-1}.)
t = time (minute)
'B' and 'n' are empirical constant

(2) Green and Ampt (1911) model

$$i = i_c + B/I$$

Where,
I = instantaneous infiltration rate of water (cm min^{-1})
i_c = steady state infiltration rate (cm min^{-1})
B = constant

(3) Phillip (1957) model

$$i = 1/2St^{-1/2} + A$$

Where,
S = sorptivity (cm $min^{-1/2}$,)
A = constant
T = time (min.)

The infiltration model parameters were estimated by linear and non linear regression analysis technique (Gomez and Gomez 1984). The Assessment of different models was evaluated using coefficient of determination (R^2), root mean square error (RMSE) and coefficient of residual mass (CRM) parameters (Smith *et al.* 1996).

(a) Coefficient of determination

$$R^2 = 1 - \frac{SSE}{SSyy}$$

Where,
SSE = sum of Squares error.
SSyy =sum of square of model.

(b) Root mean square error (RMSE)

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(X-Y)^2}{n}}$$

Where,
X = observed value.
Y = modeled value.
n = no. of predictions/observations.

(c) Coefficient of residual mass (CRM)

$$CRM = \frac{\sum_{i-1}^{n} Oi - \sum_{i-1}^{n} Pi}{\sum_{i-1}^{n} Oi}$$

Where,
Pi = predicted value.
Oi = observed value.

RESULTS AND DISCUSSIONS

Assessment of Infiltration Rate

The highest infiltration rate (2.6 cm hr^{-1}) in the HM systems of Nigatpur (Table 3 & figure 1) could be explained partly by the high organic carbon content (Table 2) and the okra-carrot-sunflower based cropping system. The adoption of above crops which have deep-root system and high carbon sequestration potential resulted in more organic carbon in soils (Wani *et al.* 2003). This improved water transmission through soil profile is due to better porosity, aggregation, antecedent soil water content and the presence of macro pore channels (Edwards *et al.* 1988; Lowery *et al.* 1996 and Shaver *et al.* 2002). Among the all location Inceptisols of Khetalpur areas, the initial as well as the steady state infiltration rates were lower in LM (Table 3 and figure 5 & 6) than in HM Khetalpur. Earlier research has proved that the same soil will have different infiltration rates under various lands uses (Friedman 2003). The variations in the time taken to reach the cumulative

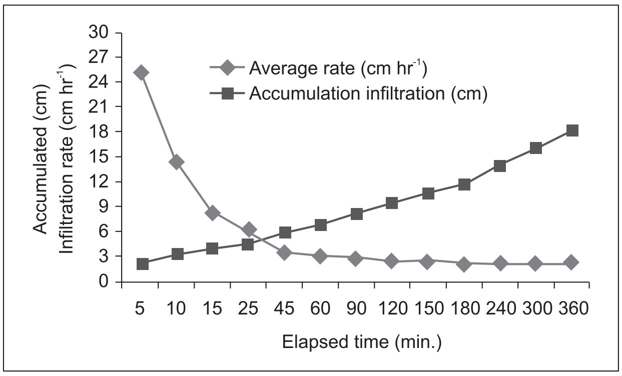

Fig. 1. Infiltration rate and accumulated infiltration at HM Nigatpur

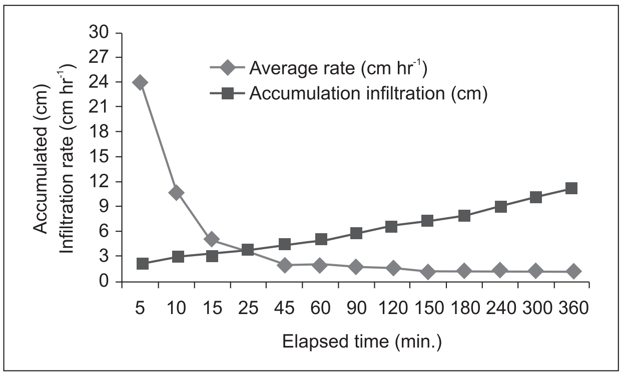

Fig. 2. Infiltration rate and accumulated infiltration at LM Nigatpur

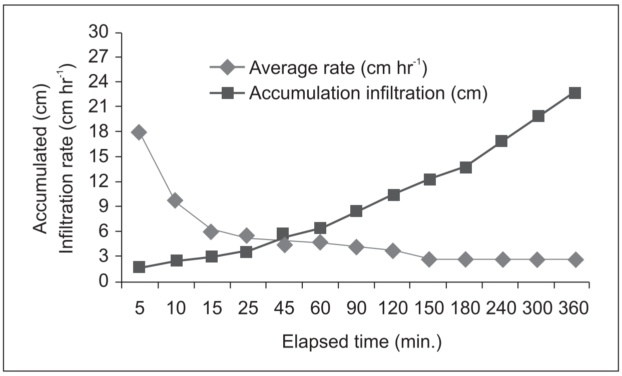

Fig. 3. Infiltration rate and accumulated infiltration at HM Khanpur

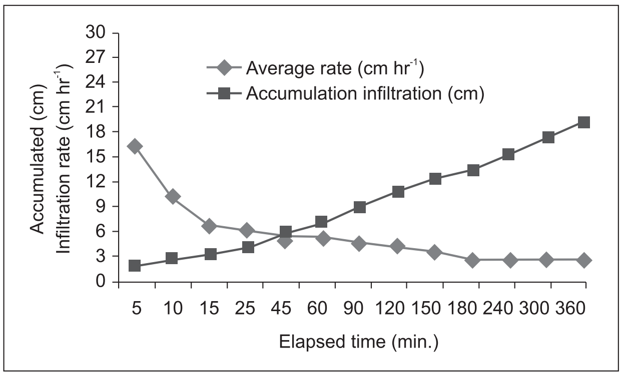

Fig. 4. Infiltration rate and accumulated infiltration at LM Khanpur

infiltration and steady state infiltration rate all location study under different management system (i.e. high and low input management system) could be attributed to the presence of varied amounts of gypsum crystals along with medium and coarse-sized lime nodules at different depths which may be due to differences in the landscape positions of these sites (Bhattacharyya, *et al.* 2003). The infiltration rate in low management at Khatalpur was relatively lower than the high management system (Figure 5 & 6). The low management in the present study was characterized by higher bulk density and calcium carbonate, which might have resulted in the formation of impermeable crusts layer that resulted in low infiltration rate as compared to the high management systems. Among the high management systems in these soils, cultivation of deep rooted crops (okra-carrot-sunflower) resulted in higher initial and steady state infiltration rate over sequential cropping of rice- wheat, which again highlights the advantages of the type of cropping system and its favorable relationship with key soil properties that influence the infiltration rate. In all locations, the initial infiltration rate and steady state infiltration rate in the soils of high management were found to be higher compared to low management. Other than the differences in the soil calcium carbonate content, the above trend in the infiltration parameters could be the result of addition of available quantities of organic manures from the existing animal source which would have improved the surface soil properties that influence the infiltration.

Assessment of the infiltration models

The Assessment of the different infiltration models at different location under HM & LM system were evaluated using coefficient of determination, root mean square error and coefficient of residual mass parameters values showed in Table 3. The value of coefficient of determination shows the fit of model and its values may varies from 0 to 1. Higher values of coefficient of determination imply better fit of the model whereas lower values of RMSE and CRM. RMSE were lower to low management Khetealpur and Nigatpur with comparison others locations Table 3. Because here infiltration rates go to constant at 150 minutes and 120 minutes to low management

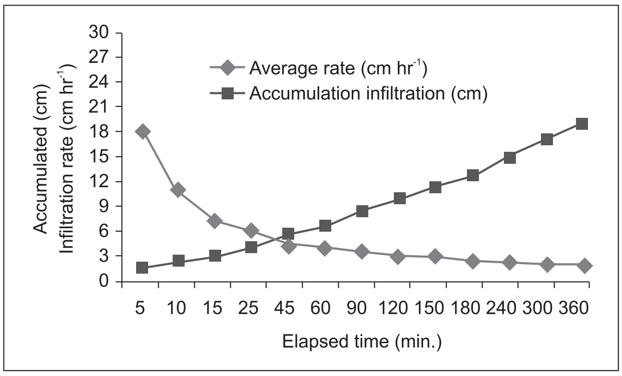

Fig. 5. Infiltration rate and accumulated infiltration at HM Khetalpur

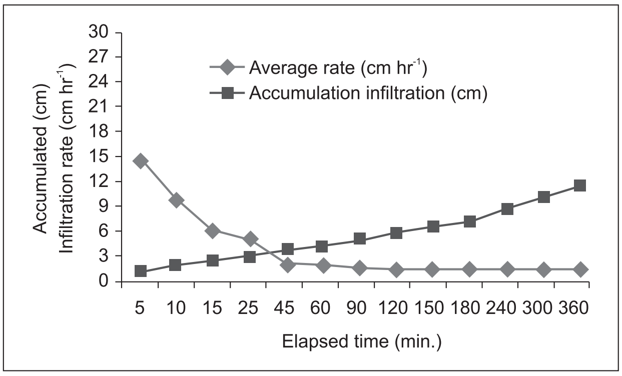

Fig. 6. Infiltration rate and accumulated infiltration at HM Khetalpur

Table 3. Evaluation of different infiltration models under high and low input management systems at different locations of study area

Place and management	Infiltration Rate (cm hr^{-1})	Model evaluations parameters								
		Kostiakov (1932)			Green and Ampt (1911)			Phillips (1957)		
		R^2	RMSE (cm hr^{-1})	CRM	R^2	RMSE (cm hr^{-1})	CRM	R^2	RMSE (cm hr^{-1})	CRM
Nigatpur (HM)	2.6	0.87	13.42	4.43E-16	0.69	1.59	-2.05 E-16	0.99	1.33	-0.487
Nigatpur (LM)	1.8	0.82	11.21	4.52 E-16	0.79	1.15	-3.24 E-16	0.97	0.15	-0.143
Khanpur (HM)	2.3	0.80	17.86	4.40 E-16	0.61	8.96	-1.69 E-16	0.99	1.71	-0.591
Khanpur (LM)	1.8	0.86	13.35	4.90 E-16	0.68	1.82	-2.15 E-16	0.99	1.33	-0.472
Khetalpur (HM)	2.0	0.84	13.67	4.41 E-16	0.63	2.35	-1.72 E-16	0.99	1.78	-0.598
Khetalpur (LM)	1.1	0.83	10.65	4.25 E-16	0.77	1.15	-2.65 E-16	0.98	0.14	-0.147

Khetealpur and Nigatpur, respectively while rest four locations infiltration rates were fond constant after 150 minutes and 180 minutes. Therefore, low management Khetealpur and Nigatpur infiltration rate were better fit in all model Kostiakov (1932), Green and Ampt (1911) model Phillips (1957) model in comparison to rest four locations Table 3. R^2 values were 0.80 to 0.87 for Kostiakov (1932), 0.61 to 0.79 for Green and Ampt (1911) model and 0.97 to 0.99 for Phillips (1957) model. RMSE values (0.14 to 1.78) of Phillips (1957) were lower than RMSE value (10.65 to 17.86) of Kostiakov (1932) and RMSE values (11.15 to 8.96) of Green & Ampt (1911) model. Phillips model gives better performances in long time (360 min. and 460 min.) (Shahsavar *et. al* 2010). The overall Assessment of the infiltration models tested in humid sub tropical area of Eastern U.P. can be ranked as follows: Phillips (1957) > Kostiakov (1932) > Green and Ampt (1911) models.

CONCLUSIONS

Adoption of high management system in Inceptisols of Eastern Utter Pradesh would results in better soil conditions that will improve the physico-chemical properties of soils that will increase the infiltration rate with less runoff. In HM, the infiltration rate was higher than LM because good agricultural practices would help in increasing the infiltration characteristics in Inceptisols. The Phillips model (1957) was better performer than Kostiakov (1932) and Green and Ampt (1911) models in Inceptisols of Varanasi, Sant Ravidas Nagar and Mirzapur district of Eastern Utter Pradesh. Overall, simple infiltration models based on Phillips (1957) gave the best representation of the infiltration rate and time relationship and also the best fit with experimental information data in Inceptisols for Eastern Utter Pradesh. This is suggested that application of organic manure, adaptation of deep root system may increase infiltration rate. Therefore, more infiltration rate is benefit to reduce runoff and increase ground water recharge.

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REFERENCES

Battacharyya, T., Chandran, P., Ray, S.K., Mandai, c., Pal, O.K., Venugopalan, M.V., Durge, S. L., Srivastava, P., Dubey, P.N., Kamble, G.K. and Sharma, R.P. 2003. Morphological properties of selected soils in 28 hence mark spots in red and black soils in semi-arid tropics, India. Working Report of National Bureau of Soil Survey and Land Use Planning Nagpur.

Bouwer, H. 1986. Intake rate: Cylinder infiltrorneter. In: *Methods of soil analysis*. Part I. 2nd Edition. (A Klute, Ed.), pp 834-842, ASA Monograph No.9, ASA, Madison, WI.

Davidoff, B. and Selim, H.M. 1956. Goodness of fit for eight water infiltration models. *J. of Amer. Soc. of Soil Sci.* **50**, pp. 759-764.

Edwards, W.M., Shipitalalo, MJ. and Norton, L.D. 1988. Contribution of macroporosity to infiltration into a continuous corn no-tilled watersheds. Implications for contaminant movement. *J of Cont. Hydro.* **3**, pp. 193-205.

Empirical USSCS: U. S. 1964. Soil Conservations Service.: Irrigation, National Eng. *Hand Book*, Sector 15, Chapter 1, Soil-water relationships. U S. Department of Agriculture's, Washington. *D.C.*

Friedman, D.B. 2003. Soil restoration-A component to managing future growth. ocean county soil conservation district, N.J.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research, John Willey and Sons, New York.

Green, W.H. and Ampt, G.A. 1911. Studies on soil physics: I Flow of air and water through soils. *J. of Agri. Sci.* **4**, pp. 1-24.

Haverkamp, R., Kutilick, M., Parlange, J. Y., Rendon, L. and Krejca, M. 1988. Infiltration under ponded conditions: 2. Infiltration equations tested for parameter-time dependence and predictive use. *Soil Sci*. **145**, pp. 317-329.

Haverkamp, R., Vauclin, M., Touma, J., Wierenga, PJ. and Vachaud, G. 1977. A comparison of numerical simulation models for one-dimensional infiltration. *J of Amer. Soc. of Soil Sci.* **41**, pp. 285-294.

Hillel, D. 1980. Fundamental of soil physics. Academic Press, New York, U.S.A.

Holtan, H.N. 1961. A concept for infiltration estimates in watershed engineering. *USDA Agri. Res. Ser. Pub.* No. 41-51.

Kastiakov, A.N. 1932. On the coefficient of water percolation in soils and on the necessity of studying it from a dynamic point of view for purposes of amelioration. Transactions of the Commission of the International Society of Soil Science.

Lal, R. and Daren, D.M. 1990. Influence of 25 Years of continuous com production by their tillage methods on water infiltration for two soils in Ohio. *Soil Till. Res.* **16**, pp. 71-84.

Lowery, B., Arshad, M.A., LAL, R. and Hickey, W.J. 1996. Soil water parameters and soil quality. In. Methods for assessing soil quality (J.W. Doran and A.J. Jones, Eds.), *Soil Sci. Soc. of Amer. Special Publication.* **49**, pp. 143-157.

Navar, J. and Synnott, T.J. 2000. Soil infiltration and land use in Linares. *Soil Sci.* **84,** pp. 557-564

Reddy, T. Y. and Reddi, G. H. S. 2010. Principles of Agronomy, Kalyani publication, New Delhi.

Phillip, J.R. 1957. Theory of infiltration: 4, Sorptivity and algebraic infiltration equations. *Soil Sci.* **84**, pp. 257-264.

Sarrantonio, M., Doran, J. W., Liegig, M.A. and Halvirson, J. J. 1996. On farm assessment of soil Quality and health. In : Methods for Assessing Soil Quality (lW. Doran and A.J. Jones, Eds.) pp. 83-106. *Soil Sci. Soc. of Amer. Special Publication* **49**, *SSSA, Madison, WI.*

Shavar, T.M., Peterson, G.A., Ahuja L.R., Westfall, D.G., Sherrod, L.A. and Dunn, G. 2002. Surface soil physical properties after twelve year of dry land no - till management. *J. of Amer. Soc. of Soil Sci.* **66**, pp. 1296-1303.

Shukla, M.K., Lal, R., Owens, L.B. and Unkefar, P. 2003. Land use and management impact on structure and infiltration characteristics of soils in the north appalachian region of Ohio. *Soil Sci.* **168**, pp. 178-191.

Singh, R., Bhargava, G.P. and Tiwan, CB, 1994. Infiltration characteristics and modeling for kutch mainland soils. *Ind. J. of Soil Cons.* **22**, pp. 22-28.

Skaggs, R.W., Huggins, L.E., Monke, E.J. and Foster, G.R. 1969. Experimental evaluation of infiltration equations. *Transactions in Amer. Soc. of Agric. Engineers.* **12**, pp. 822-828

Smith, J., Smith, P. and Addiscortt, T. 1996. Quantitative methods to evaluate and compare soil organic matter models. In: Evaluation of soil organic matter models (D.S. Powlson *et al.* Eds.) Springer- Verlag Publishers, Berlin. pp 181-199.

Shahsavar, A. M., Pazira, E., and Dadgar, M. 2010. Studying the Philip model capability to estimate water infiltration parameters. *World congress of soil sci., soil solutions for a changing world* 22-24.

Stroosnijder, L. 1976. Cumulative infiltration and infiltration rate in homogeneous soils. *Agri. Res. Repos.* **847**, pp. 69-99.

Sumuthi, I. and Padmakumari, O. 2000. Modeling infiltration under ponded and simulated rainfall conditions. *Ind. J. of Soil Con.* **28**, pp. 98-102

Wani, S.P., Pathak, P., Jangaward, L.S., Eswaran, H. and Singh, P. 2003. Improved management of Vertisols in the semi and tropics for increased productivity and soil carbon sequestration. *Soil Use and Manag.* **19**, pp. 217-222.

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Evaluation of large-scale subsurface drainage system in the Indira Gandhi Nahar Pariyojana Command Area, Rajasthan, India

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ABSTRACT

The present paper describes a large scale field installed subsurface drainage system in the Indira Gandhi Nahar Pariyojana command area in Rajasthan. Utility of subsurface drainage as an intervention to reclaim waterlogged saline lands and to ensure sustainability of irrigated agriculture has been established through experiments and pilot research conducted in waterlogged area. The subsurface drainage systems were evaluated on the basis of hydraulic characteristics of envelop materials, different drainage properties of soil and evaluation of drain spacing equations for disposal of effluent. An attempt has been made to critically review the findings emerging out of such a large number of pilots and subsurface drainage systems projects with a view to identifying management strategies requirement at regional scale. Salient findings that could serve as design guidelines or to operationalize the systems in an effective and eco-friendly manner have been put together for their application in future. The knowledge generated in this paper would help to design and plan subsurface drainage activities on which rests the food and nutritional security of India and many other developing nations.

Key words: Subsurface drainage, design guidelines, pilot research, salinity, waterlogging

INTRODUCTION

The introduction of irrigated agriculture in arid and semi-arid regions of the country has resulted in the development of the twin problem of waterlogging and soil salinization, with considerable areas either going out of production or experiencing reduced yield (Kumar *et al.*, 2009). It is estimated that an area of nearly 8.5 million ha is affected by soil salinity and alkalinity, of which about 5.5 million ha in the irrigation canal commands and 2.5 million ha in the coastal areas (Gupta, 2002). The problem of increasing salinity caused by the rise of the water table and the lack of drainage is considered as a major environmental problem that threatens the capital investment in irrigated agriculture and its sustainability (Kumar *et al.*, 2012).

Agricultural land drainage is a useful intervention in the overall water management activities (Kumar *et al.*, 2012). Effective design of subsurface drainage system requires that soil water movement during drainage be characterized in terms of soil properties, drainage system parameters and boundary conditions (Kumar *et al.*, 2009, 2012, 2013). There are numerous mathematical solutions, which have been proposed for the design of subsurface drainage system under steady and non steady state conditions. These solutions are arrived at by applying analytical or integration or analog techniques. Utility of subsurface drainage as an intervention to reclaim waterlogged saline lands and to ensure sustainability of irrigated agriculture in India has been established through experiments and pilot research conducted for over a century (Gupta, 2002). It is felt that large scale drainage projects would be increasingly implemented in India and many other developing countries (Kumar and Gupta, 2010). The knowledge generated in this century would help to design and plan subsurface drainage activities on which rests the food and nutritional security of India and many other developing nations.

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This paper presents the case study of the Indira Gandhi Nahar Priyojana (IGNP) command area basin and comments upon the outputs through field experiences of the research organizations and line departments that are active in this area. A brief review of field performance evaluation of subsurface drainage system, unsteady state drain spacing equation, physical properties of soil, and laboratory and field test of envelopes are given. In view of the stated problem at hand, this study seeks to highlight the environmental implications of poor drainage systems in the area and make possible solution and suggestions towards the amelioration of the problems. The methodology proposed in this paper could be used to investigate drainage requirements on a regional scale.

Indira Gandhi Nahar Priyojana

Indira Gandhi Nahar Project (IGNP) is one of the most gigantic projects in the world aiming to dedesertify and transform desert waste land into agriculturally productive area. The project objectives include drought proofing, providing drinking water, improvement of environment, afforestation, employment, rehabilitation, development and projection of animal wealth and increasing agricultural produce. The IGNP Command Area lies between 28°30′ and 30°32′ N latitude and 73° 45′ to 74° 46′E longitude in North Western Rajasthan, India. The maximum temperature goes in month of May-June up to 52 ^{0}C and minimum temperature goes below freezing point in winter month. The soil texture is sandy and the command area lacked natural drainage. This led to a massive spread of waterlogging and salinity, inundation of vast land depressions and fast spread of water- induced animal and human diseases (Mandal and Sharma, 2011).

The IGNP was originally approved by the Planning Commission in the year 1957 for an estimated cost of Rs.66.43 Cr in a combined shape which was revised with the proposal to execute the project components in two stages *i,e;* Stage-I & Stage-ll in 1970. Stage- I consists of a 204 km long feeder canal, having a head works discharge capacity of 460 m^3/sec, which starts from Harike Barrage (Punjab), 170 km of the feeder canal lie in Punjab and Haryana and 34 km in Rajasthan. While IGNP, Saget-I, with its CCA of 5.43 lakh ha was approved by the Planning Commission. The IGNP stage-II starts from the tail of stage-I *i.e.* from 189 km of IGNP main canal. IGNP, Stage-ll comprises of 256 km long (km189 to km 445) main canal and the requisite distribution system to irrigate Cultural Command Area (CCA) of 12.44 lakh ha consisting of 8.02 lakh ha under flow irrigation and 4.42 lakh ha under lift canals with irrigation intensity of 80% for flow and around 60% for lift. Stage-II provided irrigation to 9.01 lakh ha in the districts of Sriganganagar, Hanumangarh, Churu, Bikaner, Jodhpur, Jaisalmer and Barmer.

Rise of the water table closer to the surface and inundation of the low-lying areas have caused submergence of agricultural lands and constraints in the choice of crops and loss of production. The damages have taken place extensively in several areas and about 4,000 ha of agriculture, some waterlogged areas have completely gone out of cultivation, where the water table is either above the ground surface or very close to the surface. Waterlogged areas have also gone out of cultivation due to salinization. Waterlogging seriously constrains the choice of crops, enhances expenditure on farm operations and strongly affects the growth and yield of crops. Cultivation in about 4.4% of the area has been abandoned due to waterlogging and salinity about 5.7% areas in Stage I and 2.4% in Stage II.

A pilot project on water management in general and subsurface drainage in particular was initiated in the year 1993 at Lukhuwali area in Hanumangarh District and at Lunkarnsar of Bikaner District and called Indo – Dutch drainage project with the collaboration of Central Soil Salinity Research Institute, Karnal, Haryana.

Drainage intervention

Several ameliorative interventions have been attempted on a pilot scale to mitigate waterlogging and salinity in the IGNP command. These interventions, mainly biophysical in nature, included reduction in water allowance and drainage pilots for surface drainage, subsurface drainage, tube well drainage, skimming wells and bio-drainage (Kumar *et al.,* 2009). Most of the interventions faced operational, management, financial and institutional challenges and could not be upscaled for wider adoption in the command. Kumar *et al.* (2009) conducted study to evaluate the performance of synthetic envelopes for sub-surface drainage under the field conditions at Lunkarnsar Farm, Indira Gandhi Canal Command Area. Three types of synthetic envelopes viz. HG 22, SAPP 240 and CAN 2 were evaluated by using sand tank model and permeability apparatus to compare their performances in terms of entrance resistance and hydraulic conductivities of soil envelope system. The experiments revealed that the values of entrance resistance for envelope HG 22, SAPP 240 and CAN 2 were 1.95 day/m, 1.33 day/m and 1.51 day/m, respectively of Lunkarnsar soil. The hydraulic conductivities for envelope HG 22, SAPP 240 and CAN 2 of the total thickness (k-total) were found to be 4.53 cm/hr, 5.22 cm/hr and 4.91 cm/hr and of the contact layer (k-contact) were found to be 3.009 cm/hr, 3.62 cm/hr and 3.27 cm/hr, respectively. The Hydraulic conductivity for SAPP 240 filter was found to be the highest and entrance resistance was found to be lowest. The SAPP 240 filter is recommended for Indira Gandhi Command Area for subsurface drainage system (Kumar *et al.,* 2009)

In the command area, through installation of vertical drainage systems lower down the water table significantly. Though the results indicated that, to some extent, groundwater levels could be controlled, Installation of the subsurface drainage shows its beneficial effects in reclaiming waterlogged saline soils in a short span of 3 to 4 years in several subsurface drainage projects in command area of IGNP. The subsurface drainage projects installed in IGNP also showed similar improvements at Lukhuwali and Lunkarnsar areas. However, the technology is new to the area and pilot projects need to be operated and monitored for evaluating the impact. Bio-drainage with eucalyptus species was also attempted along small stretches of the canals. The bio-plantations may be used in certain waterlogged wastelands with suitable species and management practices (Kumar *et al.,* 2012).

Strategy for groundwater management

Provision of canals, the distribution system and the application of surface water to such a large area, besides providing direct irrigation benefits, also assists in modification of the groundwater regime (Gupta, 2002). The planning for integrated use of canal and groundwater will alleviate waterlogging problems and improve water use efficiency and productivity in the command area. Attempts have been made earlier conjunctive use of groundwater and canal supplies using simulation modeling techniques. Some studies have also been made in IGNP for projecting the problems of waterlogging and soil salinity and evaluating various options for problem amelioration (Kumar *et al.,* 2009; 2012; 2013). The pilot projects on subsurface drainage lower down groundwater, that salinity in the root zones can be quickly reduced when the cropping intensity will increase and crop yield will be more than double. However, this technology requires the participation of a group of farmers having contiguous land parcels and also issues like disposal/reuse of drainage effluent need to be addressed before embarking on large-scale adoption.

The already installed successful pilots on subsurface drainage (SSD) systems may be operated and monitored for deriving experience on these issues (Gupta, 1985; Rao *et al.,* 1986). The main objective was to suggest a technology to assess the surface and subsurface drainable surplus so that an integrated drainage system could be designed and disposal infrastructure created.

Sub-surface drainage system

Large numbers of drainage theories are available to design the subsurface drainage system for given area. The physical characteristics of soil play an important role in the design of SSD. Soil is most heterogeneous mass for which soil properties may vary with respect to location, depth and time. The most important properties of soil which affect the design and performance of subsurface drainage system are hydraulic conductivity, drainable porosity and depth of impermeable barrier. Synthetic envelopes play an important role in subsurface drainage due to its effectiveness and ease in transportability (Kumar *et al.,* 2009). Poor drainage due to drain clogging is a fairly frequent problems world over which leads to partial to complete failure of costly subsurface drainage system. Synthetic drain envelopes are being widely used to protect drainage pipe from sedimentation installed in soils where clogging hazards has been diagnosed. The main objective of placing envelope is to prevent the entry of soil particles into drain which reduces pipe capacity and to improve permeability in the immediate vicinity of the drain openings. It is therefore necessary to evaluate the performance of the drainage system and investigate the drainage properties to be used for regional scale design.

Drainage requirement: current status and need

There is a need to strengthen the capacity of the surface and subsurface drainage network in the command area, particularly the on-farm drainage network without which crops suffer from water stagnation on cropped lands. Since this discharge would be spread over the whole year, it might not pose much of a problem during critical periods. Operational schedules could be designed to dispose of this surplus at relatively safe periods. However, for the design of a horizontal pipe drainage system, the maximum value of the drainable surplus, *i.e.* 2mm day^{-1}, is recommended (Kumar and Gupta, 2010). Subsurface drainage systems installed by automated subsurface drainage laying machines. In IGNP command area used large-scale multidisciplinary applied research to investigate the use of horizontal subsurface drainage to control the problems of waterlogging and salinity. Both trenching and trenchless machines (equipped with laser-guided grade-control) were used. The performance of the machines was evaluated with respect to the installation of drain-pipes of different diameters at various depths, during the pre and post-monsoon seasons. The overall drain-laying times for the trencher, V-plough and trenchless plough were 51%, 26% and 30%, respectively, of the total installation time (Kumar and Gupta, 2010). Inverse linear relationships were found between drain diameter and drain laying rate, and between drain depth and drain laying rate. The drain-laying rates during post monsoon season were higher than pre-monsoon (Gupta, 2002).

Evaluation of sub-surface drainage system

The actual performance of drainage system designed on the basis of analytical relationship and assumption is evaluated by its effectiveness to control the waterlogging and salinity hazards in actual field conditions (Schwab *et al.*, 1957). Sewa Ram and Chauhan (1972) verified the applicability of Glover equation (Dumm, 1954) Integrated Hooghoudt equation (Bouwer and Van Schilfgaarde, 1963), Van Schilfgaarde equation (Van Schilfgaarde, 1963) and modified Glover equation (Van Schifgaarde, 1965) in Tarai region of U.P. They concluded that spacing predicated by Glover equation increased and Van Schilfgaarde equation performed generally better than others. The hydraulic heads calculated from modified Glover equations showed minimum deviation from observed values (Kumar *et al.*, 2012). The modified Glover equation is best suitable to evaluate drain spacing equations for disposal of effluent (Kumar *et al.*, 2012). The proper identification of a drainage problem and selection of a technically and economically viable solution requires detailed investigation of soil condition and other related factors. It is well known that the two main soil properties required equations for many of the drain spacing equations are the saturated hydraulic conductivity and the drainable porosity.

Envelope

In the last few decades maximum emphasis was given over irrigation potential development to raise productivity of land. Many multi-purpose projects were implemented with a huge network of canal irrigation. But soon it was found that the problems of water table rise, salinity and waterlogging were on the rise. Effective design of sub surface drainage system require that soil water movement during drainage be characterized in terms of soil properties, drainage system parameter and boundary condition while best performance can be achieved by good quality drainage material and regular maintenance. Continuous attention has been paid by scientists to evolve theoretical and mathematical solution to determine the structural strength, hydraulic resistance of pipe material and entrance resistance of envelope materials. Sedimentation problem in the subsurface drainage is the principle cause of failure of drains. The envelop material has play significant role in success of any waterlogged soils (Healy and Long, 1972; Mckeys and Broughton, 1974; Rapp and Riaz, 1975 and Broughton, 1976). The laboratory tests evaluate the ability of thin synthetic envelopes to prevent sediment from entering surface drains (Broadhead *et al.*, 1983, Tiligadas, 1988, Kumar *et al.*, 2009, 2012). A variety of materials almost all permeable porous material that are available economically in large quantities have been placed around subsurface drains as envelopes.

The above review paper shows that site specific evaluation of a drainage system should be conducted to suggest large scale drainage design parameters under similar conditions. Regional surface and subsurface drainage requirements have been worked out, suggesting that the area is prone to surface stagnation and has been facing a serious problem of a rising groundwater table over the last 30 years. The integrated drainage approach required strengthening of the surface drainage network particularly at farm scale and implementation of subsurface drainage in at least 16% of the study area. Since farmers are already sensitive to the problem, there is no reason why they would not respond to technologies to reverse the declining groundwater table with a basketful of alternative technologies being made available by research and development organizations. Subsurface drainage systems are designed to remove excess water from soil quickly enough to minimize crop. The depth and spacing guidelines for installing drainage pipes play very important role.

CONCLUSIONS

Soil salinity and waterlogging have been brought about by natural or human-induced processes and is a major environmental hazard. Evaluation and installation of subsurface drainage system is a difficult task, particularly across a country like India with such a diverse agro-climatic conditions. Present study was aimed to maintain both adequate aeration as well as moisture in their root zone for optimal growth of plants. Either high ground water table and/or excessive irrigation creates the condition of excess water and consequently results in development of waterlogged soils. In arid and semi arid region, as a result of high water table, salinity also develops. Installation of subsurface drainage system improve aeration of root zone will further improve the soil health. The hydraulic conductivity for SAPP 240 filter was found highest and entrance resistance was the lowest. Therefore, SAPP 240 filter is recommended for IGNP command area for SSD installation. Applicability of unsteady state drain spacing equations viz. Glover-Dumm, Van Schilfgaarde, Integrated Hooghoudt and Modified Glover equations were evaluated (Kumar et al., 2013). Modified Glover equation has minimum deviation from actual drain spacing than observed value to estimate the quantity of drainage effluent. Drainage intervention effect socio-economic impacts of land reclamation, employment generation, improvement in the environment and consequent lower allocations to health programmes.

REFERENCES

Bouwer, H. and Van Schifgaarde, J., 1963. Simplified method of predicting fall of water table in drained land. Trans. ASAE. 6(4): 288.

Broadhead, R.G., Schwab, G.O., Reeve, R.C., 1983. Synthetic drain envelope and particle size distribution. Trans. ASAE. 26(1) 157-160.

Broughton, R.S., 1976. Laboratory tests on commercial envelopes. Proc, Third National Drainage Symposium ASCE. Pub. 1, 1-77: 34-39.

Dumm, L.D., 1954. Drain spacing formulae - Determining depth and sapcing of subsurface drains in irrigated lands. Agric. Engg., ASAE. 35: 726-730.

Gupta, S.K. 2002. A century of subsurface drainage research in India. Irrigation and Drainage Systems 16: 69–84.

Gupta, S.K. 1985. Subsurface drainage for waterlogged saline soils. Irrigation and Power Journal 42: 335–344.

Healey, K.A. and Long, R.P., 1972. Prefabricated filter fin for subsurface drains. J. of Irrigation and Drainage. Div. of ASCE. 988(IR-4):543-553.

Kumar, K. and Gupta, S. K., 2010. Decline of groundwater tables in the upper Yamuna basin: causes and management strategies. J. Irrigation and Drainage 59: 606–620.

Kumar, R., Bhakar, S.R., Jhajharia, D. and Durbude, D.G., 2009. Performance of synthetic envelopes in Indira Gandhi Command Area Rajasthan. ISH Journal of Hydraulic Engineering, 15(2):1-15.

Kumar, R., Bhakar, S.R., Jhajharia, D. and Morvejalahkami, B., 2012. Evaluation of drain spacing equations in the Indira Gandhi Canal command area, India. ISH Journal of Hydraulic Engineering Vol. 18(3), 186–193.

Kumar, R., Bhakar, S. R. and Singh, P. K., 2013. Evaluation of hydraulic characteristics and management strategies of subsurface drainage system in Indira Gandhi Canal Command. Agric Eng Int: CIGR Journal, 15(2): 1-9.

Mandal, A.K. and Sharma, R., 2011. Delination and characterization of waterlogged salt affected soils in IGNP using remote sensing and GIS. J. Indian Soc. Remote Sensing, 39(1): 39-50.

Mckeys, E. and Broughton, R. S., 1974. A laboratory test of some drain tube filter materials. J. of Canadian Agricultural Engg., 16:62.

Rao, K.V.G.K., Singh, O.P., Gupta, R.K., Kamra, S.K., Padey, R.S., Kumbhare, P.S. and Abrol, I.P., 1986. Drainage Investigations for Salinity Control in Haryana. Bull. No. 10. CSSRI, Karnal. (95 pp).

Rapp, E. and Riaz, M. (1975). Comparisons of some filter materials for corrugated plastic drains. J. of Canadian Agricultural Engg.,vol 27:106-109.

Schwab, G.O., Don, K. and Johnson, H.P., 1957. Effect of the tile drainage on crop yield and water table level in a planosol soil. Soil Science Society American Proceedings. 21:448-452.

Sewa Ram, Chauhan, H.S., 1972. Field studies of unsteady subsurface drainage. J. Agric. Engg., ISAE. IX (4): 1-10

Tiligadas, E., 1988. Effect of different parameters on entrance resistance of corrugated plastic drains. Agriculture Water Management 13(2-4):225-232.

Van Schilfgaarde, J., 1963. Design of tile drainage for falling water table. J. Irrigation and Drain. Div. ASCE. 89(Jr-2):1-11.

Van Schilfgaarde, J., 1965. Design of tile drainage for falling water table. J. Irrigation and Drain. Div. ASCE. 89(Jr-3):71-73.

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Soil moisture release behaviour and irrigation scheduling for Aravalli soils of eastern Rajasthan uplands

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ABSTRACT

Study area consists of the alluvial plains of Kothari River, which is the tributary of Banas and situated in Eastern Rajasthan Upland. The area surrounded by Aravalli hills where sand constituted the major part of the soil. This study is concerned with the relationship of the soil moisture retention and release properties with irrigation scheduling and land use plan along with their texture, particularly the clay and silt fraction. Twelve pedons representing various topographic positions and zone of rainfall were sampled to study the soil-plant-water relationship in alluvial soils. *viz.*, upper rolling plains, middle sloping plains, lower plains. Soil moisture retention characteristics explained that the soils of the upper rolling plains have capacity to retain low amount of plant available water (AWC 7.31cm/m) as compared to the soils of middle sloping plain (AWC 12.87 cm/m) and lower plain (AWC 14.02 cm/m). Volumetric water content at different suction pressures viz. 33, 100, 500, 800, 1000, 1200 and 1500 kPa were studied in the alluvia of the river. About 75 percent of available water found to be released below the suction pressure of 500 kPa. The amount of available moisture for plant between 33 to 100 kPa was 59, 55 and 51 per cent while between 100 to 500 kPa it was 16, 20 and 22 per cent in upper rolling plains, middle sloping plains and lower plains, respectively. Silt and clay fractions were found to be the major factor controlling the available moisture. Coefficient of variation in moisture retention was noted from moderate (15–35%) to high (>35%) magnitude within the plains. In present investigation moisture retention of soils depleted to about 50 per cent at 100 kPa suction pressure so that irrigation should be delivered to replenish the soil moisture storage at this stage to keep target of maximum economic yield.

Key words: Moisture release, Irrigation scheduling, Land use planning, Alluvial soils, Aravalli Hills

INTRODUCTION

To obtain better yield from irrigation, requires appropriate management of all the inputs. Use of rational or scientific methods for scheduled irrigations is essential for good irrigation management, especially in soils of 'Eastern Rajasthan Upland' where irrigation is used to supplement rain. Good irrigation management begins with accurate measurement of soil moisture retention and release behavior and capacity of soil to store moisture at the time of vegetative growth and grain feeling stage. Over the years, a number of scheduling methods have been developed. Measurement of soil moisture levels has been the most common method of irrigation scheduling. Method based on soil moisture release for crop use a combination of crop water use and soil water estimates.

It is experienced that alluvial soils of Indo-Gangetic Plains with 15-20 per cent clay and larger portion of the silt are the most productive as these soils contain enough of clay to provide an adequate surface for interaction with water and nutrients, to have a friable structure beneficial for tillage and root growth (Pal 2003). It is well known that without knowing the moisture retention and release characteristics of alluvial soils, planning for irrigation and land use for the area is not possible. In view of necessity of adequate information the present study on alluvial soils of eastern Rajasthan upland has been planned.

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MATERIALS AND METHODS

Location

The study area as shown in map (fig.1) is comprised of thirteen geomorphic regions. It is almost rectangular in shape. The north and south-western portion of the district is an open plain marked with a few hillocks rising intermittently. The south and north-eastern portion is occupied by undulating lands and hills. The eastern portion consists of an elevated plateau. There is a distinct hill range in the north-east corner which extends up to Jahazpur town. Aravalli hilly ranges intersect the district at several places. These hills are prominent in the south-eastern part in Mandalgarh Tehsil. Bijoliya-Mandalgarh region of the district is termed as Uparmal due to its situation on a plateau. The general altitude of the district is about 380 meters above the mean sea level in plains of north. It gradually rises towards the western part of the district up to a general altitude of 500 meters above the mean sea level. The general slope of the district is towards north-east.

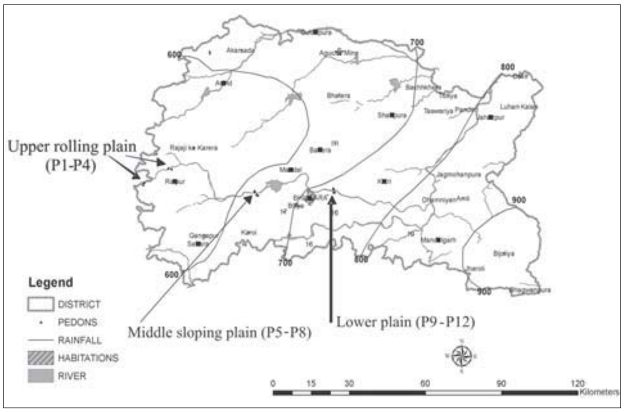

Fig. 1. Location map of study area

Morphological features

The soils under study are coarse textured, sandy clay loam to sandy with 3 to 30 per cent gravels with very slight to moderate erosion. Lower plains are liable to flooding and the surface receives fresh additions of material, which are laid down in successive layers, often of different grain sizes. Some alluvial soils are poorly drained, but others on terraces are imperfectly or freely drained. The limited water storage capacity of the coarse-textured soils is mainly due to their limited water retention, the extremely high infiltration rate and hydraulic conductivity. After comprehensive assessment it has been observed that the soils have unfavourable hydro-physical characteristics due to very coarse texture, salinity-alkalinity, moderately shallow depth and rock out crops.

Geology

The geology of the study area is quite complex. The district is almost underlined by Pre-Cambrean rocks, which consist of Bundelkhand gneiss, Banded gneissic complex, Aravalli system, composite gneisses, Delhi system and Vindhayans. The Bundelkhand gneiss is spread over in extensive area of the district, which comprises granites, and schist's out of which granite type is seen in the rocky area towards the adjoining Chittaurgarh district. The banded gneissic complex also cover extensive area in the south-eastern region while Aravalli system covering a wide area in the district is seen in the form of belts and comprises quartzite's, conglomerates, shale's, slates, phyllites and composite gneisses. Composite gneisses are classified into erinaceous and calcareous. The Delhi system comprises conglomerates occurring in the midst of the Aravalli schists and gneisses. The rock of Vindhyans comprises red, brown hard and flaggy sandstone, shale and limestone. From the mineral point of view the area is rich. The important minerals found in the district are mica, soapstone, garnet, asbestos, lead, zinc, copper, iron ore and building materials.

Climate and rainfall

The mean annual air temperature (MAAT) varies between 25.6 ^oC and 27.1 ^oC. January is the coldest month (7.8 ^oC) and May is the hottest (41.5 ^oC). The moisture index (MI) ranges from -59.7 to -39.5, indicating semi-arid dry to moist condition. The relative humidity varies between 40 to 80 percent. Average PET is 1380 mm. Water balance diagram (fig. 2) of the area indicates small to large seasonal water surplus varying from 29.1 to 325.4 mm annually. The precipitation is found greater >0.5 PET for 90-105 days. Length of growing period (LGP) ranges from 90-135 days in a year. The soil moisture and temperature regimes are Ustic and Hyperthermic, respectively. In the present investigation, an alluvial plains of Kothari river of Bhilwara district surrounded by Aravalli hills was selected, having three rainfall zones *viz.,* Upper rolling plains: Moderately sloping hills with a mean annual rainfall <600 mm (P1 to P4), Middle sloping plains: Gentle to very gently sloping plain with a mean annual rainfall 600-700 mm (P5 to P8) and Lower plains: Very gentle sloping plain with a mean annual rainfall 700-800 mm (P9 to P12). The area situated between $25^0 01'$ and $25^0 58'$N latitude

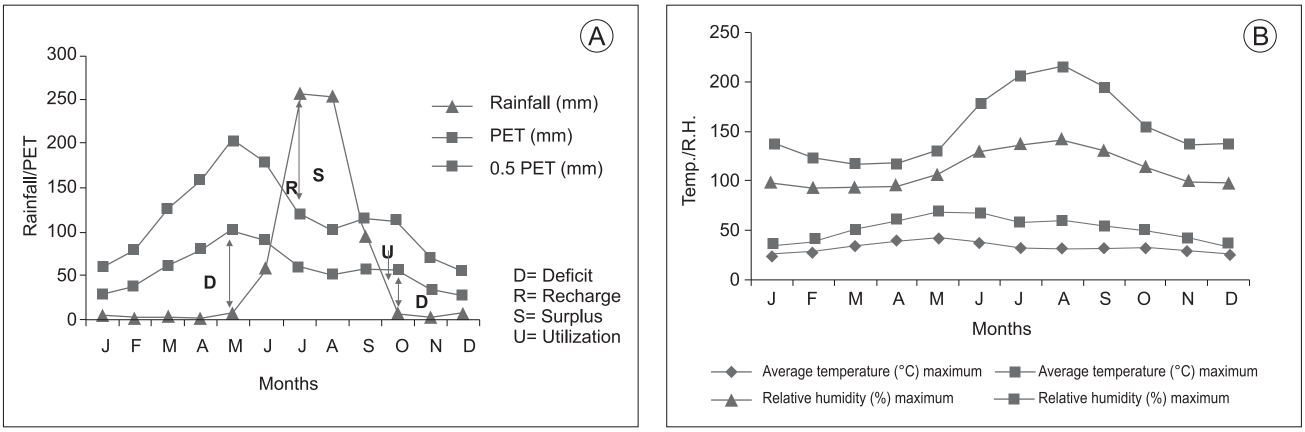

Fig. 2. A: water balance diagram of Eastern Rajasthan Uplands.
B: annual fluctuation in temperature and relative humidity of the study area.

and $74^0 01'$ and $75^0 28'$ E longitudes. Twelve pedons were selected for the study of water release and retention behaviour in soils.

All these three groups of profiles were situated approximately 50 km apart to each other from higher elevation (upper rolling plains) to lower elevation (lower plains). Four profiles within a group were selected for study and these were situated at a distance of 250 m and 500 m left and right side across the direction of river flow channel. Air dried soil samples were gently crushed with a wooden roller and passed through 2 mm sieve and analyzed for general soil properties with standard procedures (Jackson 1973) and (Page *et al.*1982). Available water capacity (AWC) was calculated using the expression suggested by Gardner *et al.* (1984) and later modified by Coughlan *et al.* (1986).

RESULTS AND DISCUSSIONS

Soil-site characteristics

The soils of alluvial plains were sandy loam to loamy sand. Among the plains, sand fraction was relatively higher (76.9 %) while silt and clay fractions were lower in the soils of upper rolling plains. The soils of lower plains contained higher amount of silt and clay fractions and lower sand fractions (65 %). The soils of middle slopping plain were moderate in sand, silt and clay fractions. An increasing trend of silt and clay fractions down the depth was also noted in all three plains but it was more prominent in the soils of lower plains due to the process of eluviation and illuviation of weathered materials. Soil pH and electrical conductivity (EC) was relatively lower (pH 7.29 & EC 0.17 dSm^{-1}) in the soils of upper rolling plain whereas higher (pH 8.10 & EC 0.60 dSm^{-1}) in the soils of lower plain but mean pH values were recorded maximum (pH 8.49) in the soils of middle sloping plains denote secondary accumulation of calcium carbonate. The EC was found within the safe limit and having no effect on crop growth and production in area. Coefficient of variation was low (<15 %) in case of pH while high (>35 %) for EC in soils of all three plains. Data pertaining to general soil characteristics are presented in table 1.

Moisture retention characteristics of soils

The amount of the water retained at 33 kPa and 1500 kPa ranged from 0.06 to 0.264 m^3/m^3 and 0.034 to 0.117 m^3/m^3 with a mean value of 0.145 and 0.072 m^3/m^3 respectively in upper rolling plains (P1-P4). The amount of water retained in middle sloping plains (P5-P8) increased over the upper rolling plains, which was ranged from 0.074 to 0.347 (mean 0.220) m^3/m^3 at 33 kPa and 0.036 to 0.236 (mean 0.097) m^3/m^3 at 1500 kPa. A maximum water retention capacity was observed in lower plains (P9-P12) that were ranged from 0.102 to 0.342 (mean 0.235) m^3/m^3 at 33 kPa and 0.032 to 0.158 (mean 0.094) m^3/m^3 at 1500 kPa (Table 2). The increase in water retention from upper rolling plains to middle and lower plains was mainly due to increase in silt and clay content. That provides higher surface area to hold moisture. Linear correlation has been reported between moisture retention and clay content (Peterson *et al.* 1968, Khan and Afzal 1993, Nagar *et al*. 1995, Diwakar and Singh 1992, Balpande *et al.* 2007).

In Ap horizons of upper rolling plains (P1-P4), water retention capacity ranged from 0.095 to 0.145 with mean value 0.119 m^3/m^3 at 33 kPa and it ranged between 0.044 and 0.071 with mean value of 0.058 m^3/m^3 at 1500 kPa while it increased in

Table 1. Physico-chemical properties of soils

Depth	Horizon					Particle size distribution (%)		
(cm)		pH	EC	$CaCO_3$	O.C. *	Sand	Silt	Clay
		(2.5:1)	(2.5:1)	(%)	(%)	(2.0-0.05 mm)	(0.05-0.002 mm)	(<0.002 mm)
Upper rolling plains with a mean annual rainfall <600 mm								
P1: Baniyon Ka Khera								
0-10	Ap	7.85	0.21	0.57	0.47	82.1	10.7	7.2
10_26	Bw1	7.50	0.10	0.95	0.32	74.0	18.5	7.4
26-46	Bw2	7.08	0.09	0.95	0.26	75.3	16.8	7.9
46-65	Bw3	7.12	0.09	1.00	0.34	74.6	18.0	7.4
65-80	Bw4	7.87	0.17	0.95	0.18	78.1	14.8	7.1
P2: Jalamali								
0-18	Ap	6.60	0.10	0.52	0.37	82.1	10.0	7.9
18-52	Bw1	6.56	0.05	0.81	0.25	80.0	12.9	7.1
52-90	Bw2	6.70	0.06	1.14	0.25	76.0	15.6	8.5
P3: Kalal Kheri								
0-16	Ap	7.05	0.21	1.52	0.34	76.5	15.8	7.7
16-47	Bw1	7.44	0.16	2.00	0.28	76.3	15.5	8.3
47-84	Bw2	7.50	0.16	2.14	0.23	81.0	11.4	7.6
84-140	Bw3	7.63	0.18	3.19	0.14	85.2	7.9	6.9
140+	C	7.65	0.16	1.19	0.09	92.4	1.6	6.0
P4: Dulkhera								
0-19	Ap	7.15	0.34	1.52	0.93	77.6	15.0	7.3
19-37	Bw1	7.20	0.26	1.23	0.28	75.1	15.8	9.1
37-75	Bw2	7.25	0.21	1.48	0.29	68.0	23.9	8.1
75-125	Bw3	7.40	0.20	1.52	0.29	65.1	27.7	7.2
125-170	Bw4	7.70	0.25	4.64	0.19	64.7	27.4	8.0
Middle sloping plains with a mean annual rainfall 600-700 mm								
P5: Karanwas								
0-17	Ap	8.20	0.21	0.90	0.30	82.5	10.1	7.3
17-30	A2	8.21	0.19	0.90	0.29	82.7	9.9	7.5
30-69	Bw1	8.91	0.24	3.76	0.24	68.3	23.8	7.9
69-96	Bw2	9.54	0.36	11.73	0.14	61.1	29.2	9.7
96-120	BC	9.61	0.40	13.25	0.10	59.9	29.9	10.2
120-140	C	9.73	0.48	16.62	0.07	60.8	29.9	9.3
P6: Sarano Ka Kheda								
0-18	Ap	8.15	0.59	0.57	0.15	83.1	6.8	10.2
18-50	A2	8.10	0.89	0.38	0.19	87.3	4.6	8.1
50-100	A3	8.06	0.57	0.43	0.15	84.5	4.8	10.7
100-140	A4	8.08	0.58	0.57	0.14	82.9	6.2	10.9
140-175+	A5	8.12	0.53	0.66	0.09	82.2	7.4	10.5
P7: Lasaria								
0-18	Ap	8.45	0.45	3.28	1.34	61.5	29.8	8.7
18-42	Bw1	8.54	0.49	3.24	0.71	62.7	29.1	8.2
42-70	Bw2	8.79	0.38	6.16	0.30	60.0	33.0	7.0
70-110	Bw3	8.86	0.38	7.12	0.26	62.2	26.3	11.5
P8: Hamirgarh								
0-19	Ap	8.41	0.17	0.57	0.47	78.7	11.9	9.4
19-50	A2	8.13	0.09	0.62	0.28	79.0	12.0	9.1
50-73	Bw1	8.12	0.09	1.04	0.28	66.8	18.1	15.2
73-100	Bw2	8.10	0.10	1.19	0.29	68.0	18.4	13.7

Depth	Horizon					Particle size distribution (%)		
(cm)		pH	EC	$CaCO_3$	O.C. *	Sand	Silt	Clay
		(2.5:1)	(2.5:1)	(%)	(%)	(2.0-0.05 mm)	(0.05-0.002 mm)	(<0.002 mm)
Lower plains with a mean annual rainfall 700-800 mm								
P9: Akola								
0-19	Ap	9.31	0.31	1.14	0.53	75.2	18.0	6.8
19-45	A2	8.62	1.42	1.00	0.21	70.1	17.2	12.7
45-85	Bw1	8.49	1.56	1.25	0.17	69.4	21.2	9.4
85-125	Bw2	8.66	1.41	1.46	0.14	67.1	21.3	11.6
125-170	Bw3	8.71	1.24	1.27	0.11	69.1	21.6	9.3
P10: Akola								
0-20	Ap	8.82	0.18	0.38	0.19	81.0	8.6	10.4
20-50	A2	8.52	0.52	0.52	0.11	82.1	8.1	9.8
50-90	A3	8.91	0.96	0.95	0.15	76.5	13.1	10.5
90-125	A4	9.55	0.55	0.81	0.07	83.7	6.5	9.8
125-170	A5	9.40	1.22	1.27	0.09	71.5	19.2	9.3
P11: Akola								
0-17	Ap	7.56	0.34	1.50	0.67	40.5	50.3	9.2
17-38	Bw1	7.65	0.20	1.52	0.48	36.9	49.8	13.3
38-62	Bw2	7.84	0.20	1.90	0.44	38.7	37.1	24.2
62-100	Bw3	7.35	0.30	2.04	0.38	43.0	33.1	23.9
P12: Akola								
0-15	Ap	6.14	0.20	0.57	0.23	77.8	12.8	9.4
15-35	Bw1	6.32	0.16	0.85	0.27	66.0	18.5	15.5
35-75	Bw2	6.89	0.19	1.04	0.21	59.0	20.5	20.5
75-120	Bw3	7.11	0.29	1.09	0.19	60.6	20.8	18.6

* Organic carbon

Bw horizons to the mean value of 0.159 m^3/m^3 at 33 kPa and 0.079 m^3/m^3 at 1500 kPa. In Ap horizons of middle sloping plains (P5-P8) the mean values of water retention were recorded 0.182 and 0.064 m^3/m^3 with 37.74 and 33.87 per cent coefficient of variations at 33 kPa and 1500 kPa, respectively while corresponding values for Bw layers were 0.293 and 0.128 m^3/m^3. A similar trend was also recorded in soils of lower plains (P9-P12). The mean value of water retained in surface to sub surface layers increased from 0.209 to 0.286 at 33 kPa and from 0.075 to 0.126 m^3/m^3 at 1500 kPa. The above results indicated that water retention increased down the depth of pedons in the soils of three plains, at both 33 kPa and 1500 kPa suction pressures (Table 2). The variability, in water retention at low and higher tension is governed by clay content and associated soil properties (Nagar *et al*., 1995).

The amount of water retained was found to be higher in sub surface layer in comparison to surface layer in all three plains. This followed the distribution pattern of silt and clay fractions in vertical direction of pedons. Silt and clay size fractions in soil take a very active part to hold the water. Maximum water content were recorded at 33 kPa in BC horizon (0.347 m^3/m^3) and at 1500 kPa in C horizon in soils of Karanwas (P5) in middle sloping plains. The high water retention at 33 & 1500 kPa might be due to higher carbonate content of clay size fractions (Massoud 1975; Singh, 1999). While minimum water retention was noted at 33 kPa in C horizon of Kalal Kheri soils (P3) and at 1500 kPa it was in A4 horizon of Akola (P10). Soil texture is the major soil property that regulates the water retention characteristics in alluvial plains.

Available water capacity (AWC)

Available water capacity (AWC) is the difference of water content at 33 kPa and 1500 kPa suction pressures. AWC ranged between 0.031 to 0.150 m^3/m^3 (Table 2) and was considerably higher in middle sloping plains (0.038 to 0.199 m^3/m^3) and in lower plains (0.071 to 0.195). AWC increased from Ap horizon to Bw horizons were 0.061 to 0.080 m^3/m^3 in upper rolling plains (P1-P4), 0.118 to 0.166 m^3/m^3 in middle sloping plains (P5-P8) and 0.133 to 0.159 m^3/m^3 in lower plains (P9-P12). Higher AWC

Table 2. Moisture retention and release characteristics of soils

Depth	Horizon	Volumetric water content at different pressures (kPa)							AWC	AWC (100 cm depth)		AWC (profile depth)	
(cm)	deg.	33	100	500	800	1000	1200	1500		(cm/m)			
(m^3/m^3)													
Upper rolling plains with a mean annual rainfall <600 mm													
P1: Baniyon Ka Khera													
0-10	Ap	0.108	0.078	0.070	0.066	0.063	0.059	0.057	0.051	0.51		0.510	
10_26	Bw1	0.146	0.107	0.097	0.092	0.088	0.084	0.080	0.065	1.05		1.046	
26-46	Bw2	0.139	0.103	0.094	0.088	0.085	0.080	0.077	0.062	1.24		1.241	
46-65	Bw3	0.145	0.105	0.096	0.091	0.087	0.082	0.079	0.066	1.26		1.258	
65-80	Bw4	0.138	0.095	0.083	0.076	0.073	0.069	0.065	0.073	2.56	6.61	1.10	5.15
P2: Jalamali													
0-18	Ap	0.095	0.065	0.057	0.052	0.050	0.046	0.044	0.051	0.92		0.92	
18-52	Bw1	0.098	0.073	0.065	0.062	0.061	0.057	0.056	0.042	1.44		1.44	
52-90	Bw2	0.127	0.096	0.087	0.083	0.080	0.076	0.074	0.054	2.58	4.94	2.04	4.40
P3: Kalal Kheri													
0-16	Ap	0.127	0.086	0.076	0.071	0.067	0.060	0.059	0.068	1.10		1.10	
16-47	Bw1	0.131	0.093	0.083	0.080	0.076	0.072	0.068	0.063	1.95		1.95	
47-84	Bw2	0.115	0.080	0.073	0.069	0.065	0.060	0.058	0.058	2.13		2.13	
84-140	Bw3	0.112	0.078	0.069	0.065	0.061	0.056	0.054	0.058	0.93	6.10	3.25	
140+	C	0.065	0.047	0.043	0.041	0.038	0.036	0.034	0.031			0.31	8.73
P4: Dulkhera													
0-19	Ap	0.145	0.101	0.089	0.085	0.079	0.074	0.071	0.074	1.41		1.41	
19-37	Bw1	0.162	0.117	0.103	0.098	0.094	0.088	0.085	0.077	1.38		1.38	
37-75	Bw2	0.249	0.176	0.148	0.139	0.131	0.122	0.117	0.133	5.05		5.05	
75-125	Bw3	0.264	0.180	0.150	0.138	0.129	0.119	0.113	0.150	3.75	11.59	7.50	
125-170	Bw4	0.247	0.160	0.138	0.129	0.119	0.110	0.102	0.144			6.49	21.83
Middle sloping plains with a mean annual rainfall 600-700 mm													
P5: Karanwas													
0-17	Ap	0.139	0.090	0.073	0.067	0.061	0.055	0.050	0.089	1.51		1.51	
17-30	A2	0.140	0.092	0.074	0.068	0.063	0.057	0.052	0.087	1.14		1.14	
30-69	Bw1	0.308	0.218	0.186	0.172	0.160	0.148	0.139	0.169	6.60		6.60	
69-96	Bw2	0.330	0.244	0.214	0.199	0.191	0.180	0.173	0.158	4.26		4.26	
96-120	Bc	0.347	0.265	0.236	0.225	0.215	0.205	0.198	0.149	0.60	14.12	3.59	
120-140	C	0.327	0.277	0.260	0.253	0.247	0.241	0.236	0.091			1.82	18.93
P6: Sarano Ka Kheda													
0-18	Ap	0.137	0.095	0.080	0.075	0.070	0.064	0.060	0.077	1.39		1.39	
18-50	A2	0.074	0.053	0.046	0.043	0.041	0.038	0.036	0.038	1.22		1.22	
50-100	A3	0.119	0.082	0.070	0.065	0.060	0.056	0.053	0.066	3.29	5.90	3.29	
100-140	A4	0.129	0.090	0.077	0.072	0.067	0.063	0.060	0.070			2.78	
140-175+	A5	0.128	0.088	0.075	0.071	0.067	0.062	0.058	0.070			2.44	11.12

were recorded in Bw horizon of middle and lower plains were mainly due to higher content of clay and silt down the depth of pedons. Mean AWC increased linearly with increasing clay content.

This was indicated that increase in clay and silt content had contributed marginally towards AWC due to corresponding increase in water retention at both the levels i.e. 33 & 1500 kPa (Peterson *et al.*, 1968; Singh, 1999). Coefficient of variations was moderate (15 to 35 %) to high (>35 %) in case of Ap layers and low (<15 %) to moderate in case of Bw layers in all the plains and this was due to the variations in content of clay and silt fractions in Ap than Bw layers.

Available water capacity (AWC) for profile

AWC per horizon was multiplied with thickness of horizons and equated for control section (100 cm depth). Mean AWC (100 cm depth) were 7.31, 12.87 and 14.02 cm/m in upper rolling plains (P1-

P4), middle sloping plains (P5-P8) and lower plains (P9-P12), respectively. It was maximum 19.24 cm/m in Lasaria soils (P7) of middle sloping plains followed by 16.55 cm/m in Akola soils (P11) of lower plains. Higher available water holding capacity was also noticed by Maji *et al.* (2005) in low-lying areas and low to medium in the soils developed on higher elevations. In Ap horizons the mean value of AWC was 0.98, 2.14 and 2.35 while in Bw horizons it was 2.11, 4.25, 4.32 cm/m in upper rolling plains (P1-P4), middle sloping plains (P5-P8) and lower plains (P9-P12), respectively. It followed an increasing trend down the depth due to an increased level of clay and silt fractions. A significant positive correlation was found between AWC and clay content (r = 0.354**) and silt content (r = 0.782**). The contribution of silt towards AWC was higher (R^2 = 0.61) as compared to clay (R^2 = 0.13) due to higher percentage of silt in alluvial plains of Kothari river. The regression equations were also fitted between AWC and silt plus clay content, depicted in fig. 3.

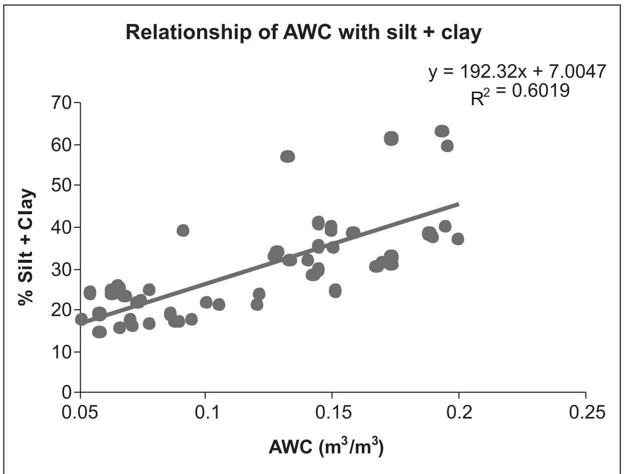

Fig. 3. Plant available water increase with silt plus clay content

Moisture release characteristics

Moisture retention characteristics at different suction pressures viz. 33, 100, 500, 800, 1000, 1200 and 1500 kPa were studied in the alluvial system of Kothari river plains. Amount of moisture released between two subsequent suction pressures were also calculated on volume basis considering the value 100 per cent for the moisture held between 33 and 1500 kPa. A mean content of moisture held between 33 to 100 kPa were 58.92, 55.17 and 50.86 per cent of AWC and between 100 to 500 kPa it was 16.31, 19.96 and 22.36 per cent in upper rolling plains (P1-P4), middle sloping plains (P5-P8) and lower plains (P9-P12) respectively. Bulk of moisture is released between 33 to 100 kPa (Diwakar and Singh, 1992). It can be inferred from the above data that approximately 75 per cent of water of AWC released up to the suction pressure of 500 kPa and only 25 per cent was released between 500 to 1500 kPa. Comparatively higher quantity of soil moisture was retained between 100 to 500 kPa in soils of lower plains indicates that the moisture adsorbed on the clay complexes and also due to increased level of clay. In case of lower plains (P9-P12) comparatively higher suction pressure required to release the water available to plants while in upper rolling plains (P1-P4) where clay and silt content was low maximum moisture (60 %) released below 100 kPa. While a reverse pattern of moisture release was noted between suction pressures of 100 to 500 kPa. Data also represented in graphical form in fig. 4. The figure showed that it was curvilinear below 500 kPa but became linear above 500 kPa, also indicates that very little amount of moisture released above 500 kPa of suction pressure.

Moisture release behavior in the soils of alluvial plains was also studied in vertical direction of the pedons. There was a similar pattern of moisture release in Ap and Bw horizons. A higher moisture content and moisture release at different suction pressures was noted in Bw horizons due to relatively larger amount of fine fractions in sub surface layers. A graphical representation of moisture release in surface and sub surface horizons of different alluvial plains showed in fig. 5. In both the layers of pedons (Ap & Bw) moisture release graph became linear after 500 kPa suction pressures. It was observed that relationship between matric suction and water content exhibited an excellent fit to power function as compared to linear or exponential and the amount of clay appears to affect FC and PWP linearly (Nikam *et al.*, 2006).

Irrigation planning

Water stored in the soil (in the crop's root zone) is withdrawn by evapotranspiration and deposited back into the soil through precipitation and irrigation. When soil moisture storage falls below a given threshold value, irrigation is applied to restore the moisture. *Soil moisture release curve* or *soil moisture retention curve* (Figure 4 & 5), is the relationship of how much water is retained against a given pressure potential (suction). It is essentially a representation of energy required to extract water from the soil over a range of soil moisture

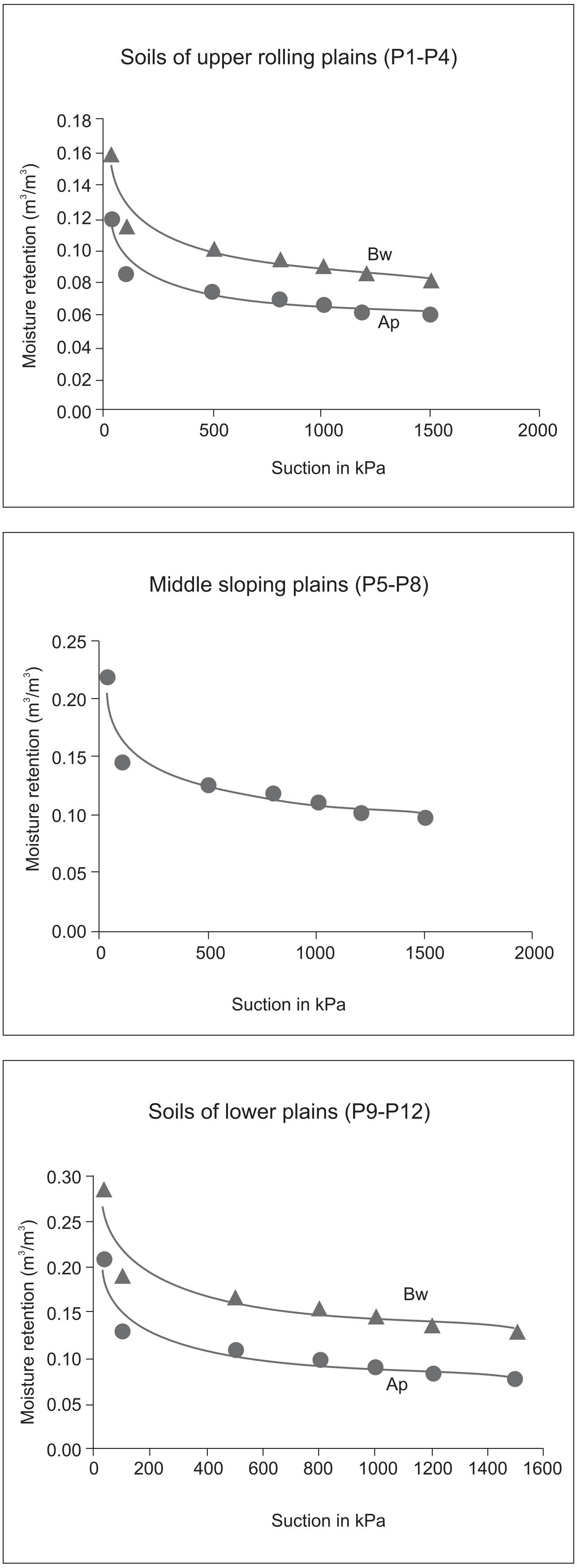

Fig. 4. Moisture release curves of soil profiles in three alluvial plains

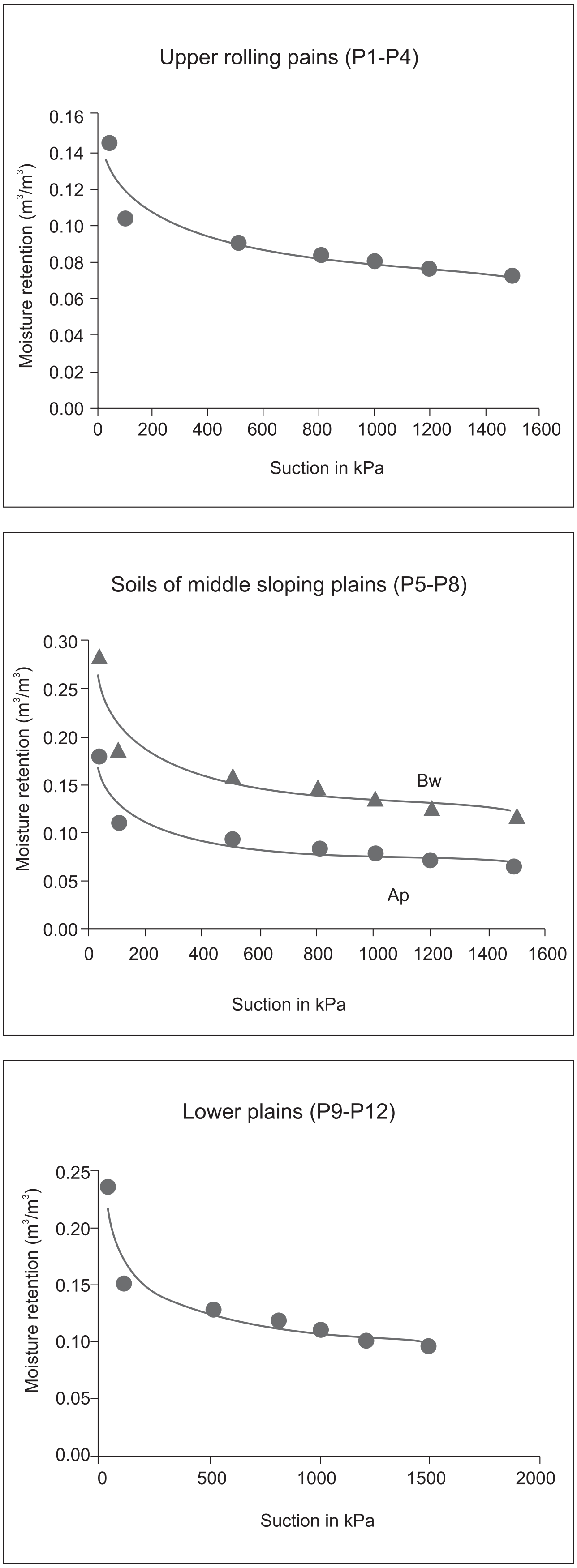

Fig. 5. Moisture release curves of surface and sub-surface layers in three plains

conditions. Critical levels of suction are *field capacity* (33 kPa) and *permanent wilting point* (1500 kPa). *Plant available water* is that which is stored between field capacity and permanent wilting point. The amount of water extracted from soil to the threshold value is often termed, "allowable depletion"; it is generally between 40% and 60% of the plant available water storage capacity of the effective root zone. It is generally accepted that for optimum growth and development of plants the soil water depletion should not be allowed to exceed "allowable depletion". In present investigation moisture retention of soils depleted to about 50 per cent at 100 kPa suction pressure so that irrigation should be delivered to replenish the soil moisture storage at this stage to keep target of maximum economic yield. Slight early irrigation will ensure optimum growth and more profit for the growers in soils of upper rolling plains as compared to lower plains because the soils of elevated area were relatively coarser in texture consequently retains the moisture for shorter period of time. The point at which a decision to irrigate is made will depend on evaluation of the amount of water left in the soil at different depth of the soil profile. For younger plants the top few hundred millimeters irrigation is sufficient and amount of water will be based on what is left in the soil to this soil depth. As the plant get maturity depth of irrigation water should be increased. Because the soil's moisture holding capacity is limited, excess water applications will result in deep percolation and/or runoff losses, this will also ensure water use in more efficient way. Making efficient use of existing water resources through demand management is an economical and environmentally acceptable way to meet growing demand for water.

The optimization of land utilization

Soil erosion resistant crops like pulses or grasses with economically important trees, like; mango, guava and Aonla should be planted in the soils of upper rolling plains (P1-P4). Although, the fertility, coarse fragments, severe erosion excessive slope and low AWC, produce the environment that is not congenial for plantation. However, plantation of deep rooted fruit trees could be possible by digging the pit deep up to the rock. The excavated material should be mixed with the good soils along with proper fertilizing and manuring. The watering of trees should be done from time-to-time till their establishment. Plantation must be done at the time of onset of monsoon so that they can easily be established during the rainy season. These should be given proper protection from the grazing animals. The grasses should be planted in and around rolling topography to check the onslaught of erosion. After keeping it protected, for some years, the landscape will be in a position to produce fodder and fruits for the area and also the major constraint, erosion may come closer to the rate of soil formation. This will definitely help in initiating of pedogenetic development in soils situated on higher elevations. Once fruit crops continue to exist for a period of 10-15 years there would be possibility to generate suitable environment in soil system. In order to meet out the dietary need and food habit of the people, sorghum, Bajra and pulses depending on the onset of monsoon are recommended to grow in the soils of middle sloping plains (P5-P8) during Kharif season, whereas during Rabi, this should be cultivated for wheat alone or wheat and gram in combination. Maize can also be grown in middle sloping plains of the river system. After the harvest of maize, either mustard or gram alone or in combination may be grown in the interspaces. This will definitely help to meet out the partial demand of oil and pluses for the time being and help to reduce soil losses. Later on the planted trees will be ready for the fodder, fruit and timber. Groundnut, pigeon pea in Kharif, wheat, mustard and gram combination during Rabi, along with the trees of mango, guava, papaya, citrus and Aonla may be cultivated in the lower plains (P9-P12) for optimizing land use. The soils of lower plains may be grown for exclusive bajra or maize during Kharif while wheat or barley may be taken in Rabi, depending upon the water available for irrigation to protect the crop from severe water stresses. However, the trees of guava, mango and Aonla may be planted on the ridges or the boundary of the fields. These soils require careful application of soil water conservation techniques to restrict the losses through erosion and to maintain soil fertility for longer duration.

REFERENCES

Balpande, H.S., Challa, O. and Prasad, J. 2007. Characterization and classification of grape-growing soils of Nasik district, Maharashtra. *Journal of Indian Society of Soil Science* 55: 80-83.

Bridges, E. M. 1979. *World Soils.* 2nd Edition, Cambridge University press, Cambridge, pp 91-100.

Coughlan, K. J; McGarry, D. and Smith, G. D. 1986. The physical and mechanical characterization of Vertisols. In First Regional Seminar on Management of Vertisols under Semi-arid condition. IBSRAM

Proc. No.6 Nairobi, Kenya, 89-106.

Diwakar, D.P.S. and Singh, R.N. 1992. Tal soils of Bihar III. Aggregation and water retention capacity. *Journal of Indian Society of Soil Science* 40: 667-673.

Gardner, E.A; Shaw, R. J., Smith, G. D. and Coughlan, K. J. 1984. Plant available water capacity: concept, measurement, prediction. In *Properties and Utilization of Cracking Clay Soils.* (J.W. McGarity, E. H. Hoult and H. B. Co. Ed.), University of New England, Armidale, 164-175.

Jackson, M.L. 1973. *Soil Chemical Analysis.* Prentice Hall of India Private Ltd. New- Delhi.

Khan, G.S. and Afzal, T. 1993. Hydaulic characteristics of some important soil series of Pakistan. *Soils Fertil.* 56: 32.

Maji, A.K., Obi Reddy, G.P., Thayalan, S. and Walke, N.J. 2005. Characteristics and classification of landforms and soils over basaltic terrain in sub-humid tropics of central India. *Journal of Indian Society of Soil Science* 53: 154-162.

Massoud, I.F. 1975. Some physical properties of highly calcareous soils and related management practices. In: *Calcareous Soils*, pp 75-94. Water resource and development service, Land Water Development Division, FAO, Rome.

Nagar, R.P., Gupta, P.K. Karkansi, P.T., Sharma, S.P. and Saxena, S. 1995. Soil water characteristics of different soil series in chambal command area of Rajasthan. *Journal of Indian Society of Soil Science* 44: 329-334.

Nikam, M.S., Prasad, J., Patil, N.G. and Srivastava, R. 2006. Moisture retention characteristics of forest, grassland and cultivated non-vertic shallow soils in Nagpur district of central India. *Journal of Indian Society of Soil Science* 54: 240-242.

Page, A. L., Miller, R.H. and Keeney, D. R. 1982. Soil Chemical Analysis, Part-2 (Ed.) No. 9, Agronomy Series ASA- SSSA Publisher, Madison, Wisconsin, USA.

Pal, D. K. 2003. Significance of clays, clay and other minerals in the formation and management of Indian soils, *Journal of Indian Society of Soil Science* 51: 338-364.

Peterson, G.W., Cunnigham, R.L. and Matelski, R.P. 1968. Moisture characteristics of Pennsylvania soils. I- moisture retention as related to soil texture. *Soil Science Society of American Proceedings* 32: 271-275.

Singh, S.K. 1999. Studies on variability in soil properties as related to genesis in Vertisols of Rajasthan, Ph.D. thesis submitted to RAU-Bikaner.

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Use of plastic mulch for enhancing water productivity of off-season vegetables in terraced land in Chamoli district of Uttarakhand, India

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ABSTRACT

A field experiment was carried out with farmers' participation to investigate the performance of black plastic mulch on earliness, yield, water productivity and production economics of summer squash, tomato and capsicum under mid-high hills of district Chamoli (Uttarakhand) during the years 2009 and 2010. The mulch advanced the harvesting time by 10 days in summer squash and by two weeks in tomato and capsicum. Besides extending the harvest duration of crop, the black plastic mulch increased the total yield by the order of 33.34 percent to 47.60 percent in respective crops. In vegetable cultivation, the mulch not only reduced 30-40 percent of crop water requirement but also doubled the water use efficiency (WUE). The economic analysis of the study revealed that the maximum cost of cultivation was observed with summer squash while the highest gross as well as net returns were in tomato followed by capsicum and summer squash under both mulch (Demonstration plot) and without mulch (farmer's practice). The maximum gain indicated as IBCR was in summer squash cultivation (above 04) while tomato and capsicum recorded its values in between 3 and 4 during both the years of investigation.

Key words: Economics, Plastic mulch, Productivity, Water use efficiency, Vegetables

INTRODUCTION

The climatic conditions of Uttarakhand are conducive for year-round production of vegetables, many of which are seasonal in other parts of the northern India. Off-season vegetables have high demand, fetch relatively higher returns per unit area and time for the producer and have higher market growth prospects. Though there has been a considerable increase in the area under vegetable cultivation in the state in the recent past, nevertheless, various biotic (diseases and insect-pest) and abiotic (low temperature, drought, rain-fed conditions with high or erratic rainfall etc.) stresses adversely affect the productivity as well as quality of the produce (Singh *et al.*, 2011). Solution to this problem is being offered by the plastic mulch technology, which can partially combat the adverse natural factors of production. The advantages of using plastic mulches for the production of high value vegetable crops have been recognized since the Early 1960s (Emmert, 1956). Amongst the plastic films, Black plastic

is the most popular and widely used as mulch because it retards weed growth and raises the soil temperature to feavourable extent in the winters (Singh *et al.*, 2005). Krishi Vigyan Kendra, Gwaldam (Chamoli) was the pioneer to do extensive research work and develop package of practices (POPs) for growing high value off-season vegetable crops under plastic mulch in water scarce situation of Uttarakhand hills. Taking a step ahead Krishi Vigyan Kendra, Chamoli conducted number of demonstrations for commercial cultivation of off-season vegetables under rainfed situation of Uttarakhand hills using plastic mulch technology.

MATERIALS AND METHODS

The experiments/demonstrations were conducted in farmers' participatory mode. Amongst the villages selected, each had one crop

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i.e. summer squash at Gwaldam, tomato at Malbajwar and capsicum at Talwari. Summer squash and tomato were transplanted at an area of 1 ha at selected farmers' fields, while for capsicum it was 0.5 ha. The demonstration plots elevation varied from 1600 (Malbajwar- 1600 metres amsl; Talwari- 1650 metres amsl) to 1950 meters amsl (Gwaldam) in *Pindar* valley of district Chamoli (Uttarakhand). The demonstrations were laid out in two treatments i.e. 1- cultivation under black plastic mulch (Demonstration plot- DP) and 2- cultivation without mulch (Farmers' practice- FP) for two consecutive years *viz*., Spring-summer season of 2009 and 2010. The hybrid seeds of summer squash (Ducato), tomato (Avtar) and capsicum (Tanvi) were supplied to the selected farmers for nursery raising. Recommended cultivation practices were followed for both the treatments. Raised beds were prepared and one day before transplanting, all the beds under DP were covered by 25 µ thick UV stabilized black plastic mulch sheet. Spacing of 100 cm x 75 cm, 60 cm x 45 cm and 50 cm x 50 cm were kept for summer squash, tomato and capsicum, respectively, during both the years of demonstrations. Small holes at appropriate distances were made for transplanting the respective crops. The summer squash was transplanted on 7th March, tomato on 10th March and capsicum on 19th March during both the years. All three crops were planted under open field condition (with or without mulch as per treatment) after the possibility of frost occurrence was over. Observations were recorded for days to first harvest, marketable fruit yield (q/ha), harvest duration during both the years of the experimentation. Water use efficiency and water productivity were computed by following the standard procedures (Michael, 2009).

In economic analysis, cost of cultivation includes the cost of all inputs purchased by the farmers/ supplied by the KVK (in demonstration plots), wages of labour (including family labour) since seed sowing to final picking/harvesting and expenditure on transportation and marketing. The gross and net returns were worked out accordingly by taking the average sale price of respective crop during the periods of harvesting which were as Rs. 500.00 q^{-1} for summer squash, 800.00 q^{-1} for tomato and 1400.00 q^{-1} for capsicum and cost of cultivation of respective crops into consideration. Additional cost in demonstration plots (DP) was calculated by deducting the expenditure incurred on weeding, hoeing and extra pesticide sprays in unmulched plots (FP) from the expenditure on plastic mulch purchase, its installation as well as the cost involved in harvesting and transportation of additional yields under mulch. Benefit-cost ratio (BCR) was also calculated and economic viability of the technology was judged by working out incremental benefit-cost ratio (IBCR), which was calculated as a ratio of additional returns and corresponding additional costs incurred.

RESULTS AND DISCUSSIONS

Earliness and yield

Black plastic mulch positively influenced the plant growth as the harvesting was advanced by 11 and 10 days in summer squash during the first and the second years of the study compared to the unmulched plots (farmers' practice), whereas, in tomato and capsicum the period was approximately two weeks earlier during both the years of demonstrations. Higher marketable fruit yields under mulch were also recorded and these were 565.50 and 585.25 q ha^{-1} in demonstration plots (DP) against 391.60 and 396.50 q ha^{-1} (FP) in summer squash, 410.70 and 398.70 q ha^{-1}in DP against 308.00 and 305.40 q ha^{-1} in FP in tomato as well as 204.60 and 225.75 q ha^{-1} in DP against 145.35 and 159.00 q ha^{-1} in FP in capsicum during the first and the second years of demonstrations, respectively (Table 1). Higher soil temperature under black plastic improved the plant microclimate leading to early growth and development which resulted in early harvests (Abdul Baki, 1995). Further mulch films have a positive effect on plant growth and yields as they are nearly impervious to carbon di-oxide and hence there is also a possibility of creation of 'chimney effect', resulting in abundant CO_2 available for photosynthesis to the plants as reported by Singh *et al.*, 2005. Better plant growth and early fruiting by mulching have also been observed by White (2004) in summer squash and Singh *et al.* (2005) in tomato. The yield increases due to mulch effect were 44.41% and 47.60% in summer squash, 33.34% and 30.55% in tomato and 40.76% and 41.98% in capsicum during first and second years of demonstrations respectively. This attractive performance of demonstration fields owed its success to the soil and moisture conservation, suppression of weeds, improved nutrient availability and prevention against drastic variation in soil temperature under plastic mulch. Reduction in labour requirement and drudgery is the additional advantage of mulch in stress prone

Table 1. Effect of black plastic mulch on earliness and yield of summer squash, tomato and capsicum

Crop/ variety	Season / year	Area (ha)	No. of farmers	Days to first harvest		Marketable fruit yield (q ha^{-1})		% increase over FP
				DP	FP	DP	FP	
Summer squash								
Ducato	2009	1.0	18	41	52	565.50	391.60	44.41
Ducato	2010	1.0	16	40	50	585.25	396.50	47.60
Tomato								
Avtar	2009	1.0	15	68	83	410.70	308.00	33.34
Avtar	2010	1.0	18	71	85	398.70	305.40	30.55
Capsicum								
Tanvi	2009	0.5	11	63	77	204.60	145.35	40.76
Tanvi	2010	0.5	08	62	75	225.75	159.00	41.98

hilly conditions of Uttarakhand as crop raising is labour intensive due to lack of mechanization in hill agriculture (Singh and Singh, 2009). Black plastic mulch has an additional advantage that the absence of light within it did not allow photosynthesis under the film and therefore weed growth was depressed (Bhatt *et al.*, 2011). Highest absorption of photosynthetic flux (PPF 400-700 nm) and increase in soil temperature was reported by the use of black plastic mulch (Hatt *et al.*, 1994), while the greatest reflection of PPF and blue light was observed in white plastic mulch. The greater availability of PPF enhances the photosynthetic activity of the plant resulting in increase in yield and quality of produce. Harvest duration was also reported to be higher in demonstration plots (DP) as compared to farmers' practice (FP) in all the three crops under investigation and the harvest durations were increased approximately by 3 weeks in summer squash and 3-4 weeks in tomato and capsicum (Table 2). This may be attributed to the fact that mulch film provides a better environment for root growth and conserves adequate moisture for the plants (Singh and Singh, 2010) which helps in maintaining proper cell turgidity and higher meristematic activity eventually leading to more foliage development and consequently better plant growth with less stress to plants.

Water use efficiency and water productivity

The data presented in Table 2 reveal that the actual water applied was lower in mulch treatments (DP) and water requirement was almost 30-40% less than unmulched treatments (FP) of all the three crops. The water saving (%) was recorded highest in tomato (38.51 and 40.40) followed by summer squash (32.59 and 31.48) and capsicum (27.82 and 30.12) during first and second years respectively. It is probably due to the reduced wet evaporating surface and greater foliage spread of all three crops which greatly reduced the moisture

Table 2. Effect of black plastic mulch on crop duration and water use efficiency in summer squash, tomato and capsicum

Crop	Year	Dates of sowing	Dates of transplanting	Dates of final harvesting		Harvest duration (days)		Actual total depth of water applied (cm)		Water conserved over FP (%)	Water use efficiency (q ha^{-1} cm^{-1})		Water productivity (lit kg^{-1})	
				DP	FP	DP	FP	DP	FP		DP	FP	DP	FP
Summer squash														
	2009	01.02.09	07.03.09	07.07.10	01.07.10	80	59	21.1	31.3	32.59	26.80	12.51	37.31	79.94
	2010	01.02.10	07.03.10	11.07.09	04.07.09	85	67	22.2	32.4	31.48	26.36	12.24	37.94	81.70
Tomato														
	2009	01.02.09	10.03.09	12.08.09	04.08.09	87	62	28.9	47.0	38.51	14.21	6.55	70.37	152.67
	2010	01.02.10	10.03.10	02.08.10	21.07.10	74	48	26.7	44.8	40.40	14.93	6.82	66.98	146.63
Capsicum														
	2009	01.02.09	19.03.10	08.08.09	22.07.09	80	50	26.2	36.3	27.82	7.81	4.00	128.04	250.00
	2010	01.02.10	19.03.10	28.08.10	15.08.10	97	70	27.6	39.5	30.12	8.18	4.03	122.25	248.14

losses from the soil surface. From the data, it is evident that the use of black plastic mulch has enhanced the water use efficiency (WUE) and water productivity (WP) to a great extent of all the three crops under investigation in DP as compared to bare field cultivation (FP). The black plastic treatment not only reduced the water requirement but also increased yield significantly thus WUE was almost doubled or more in all the three crops during both the years of investigation. Overall water requirement was highest for tomato followed by capsicum and summer squash crops while the WUE in summer squash was highest followed by tomato and capsicum irrespective of the treatments. Summer squash, due to its short duration and precocious nature with very high yield potential required less water for its cultivation with very high WUE. The increased WUE through plastic mulching were also reported by Zotaralli *et al.* (2008) in summer squash and Mukherjee *et al.* (2010) and Agrawal *et al.* (2010) in tomato. Water productivity (WP) also enhanced under DP as less water is required to produce per kg of summer squash, tomato and capsicum. The data as presented in Table 2 suggested that 215, 218 and 199 % (after pooling both years' data) more water is required to produce same yield, respectively in summer squash, tomato and capsicum. The similar result with increased WP with protected condition was also reported by Madile *et al.* (2012) in capsicum.

Economic analysis

The economic analyses of all three vegetables cultivated under black plastic mulch were carried out with the objective to investigate the economic feasibility of this technology (Table 3). Cost of cultivation, gross return, net return and benefit-cost ratio (BCR) for all the three crops were calculated under both the growing environments i.e. under mulch (DP) and without mulch (FP). Among all three important off-season vegetables of Uttarakhand hills the cost of cultivation of summer squash recorded highest i.e. 119250.00/ ha for DP and 97650.00 for FP followed by capsicum (110700.00/ha for DP and 85700.00 for FP) and tomato (106500.00/ha for DP and 82300.00/ha for FP). However, highest gross and net returns were observed in tomato and it was also evident with the benefit-cost ratio (BCR). Maximum BCRs were recorded with tomato (3.09 and 2.99 for DP and 2.99 and 2.97 for FP in first and second years respectively) followed by capsicum (2.59 and 2.86 for DP and 2.37 and 2.60 for FP in first and second years respectively) and summer squash (2.37 and 2.45 for DP and 2.01 and 2.03 for FP in first and second years respectively). The additional costs involved in summer squash, tomato and capsicum cultivated under mulch (DP) were 21600.00, 24200.00 and 25000.00 per crop cycle respectively. Additional returns and incremental benefit-cost ratio (IBCR) were also calculated for the technological intervention (mulch). IBCR values clearly indicated a net gain of 4.03 and 4.37 in summer squash, 3.40 and 3.25 in tomato and 3.32 and 3.74 in capsicum during first and second years respectively against the per rupee invested for the adoption of plastic mulch technology. As a whole, the economic analysis points out that the use of this technology in

Table 3. Economic analysis of the use of black plastic mulch in summer squash, tomato and capsicum production

Crop	Year	Cost of cultivation (Rs.)		Gross return (Rs.)		Net return (Rs.)		BCR (DP)	BCR (FP)	Additional yield (q ha^{-1})	Additional cost (Rs.)	Additional return (Rs.)	IBCR
		DP	FP	DP	FP	DP	FP						
Summer squash													
	2009	119250	97650	282750	195800	163500	98150	2.37	2.01	173.90	21600	86950	4.03
	2010	119250	97650	292625	198250	173375	100600	2.45	2.03	188.75	21600	94375	4.37
Tomato													
	2009	106500	82300	328560	246400	222060	164100	3.09	2.99	102.70	24200	82160	3.40
	2010	106500	82300	318960	244320	212460	162020	2.99	2.97	93.30	24200	74640	3.08
Capsicum													
	2009	110700	85700	286440	203490	175740	117790	2.59	2.37	59.25	25000	82950	3.31
	2010	110700	85700	316050	222600	205350	136900	2.86	2.60	66.75	25000	93450	3.74

off-season cultivation of important vegetable crops would substantially increase the overall income as well as improve livelihood of the resource poor farming community of the Uttarakhand hills.

CONCLUSIONS

The study indicates that in hilly terraces, black plastic mulch is able in conserving the scarce water resources besides improving the productivity, net gain and socio-economic status. Sincere extension efforts are required to educate the farmers for adopting this technology. Initial cost on purchasing and installation of plastic mulches would be the hindrance in large scale adoption of this technology by the farming community. To overcome this barrier, the Government of India has provided subsidy @ 50% under National Horticulture Mission (NHM) and Horticulture Mission for North East and Himalayan States (HMNEH) for adopting this technology. Finally from the above investigation, it can be concluded that by the adoption of this technology by more number of farmers, the off-season vegetable cultivation may get wide spread in area resulting in higher and quality production of the vegetables in the state and providing premium remuneration to the hill farmers.

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REFERENCES

Abdul Baki A A, Spenie C Z and Hoover R. 1992. Black polyethylene mulch doubled yield of fresh market field tomatoes. *HortSci.* 27:787-789.

Agrawal Narendra, Panigrahi H K, Sharma D and Agrawal R. 2010. Effect of different colour mulches on the growth and yield of tomato under Chattisgarh region. *Ind. J. Hort.* 67:295-300.

Bhatt Lalit, Rana Renu, Uniyal S P, Singh V P. 2011. Effect of mulch materials on vegetative characters, yield and economics of summer squash (*Cucurbita pepo*) under rainfed mid-hill condition of Uttarakhand. *Veg. Sci.* 38:165-168.

Emmert E M. 1956. Black polythene for mulching vegetables. *J. Amer. Soc. Hort. Sci.* 69(4): 464-469.

Hatt H A, McMahon M J, Linvill D E and Decoteau D R. 1994. Influence of spectral qualities and resulting soil temperatures of mulch films on bell pepper growth and production. *Plasticulture*, 101:13-22.

Madile A K, Singh P K, Sharma H C, Singh R P and Joshi Ganga. 2012. Tensiometer based drip irrigation scheduling for enhancing water productivity of capsicum (*Capsicum annum* L.) under polyhouse. *Ind. J. Soil. Cons.* 40:41-45.

Michael A M. 2009. Irrigation- theory and practices (2nd ed.). Vikas publishing house, New Delhi p. 768.

Mukherjee A, Kundu M and Sarkar S. 2010. Role of irrigation and mulch on yield, evapotranspiration rate and water use pattern of tomato (*Lycopersicon esculentum* L.). *Agril. Water Manag.* 98:182-189.

Singh Balraj, Kumar Mahesh and Singh G C. 2005. Effect of different plastic mulches on growth and yield of winter tomato. *Ind. J. Hort.* 62:200-202.

Singh V P and Singh P K. 2009. Effect of coloured poly mulches on growth and yield of summer squash under mid-hill condition of Uttarakhand. In Proc. 4th Uttarakhand State Science and Technology Congress, Pantnagar, November 10-12 pp. 20.

Singh V P and Singh P K. 2010. Enhancement of earliness and productivity in summer squash and tomato using plastic mulches through front line demonstrations in mid-hills of Uttarakhnad. In Proc. of National Symposium on Conservation Horticulture-2010, March 21-23, Dehradun pp. 302.

Singh V P, Singh P K, Rai Ratna and Bhatt Lalit. 2011. Enhancing earliness and productivity in summer squash through black polymulch in Uttarakhand hills. *Prog. Hort.* 43:163-165.

White J M. 2004. Summer squash yield and fruit size when grown on eight mulch colors in central Florida. Proc. Fla. State Hort. Soc. 117:56-58.

Zotarelli Lincoln, Dukes Michael D, Scholberg Johannes M, Hanselman Travis, Femminella Kristen Le and Munoz-carpena Rafael. 2008. Nitrogen and water use efficiency of zucchini squash for a plastic mulch bed system on a sandy soil. *Scientia Hort.* 116:8-16.

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Effect of sequential tillage practices and N levels on soil health and root parameters in maize (*Zea mays*)–wheat (*Tritium aestivum*) cropping system

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ABSTRACT

Field experiments were conducted at New Delhi during the *kharif* and *rabi* season of 2009-10 and 2010-11 with maize (*Zea mays* L.)–wheat (*Triticum aestivum* L. emend.) cropping system to evaluate the effect of different sequential tillage practices and N levels on soil health and root growth parameters of maize–wheat cropping system. The results revealed that most of the soil health parameters, except microbial and enzymatic activities were not influenced significantly due to different sequential tillage practices. However, soil organic carbon (SOC) and available NPK contents were maximum with ZT-ZT sequence, while minimum values were recorded under CT-CT sequence. Similarly, microbial biomass carbon (MBC), dehydrogenase activity and FDA hydrolysis activities were maximum under ZT-ZT, which were significantly higher than CT-CT sequence. At 0-10 cm soil depth, the mean weight diameter (MWD) and grand mean diameter (GMD) were was 54.20% and 9.12 % higher under ZT-ZT than CT-CT respectively. The maximum percentage of macro aggregates was recorded with ZT-ZT (24.40 %), while minimum with CT-CT (16.80 %) at the top 0-10 cm depth of soil layer. However, reverse was true for micro aggregates. Skipping CT with ZT practices exhibited higher values of MWD, GMD and macro aggregates than continuous CT-CT sequence. In contrast to this, the hydraulic conductivity and infiltration rates were recorded marginally higher with CT-CT sequence. Most of the root growth parameters of both the crops were found statically similar under all the tillage sequencers, except average root volume density (RVD) of maize which was recorded significantly higher under ZT-ZT sequence. However, root growth parameters of both maize and wheat were responded significantly to different levels of N, while most of soil physical, chemical and biological parameters did not differ significantly with different levels of N. The soil available N was maximum (156.7 kg N/ha) at 180 kg N/ha, which was significantly higher than at 0 and 60 kg N/ha, whereas, the maximum values of soil MBC was recorded at 60 kg N/ha, which was significantly higher than 120 and 180 kg N/ha. The average root length density and RVD were influenced significantly up to 120 kg N/ha, while average root surface area and average root diameter were influenced significantly up to 60 kg N/ha of both the crops.

Key words: Maize–wheat cropping system, Nitrogen levels, Root growth parameters, Soil physical chemical and biological parameters, Sequential tillage

INTRODUCTION

Appropriate tillage and fertilizer management practices need to be developed for sustainable crop production without jeopardizing the quality of soil and the environment. A proper tillage can alleviate the soil related constraints while improper tillage may leads to degradative processes. Intensive tillage and current agricultural practices results in a decrease in soil organic matter leading to soil degradation, loss of soil biological fertility and biodiversity (Bahrani *et al.*, 2007). Sustaining soil health is of primary importance in terms of cycling plant nutrients and improving soils physico-chemical and biological properties. Lal (2005) calculated that increasing soil organic carbon (SOC) by 1 Mg /ha/year can increase food grain production by 32 million Mg/ year in developing countries. Tillage is used for creating better environment for plant growth but the degree varies widely with the type of tillage method. Altering

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the tillage system by sequential tillage practices will influence the soil health, root growth of the crops and weed species composition. The tillage sequence within a crop rotation is often unrecognized as a rotational component but like crop rotations, the sequence may reduce weeds, and other pests if managed properly in annual cropping systems. Soil health (physical, chemical and biological properties) is an important criterion to maintain it under dynamic equilibrium so as to sustain the productivity, improve the resource-use efficiency of maize–wheat cropping system. While there is an abundance of field studies that support the beneficial impact of zero tillage on soil health (Govaerts *et al*., 2007; Behera and Sharma, 2011). Biological activities can be used as practical biological indicators to apply the more appropriate management system for increasing soil sustainability. However, impact of resource conserving technologies on soil microbial health indices under tropical conditions is not well studied. To assure normal plant growth, the soil must be in such conditions that roots have enough air, water and nutrients. Root morphology of any crop is dependent on the soil environment which ultimately governed by the tillage practices. Interactions between root systems and rhizobacteria affect crop health, yield and soil quality. Release of exudates by plants activate and sustain specific rhizobacterial communities that enhance nutrient cycling, nitrogen fixing, biocontrol of plant pathogens, plant disease resistance and plant growth stimulation (Sturz and Christie, 2003). Inspite of immense importance, roots seldom receive due attention of the researchers because of underground habitat and inherent difficulty in studying them. The importance of N fertilizers in increasing the crop yields is widely accepted and documented. Long term fertilizer experiments revealed that applications of inorganic fertilizers have favorable effects on soil physico-chemical and biological properties up to some extent (Haynes and Naidu, 1998). This is mainly attributed to the sufficiency of nutrients provided by inorganic fertilizers, thereby increasing the above ground and root biomass and hence organic matter (Rassol *et al.*, 2007). Thus, favourable soil physico-chemical and biological properties are important in improving soil fertility, agronomic productivity and resource use efficiency. Much works were carried out on continuous zero tillage, for more than decades there is paucity of information in respect to sequential tillage impacts on changes in soil health and root growth for the system as a whole. Hence, the present investigation was undertaken to study the effect of sequential tillage practices and N levels on soil health and root growth parameters in maize (*Zea mays*)–wheat (*Tritium aestivum*) cropping system.

MATERIALS AND METHODS

Experimental site, soil and weather

Field experiments were conducted on a fixed site during rainy season (June to October) and winter season (November to April) of 2009-10 and 2010-11 at the research farm of Indian Agricultural Research Institute, New Delhi (28.4^o N latitude, 77.1^o E longitude and 228.6 m above mean sea level). The mean annual rainfall of Delhi is 672 mm and more than 80% generally occurs during the monsoon season (July-September) with mean annual evaporation 850 mm. The soil at site was sandy loam with bulk density of 1.57 Mg/m^3, field capacity 17.48 % (w/w) and infiltration rate 1.26 cm/hr. It had 0.37 % organic carbon, 147.6 kg $KMnO_4$ oxidizable N/ha, 11.8 kg 0.5 N $NaHCO_3$ extractable P/ha, 235.1 kg 1.0 N NH_4OAc exchangeable K/ha, 7.5 pH and 0.31 dS/m EC at the start of the experiment.

Experimental detail and crop culture

The experiment was conducted in split plot design with three replications in a fixed layout with plot size of 17.5 m^2 for both maize and wheat crops. All plots received the same treatment throughout the period of study. There were four main plot treatments comprising of sequential tillage practices: conventional tillage (CT) in maize followed by CT in wheat (CT–CT); CT in maize followed by zero tillage (ZT) in wheat (CT–ZT); ZT–CT and; ZT–ZT, while subplot treatments consisted of four nitrogen levels, viz. 0, 60, 120 and 180 kg/ha.

The CT consisted of two pass of a disc harrow, followed by two pass of cultivator with planking in the last pass. The ZT consisted of no-tillage with minimum soil disturbance and one pass of ZT seed drill for sowing of crop. The maize crop was established under flat planting technique of crop establishment at a spacing of 67.5 cm from row to row and 20 cm from plant to plant by dibbling the seeds (20 kg/ha). The wheat crop was also sown under flat planting at a spacing of 18 cm from row to row with 100 kg seed/ha. Before sowing, weeds were controlled using tank mix paraquat + glyphosate (each 0.5 kg *a.i.*/ha) in ZT practices. In maize, atrazine (50 WP @ 1.kg *a.i* /ha) was applied as preemergence to control weeds. In wheat, Tank mix solution of isoproturon (75 WP at 1 kg *a.i.*/ha) and 2,4-D sodium salt (80 WP at 0.5 kg *a.i.*/ha) was applied to control grassy as well as broad leaf weeds after 35 DAS. Full dose of P (26.2 kg /ha) and K (33.3 kg/ ha) applied at the time of sowing in both the crops. Whereas, N was applied in three equal splits (at sowing, knee-high and tasseling stages) to maize and in two equal splits (one at sowing and other after first irrigation) to wheat as per the treatments.

Observations and statistical analysis

Soil physical and chemical parameters were recorded at end of the research experiments, while soil biological parameters were recorded at 90 DAS (peak flowering stage) of last wheat crop.

Physical properties of soil such as bulk density, hydraulic conductivity, infiltration rate, soil aggregation and soil moisture were calculated by adopting the following methodologies. Soil bulk density of surface (0-15 cm) and sub-surface (15-30 cm) soil was determined by the core sampler method from three randomly chosen areas of each plot. The core sampler method was followed for determining the soil bulk density. Hydraulic conductivity was estimated by using the formula K =QL/HAT where, Q is the quantity of water collected, L is the length of sample (cm), H is the loss in head (cm). Infiltration rate is measured using double ring infiltrometer by recording the change in the water level in cylinder and it was expressed as mm/hr**.** Soil aggregation stability was measured by adopting wet sieving techniques. Soil samples collected from individual plots were separated for content of organic carbon by wet digestion method, available nitrogen by alkaline $KMnO_4$ method, available phosphorous by 0.5 M sodium bicarbonate extraction method and available potassium by Flame photometry method. Microbial activity in terms of fluoresein diacetate (FDA) hydrolysis in soil was measured by procedure described by Green *et al*. (2006). The procedure given by Casida *et al*. (1964) was used for estimation of dehydrogenase activity. Microbial biomass carbon in soil samples was estimated by the method described by Nunan *et al*. (1998). Root samples were taken in second year only at tasseling stage in maize and grain filling stage in wheat by adopting standard procedure (Aggarwal and Sharma, 2002) and data on different root parameters were obtained by image analysis of root samples using the WinRHIZO™ software.

Analysis of variance (ANOVA) was used to determine the effect of each treatment. When F ratio was significant, a multiple mean comparison was performed using Fisher's Least Significant Difference Test (0.05 probability level). The data were analyzed by statistical package MSTAT-C software.

RESULTS AND DISCUSSIONS

Soil physical parameters

Bulk density

In maize–wheat cropping system the bulk density (BD) was not influenced significantly due to different sequential tillage practices in both surface (0-15 cm) and sub surface (15-30 cm) soil layers. However, the maximum BD was observed under ZT-ZT with 1.625 and 1.638 g/cm^3 at 0-15 and 15-30 cm, soil depths, respectively, while minimum was BD recorded with CT-CT sequence (Table 1). It was also observed that skipping of zero tillage practices either in *kharif* or in *rabi* season, resulted marginally lower BD than continuous zero tillage (ZT-ZT) practices at both the soil depths. The BD was increased with increased in the soil depth; more BD was recorded in lower layers of the soil profile than upper layers under all the treatments. The higher value of BD under ZT-ZT sequence with surface and sub-surface layer may be due to non-disturbance of the soil matrix for almost two years in the sequence, which may perhaps, resulted in less total porosity compared to tilled plots (Bhattacharyya *et al*., 2008). Similarly, Ram *et al.* (2010) also have reported higher BD values under continuous ZT practices than CT practice in maize–wheat cropping system from Punjab, India. Scientists hypothesized that continued use of reduced, shallow and zero-tillage would require a shift to short-term CT to correct soil problems. However, Logsdon and Karlen (2004) showed that BD is not a useful indicator and confirm that farmers need not worry about increased compaction when changing from CT to NT on deep loess soils in USA. The Soil BD did not influence significantly due to different levels of N in both the soil layers. However, marginally lower BD values were recorded at higher levels of N, particularly in upper soil surface.

Hydraulic conductivity

The sequential tillage practices did not influence hydraulic conductivity (HC) significantly at the end of the two year maize–wheat cropping system this was probably due to the short duration of the study (Table 1). Buschiazzo *et al*. (1998) also have observed that a period of 2-3 years was not enough for tillage to affect hydraulic conductivity of sandy loam and other soils in Argentinean Pampas. However, considerably higher values of hydraulic conductivity were observed under CT-CT (1.091 and 0.934 cm/hr) in both the soil layers, respectively, The lower HC in ZT involving sequential tillage sequences was might be due to higher BD and compaction in surface as well as sub surface layers which restrict the water flow in the soil. The HC was non-significant with different levels of N, however it was recorded marginally higher at higher levels of N, and this was might be due to greater root system in N fertilized plots. Further, decomposing roots of previous crops might have resulted in the channels which act as macrospores, thereby increasing the saturated HC Rasool *et al.* (2007) were also reported higher HC in fertilized plots ($N_{120}P_{30}K_{30}$) than control (no external sources of nutrients were applied).

Infiltration rate

The data on infiltration rate have been presented in Table 1, revealed that infiltration rate was not influenced significantly due to different sequential tillage practices. However, CT-CT treatment recorded maximum infiltration rate (12.14 mm/hr) which was 8.78 % higher than the infiltration rate (11.16 mm/hr) recorded in ZT-ZT. Moreover, skipping of zero tillage either in *kharif* (CT-ZT) or in *rabi* (ZT-CT) improved the infiltration rate by 4.03 and 7.08% over continuous zero tillage practices (ZT-ZT), respectively. Infiltration characteristics of the soil depend on the size distribution, geometry, continuity, and the stability of the pores. Water transmission through the soil profile also depends on the antecedent water content, aggregation and the presence of macro-pore channels. The lower infiltration rate under ZT involving sequential tillage sequences was might be due higher BD and lower aggregation at 20-30 cm soil depth. A lower aggregation results in a reduction of the infiltration and storage capacity

Table 1. Effect of sequential tillage practices and N levels on soil physico-chemical properties in maize–wheat cropping system

Treatment	Bulk density (g/cc)		Hydraulic conductivity (cm/hr)		Infiltration rate (mm/hr)	Electrical conductivity (dS/m)	pH	Organic carbon (%)	Avail-able N (kg/ha)	Avail-able P (kg/ha)	Avail-able K (kg/ha)
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm
Tillage practices											
CT - CT	1.607	1.624	1.091	0.934	12.14	0.314	7.45	0.385	146.6	10.11	229.9
CT - ZT	1.615	1.631	1.061	0.925	11.61	0.315	7.44	0.392	147.7	10.60	230.5
ZT - CT	1.611	1.627	1.070	0.931	11.95	0.314	7.49	0.389	147.5	10.38	231.4
ZT - ZT	1.625	1.638	1.058	0.922	11.16	0.316	7.42	0.407	148.5	10.85	232.5
SEm±	0.008	0.008	0.140	0.034	0.281	0.006	0.056	0.010	2.525	0.446	5.530
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg/ha)											
0	1.623	1.632	1.063	0.907	11.38	0.313	7.44	0.372	130.3	10.93	239.5
60	1.611	1.629	1.049	0.928	11.68	0.314	7.44	0.395	148.9	10.73	233.9
120	1.617	1.631	1.076	0.940	11.86	0.316	7.45	0.404	154.4	10.41	226.1
180	1.607	1.628	1.092	0.938	11.94	0.316	7.45	0.403	156.7	9.86	224.9
SEm±	0.008	0.006	0.057	0.033	0.171	0.006	0.053	0.010	2.508	0.337	4.771
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	7.321	NS	NS

Table 2. Effect of sequential tillage practices on soil aggregates in maize–wheat cropping system

Treatment	Mean weight diameter (MWD) (mm)			Grand mean diameter (GMD)			Percentage of micro aggregate (<0.25 mm)			Percentage of macro aggregate (>0.25 mm)		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Tillage practices												
CT - CT	0.500	0.275	0.208	0.373	0.368	0.363	83.20	78.00	79.56	16.80	22.00	20.44
CT - ZT	0.553	0.281	0.235	0.403	0.375	0.348	77.80	78.16	81.98	22.20	21.84	18.02
ZT - CT	0.545	0.289	0.229	0.399	0.375	0.363	78.74	78.58	80.50	21.26	21.42	19.50
ZT - ZT	0.771	0.314	0.207	0.407	0.363	0.366	75.60	79.30	81.10	24.40	20.70	18.90

of the soil by forming a relatively impermeable soil layer by sealing of pores (Le Bissonais, 2003). Zero tillage without residue retention leads to crust formation, with low aggregation and reduced infiltration (Govaerts, *et al.,* 2007). Infiltration rate was also not influenced significantly due to different levels of N. However, it was increased with increased levels of N from 0 kg N/ha to 180 kg N/ha. Marginally higher values of infiltration rate at higher levels of N might be due to greater root system in N fertilized plots. Further, decomposing roots of previous crops might have resulted in the channels which act as macro pores that may facilitate fast entry of water in the soil.

Soil aggregation

Soil aggregation was analysed at the main plot level to determine the wet stability of aggregates, expressed in terms of mean weight diameter (MWD), grand mean diameter (GMD), micro aggregate (< 0.25 mm) and macro aggregate (> 0.25 mm), in relation to sequential tillage practices. In most of the soil depths (0-10, 10-20 and 20-30 cm) the MWD and GMD were found to maximum with continuous zero tillage practices (ZT-ZT), while minimum values of these parameters were recorded under continuous conventional tillage practices (CT-CT) (Table 2). At 0-10 cm soil depth the MWD was recorded 54.20% higher and GMD was 9.12 % higher under ZT-ZT than CT-CT treatment. Skipping zero tillage practices also exhibited higher values of MWD and GMD than CT-CT sequential tillage practices. The MWD and GMD exhibited a decreasing trend from top to bottom of the soil in all the sequential tillage treatments. The maximum percentage of micro aggregate was obtained with CT-CT (83.20 %), while the minimum was obtained with ZT-ZT (75.60 %) at the top 0-10 cm depth of soil layer (Table 2). Whereas, the maximum percentage of macro aggregates was recorded under ZT-ZT (24.40 %), while minimum was recorded with CT-CT (16.80 %) at the top 0-10 cm depth of soil layer. The percentage of macro aggregates exhibited a decreasing trend from top to bottom of the soil in most of the sequential tillage treatments, while reverse trend was observed with percentage of micro aggregate in most of the sequential tillage treatments. Soil structure stability is the ability of aggregates to remain intact when exposed to different stresses. The higher values of MWD and GMD under ZT sequential tillage practices might be due to non-disturbance of the soil with tillage practice. Meena and Behera (2008) also reported higher MWD under ZT practices than CT practices. Madari *et al*. (2005) from Brazil reported that no-tillage with residue cover had higher aggregate stability, higher aggregate size values and total organic carbon in soil than CT. In case of micro and macro-aggregate percentage, ZT protected the soil structure from destructive tillage effects resulting in decreased percentage of micro-aggregate while concurrently improving the percentage of macro-aggregates. The decline in the size of aggregates with CT could be attributed to mechanical disruption of macro-aggregates, which might have exposed SOM previously protected from decomposition (Six *et al.,* 2000). Whalen *et al*. (2003) reported that improvements in aggregation can occur within 2–3 years of establishing conservation practices.

Soil chemical parameters

Electrical conductivity and pH

Both electrical conductivity (EC) and pH were not influenced significantly due to various sequential tillage practices (Table 1). Numerically same values of EC were obtained under all the sequential tillage treatments. However, the maximum value of pH was recorded under ZT-CT (7.49), while minimum was recorded under ZT-ZT (7.42). The non-significant variation in pH might be due to buffering capacity of soil which offered resistant against change in pH. Beri *et al.* (1992) concluded from 10 years of experiment that pH of soil was not influenced due soil management practices even with the residue application. The similar results also reported by Kumar *et al.* (2004). Similarly, EC indirectly depicts the salt concentration of the soil which is the native property of soil may not be influenced by any management techniques within a short period of 1-2 years might be the reason for non-significant values of soil EC. Both parameters were also not influenced significantly due to different levels of N. However, both were increased marginally with each increased levels of N from control to 120 kg N/ha.

Organic carbon

Soil organic carbon (SOC) did not change significantly due different sequential tillage practices as well as N levels (Table 1). However, sequential tillage practices that include ZT either in *kharif* to maize (ZT-CT) or in *rabi* to wheat (CT-ZT) or in both seasons (ZT-ZT) were improved the SOC by 1.04, 1.82 and 5.71% over continuous CT

(CT-CT) practices, respectively. Moreover, skipping of CT practices either in *kharif* or in *rabi* also improved the SOC over CT-CT, but, lower than ZT-ZT sequential tillage practices. Zero tillage resulted in greater accumulation of soil organic matter in surface layers (0–20 cm) than conventional tillage (Govaerts, *et al.,* 2007). Surprisingly, in our study the SOC indicated statistically same contents in ZT and CT. Evidently, the SOC indicated numerically more or less closer with the sequential tillage treatments this may be due breaking and introducing the ZT between *kharif* and *rabi* seasons where soil is virtually not left for development. Similar observation was also made by Obalum and Obi (2010). Bayer *et al.* (2000) concluded that no-tillage minimizes SOM losses and is a promising strategy to maintain or even increase soil C and N stocks. The SOC content was marginally higher at higher levels of N (60, 120 and 180 kg N/ha) than no N receiving treatment, this may be attributed due to the sufficiency of nutrients provided by inorganic fertilizers, thereby increasing the above ground and root biomass and hence organic matter (Rassol *et al.,* 2007). Shah *et al.* (2003) reported that SOC was increased by N inputs, from both fertilizer and by residue application.

Available NPK

At the end of 2 years research study in maize–wheat cropping system the available NPK status in soil was not influenced significantly due to different sequential tillage practices (Table 1). Moreover, the status of these nutrients were not varied much from the initial status (147.6, 11.8 and 235.1 NPK kg/ha). This might be due to the richness in application of uniform RFD of P and K and higher doses of N (120 and 180 kg N/ha) which would have satisfied the requirement of the crop in terms uptake apart from the various forms of losses (volatilisation, runoff and leaching) and lower levels of N (0 and 60 kg N/ha) resulted in fairly the same initial available status. This is in agreement with results of Verhulst *et al*. (2009) which indicated the soil was rich in those nutrients or adequate amounts of fertilizers were applied. However, soil available N was significantly lower at control (0 kg N/ha) than higher levels of N (60, 120 and 180 kg/ha), this was due to N was not applied in control in all the crops leads to more extraction of available N from soil. Available P and K in soil were non-significant with different levels of N in the system which may get replenished from the fixed reserve of fixed sources (Subba Rao *et al*., 1998). However, these (available P and K) were decreased from 0 to 180 kg N/ha, because of less uptake of nutrients at control by the crops results in higher nutrient in soil. Moreover, N was deficient at 0 kg N/ha, which played a limiting factor role; as the sufficiency of N increased, P and K uptake were also increased because of positive interactions between N, P and K; which resulted lower available P and K at higher levels of N. This continuous withdrawal of K by crops without adequate replenishment from external sources might cause K deficiency in the long run (Behera *et al*., 2007).

Soil biological parameters

Soil microbial biomass carbon (MBC), dehydrogenase (DH) activity and fluorescein diacetate (FDA) hydrolysis activity were significantly influenced due to different sequential tillage practices (Table 3). The continuous zero tillage system (ZT-ZT) resulted significantly higher MBC over CT-CT, CT-ZT and ZT-CT by 18.75, 15.47 and 15.60 %, respectively. However, even involving ZT practice in one season, viz. CT-ZT and ZT-CT also resulted marginally higher soil MBC over continuous CT-CT system. Similarly, the maximum DH activity was measured under ZT-ZT (122.8 µg /g soil/24 hr), which was significantly higher than CT-CT and CT-ZT systems, but was remained non-significant with ZT-CT. Likewise, maximum activity of FDA hydrolysis was measured under double zero tillage (ZT-ZT) practices, which was significantly higher than CT-CT and ZT-CT. Adoption of zero tillage practices in the system, viz. CT-ZT and ZT-CT resulted significantly higher activity of FDA over CT-CT. The least activity of FDA hydrolysis was observed under CT-CT, which was significantly lower than rest sequential tillage practices. In this study, increased soil microbial and enzymatic activities with ZT involving sequential tillage systems have showed the consistency with the results of others researchers (Dong *et al.,* 2009). The improvement in soil microbial and enzymatic activities under zero tillage practices might be due to better physico-chemical properties of soil. Furthermore, better soil aggregation helps in maintaining optimal moisture content as well as aeration in the soil. Roldan *et al.* (2003) showed that after 5 years of zero till maize in Mexico, soil wet aggregate stability had increased over CT and it had higher soil enzymes, SOC and MBC. They concluded that no-till is a sustainable technology. Soil FDA hydrolysis is a measurement of the contribution of several enzymes, mainly involved in the decomposition of organic matter in soil. Hence, the higher the values of FDA hydrolysis are a sign of positive soil health and microbial activity.

Among, the different levels of N, application of 60 kg N/ha had the maximum soil MBC, which was significantly higher than at 120 and 180 kg N/ha, but was statistically on par with control. However, the differences were not significant for DH activity and FDA hydrolysis activity at different levels of N. Though, maximum activities were recorded at 60 kg N/ha, while minimum was observed at 180 kg N/ha. The FDA hydrolysis activity were decreased at 120 and 180 kg N/ha over 60kg N/ha by the tune of 6.25 and 7.42%, respectively. The microbial and enzymatic activities were improved at lower levels of N (60 kg N/ha), might be due to small doses of N act as subtract for microbes in soil, resulted in increased microbial activity, while at microbial activity decreased at higher levels of N (120 and 180 kg N/ha), might be due to toxic effect of N fertilizers. Singh *et al.* (2009) have also been reported that 100 and 125% of recommended dose of N (RDN) 120 kg N/ha for maize and wheat crops, as urea significantly decreased the soil MBC over 50 and 75% RDN, the remaining portions were supplied by organic sources of N. The low DH activity in response to higher levels of N may be because of interference of nitrate, which serves as an alternate electron acceptor resulting in reduction of enzyme activity (Casida *et al.*, 1964). Similar, results were also reported by Singh *et al.* (2009).

Root growth study

Data pertaining to effect of sequential tillage practices and N levels on root growth parameters of maize, viz. root length density (RLD), root surface area density (RSD), root diameter (RD) and root volume density (RVD) has been presented in Table 4. All the root growth parameters were similar due to different sequential tillage practices, except RVD. However, the maximum values of RLD (2.22 cm/cm^3) and RSA (1.37 cm^2/cm^3) were recorded under CT-CT, while minimum values (2.03 cm/cm^3 and 1.26 cm^2/cm^3) of these parameters were recorded under ZT-ZT system, respectively. Whereas, the most thickly roots were recorded under ZT-ZT (1.35 mm), while most fine roots were recorded under CT-CT (1.30 mm). Similarly, ZT-ZT system also resulted maximum RVD (4.27×10^{-2} cm^3/cm^3), which was significantly higher (17.63 %) than CT-CT system, but was remained statistically similar with CT-ZT and ZT-CT systems. The minimum RVD was recorded with CT-CT, which was significantly lower than ZT-CT and ZT-ZT treatments. All the root growth parameters were significantly influenced due to different levels of N. In general all the growth characters of root were exhibited tendency to increase with each increased levels of N from 0 to 180 kg/ha, except RD. However, the maximum values of RLD and RVD were recorded at 120 kg N/ha, which were significantly higher than the 0 and 60 kg N/ha, but were remained statistically similar with 180 kg N/ha. Whereas maximum RSD was recorded at 180 kg N/ha (1.53 cm^2/cm^3),

Table 3. Effect sequential tillage practices and N levels on soil biological properties in maize–wheat cropping system

Treatment	Microbial biomass carbon (µg /g soil)	Soil dehydrogenase activity (µg /g soil/ 24 hr)	FDA Hydrolysis (mg fl/g soil/ hr)
Tillage practices			
CT - CT	176.0	106.5	2.24
CT - ZT	181.3	109.0	2.53
ZT - CT	180.8	119.0	2.48
ZT - ZT	209.0	122.8	2.61
SEm±	3.529	3.413	0.034
CD (P=0.05)	12.21	11.8	0.119
Nitrogen levels (kg/ha)			
0	191.5	118.0	2.54
60	200.8	119.0	2.56
120	179.8	110.5	2.40
180	175.0	109.8	2.37
SEm±	4.068	3.752	0.056
CD (P=0.05)	11.90	NS	NS

Table 4. Effect of sequential tillage practices and N levels on root growth parameters of maize and wheat crops at 0-15 cm depth during 2010

Treatment	Maize				Wheat			
	Root length density (cm/cm^3)	Root surface area density (cm^2/cm^3)	Average root diameter (mm)	Root volume density (x 10^{-2} cm^3 /cm^3)	Root length density (cm/cm^3)	Root surface area density (cm^2/cm^3)	Average root diameter (mm)	Root volume density (x 10^{-3} cm^3/cm^3)
Tillage practices								
CT - CT	2.22	1.37	1.30	3.63	1.98	0.42	0.48	3.22
CT - ZT	2.19	1.35	1.32	3.99	1.88	0.36	0.51	3.41
ZT - CT	2.13	1.33	1.34	4.11	1.94	0.40	0.46	3.38
ZT - ZT	2.03	1.26	1.35	4.27	1.71	0.30	0.55	3.43
SEm±	0.103	0.045	0.015	0.105	0.066	0.026	0.020	0.092
CD (P=0.05)	NS	NS	NS	0.362	NS	NS	NS	NS
Nitrogen levels (kg/ha)								
0	1.34	1.14	1.20	3.67	1.53	0.28	0.42	2.98
60	1.94	1.25	1.39	3.83	1.86	0.36	0.54	3.06
120	2.65	1.36	1.36	4.43	2.03	0.40	0.51	3.60
180	2.65	1.53	1.35	4.06	2.09	0.44	0.53	3.81
SEm±	0.089	0.044	0.030	0.141	0.026	0.019	0.016	0.072
CD (P=0.05)	0.261	0.129	0.086	0.412	0.076	0.055	0.047	0.209

which was significantly higher than rest of the N levels. The N level 60 kg/ha resulted maximum RD, which was significantly higher than 0 kg N/ ha, but was remained on par with 120 and 180 kg N/ha. The minimum values of all the root growth parameters were recorded at 0 kg N/ha.

The perusal of data (Table 4) indicated that sequential tillage practices did not influence the root growth parameters of wheat. However, the maximum vales of RLD (1.98 cm/cm^3) and RSA (0.42 cm^2/cm^3) were recorded under CT-CT, while minimum values (1.71 cm/cm^3 and 0.30 cm^2/cm^3) of these parameters were recorded under ZT-ZT system, respectively. Whereas, maximum values of RD (0.55mm) and RVD (3.43 x 10^{-3} cm^3/cm^3) were recorded under ZT-ZT, while minimum RD (0.46 mm) and RVD (3.22 x 10^{-3} cm^3/cm^3) were recorded under ZT-CT and CT-CT system, respectively. Root growth parameters were influenced significantly due to different levels of N. Most of the root growth parameters were increased with each successive levels of N from 0 to 180 kg/ha, except RD. However, the maximum values of RLD, RSA and RVD were recorded at 180 kg N/ha, which were significantly higher than the 0 and 60 kg N/ha, but remained statistically similar with 120 kg N/ha. The N level 60 kg/ha resulted maximum RD, which was significantly higher than 0 kg N/ha, but remained on par with 120 and 180 kg N/ha.

Most of the root parameters of both maize and wheat were similar due to sequential tillage practices. However, RD and RVD were recorded more under ZT involving sequential tillage sequences, while RLD and RSD were recorded higher under CT-CT practices. These results were also similar with the finding of Maurya and Lal (1980). They reported that there was more roots density of maize in surface layer (0-10 cm) with no-tillage than in conventionally ploughed plots. In our study the more thick roots (RD) with ZT treatment corroborated the findings of Chassot and Richner (2002). Meena and Behera (2008) revealed that root growth parameters were significantly influenced due to tillage and residue management practices. The root length was significantly lower in zero tillage than conventional tillage, while root dry weight and root volume were more in zero tillage than conventional tillage. The RLD and RSD were lower in zero tillage due to compaction of soil, which might be restricted the smooth growth of roots into down layers, resulted more thickly and lateral spreading of roots which ultimately increase the RD and RVD in surface layers. A higher soil BD under ZT practices may reduce root length (de Freitas *et al.*, 1999). The higher root growth parameters with increased levels of N might be due to higher doses of N helped in decomposition of roots of previous crops and applied residues which leads to improved physical environment in soil and better root growth. These results are also in agreement with the finding of Mohanty *et al.* (2007). They reported that RLD and RMD (root mass density) were increased significantly from no fertilization (0% NPK) to recommend dose of fertilizers (100% NPK) and maximum at 100% NPK with FYM 4 t/ ha.

The results of the study suggest that sequential tillage practices involving ZT in conjunction with application of 120 kg N/ha may be adopted for sustaining the soil health under maize–wheat cropping system as it favourably influenced the soil environment.

REFERENCES

Aggarwal, P. and Sharma, N.K. 2002. Water uptake and yield of rainfed wheat in relation to tillage and mulch. *Indian Journal of Soil Conservation* **30**(2): 155–160.

Bahrani, M.J., Raufat, M.H. and Ghadiri, H. 2007. Influence of wheat residue management on irrigated corn grain production in a reduced tillage system. *Soil and Tillage Research* **94**: 305-309.

Bayer, C., Mielniczuk, J., Amado, T..J.C., Martin, N.L. and Fernandes, S.V. 2000. Organic matter storage in a sandy loam Acrisol affected by tillage and cropping systems in southern Brazil. *Soil and Tillage Research* **54**: 101–109.

Behera, U.K., Sharma, A.R. and Pandy, H.N. 2007. Sustaining productivity of wheat–soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil* **297**: 185–199.

Behera, U.K. and Sharma, A.R. 2011. Effect of conservation tillage on performance of greengram-mustard-cowpea cropping system. *Journal of Soil and Water Conservation* **10**(3): 233–236.

Beri, V., Sidhu, B.S., Bhat, A.K., Bijenderpal, Singh, B., Beri, B., Chaudhary, M.R., Sidhu, P.S., Pashricha, N.S. and Bajwa, M.S. 1992. Nutrient balance and soil properties as affected by management of crop residue. *Proceedings of the International Symposium on Nutrient Management for sustainable Productivity* **2**: 133–135.

Bhattacharyya, R., Kundu, S., Pandey, S.C., Singh, K.P. and Gupta, H.S. 2008. Tillage and irrigation effects on crop yields and soil properties under the rice–wheat system in the Indian Himalayas. *Agricultural water management* **95**: 993–1002.

Buschiazzo, D.E., Panigatti, J.L. and Unger, P.W. 1998. Tillage effects on soil properties and crop production in the sub-humid and semi-arid Argentinean Pampas. *Soil and Tillage Research* **49**: 105–116.

Casida, L.E.J., Klein, D.A. and Santaro, T. 1964. Soil dehydrogenase activity. *Soil Science* **98**: 371–376.

Chassot, A., and Richner, W. 2002. Root characteristics and phosphorus uptake of maize seedlings in a bilayered soil. *Agronomy Journal* **94**: 114–127.

de Freitas, P.L., R.W. Zobel, and Snyder, V.A. 1999. Corn root growth in soil columns with artificially constructed aggregates. *Crop Science* **39**: 725–730.

Dong, W., Hu, C., Chen, S. And Zhang, Y. 2009. Tillage and residue management effects on soil carbon and CO_2 emission in wheat–corn double-cropping system. *Nutrient Cycling in Agroecosystems* **83**: 27–37.

Govaerts, B., sayre, K.D., Lichter, K., dendooven, L. and Deckers, J. 2007. Influence of permanent raised bed planting and residue management on physical and chemical soil quality in rain fed maize/wheat systems. *Plant and Soil* **291**: 39–54.

Green, V.S., Ctott, D.E. and Diack, M. 2006. Assay of Fluorescein diacetate hydrolytic activity–optimization of soil samples. *Soil Biology and Biochemistry* **38**: 693–701.

Haynes, R.J. and Naidu, R. 1998. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: A review. *Nutrient Cycling in Agroecosystems* **51**: 123–137.

Kumar, S., Pandey, D.S. and Rana, N.S. 2004. Effect of tillage, rice residue and nitrogen management practices on yield of wheat (Triticum aestivum) and chemical properties of soil under rice (Oryza sativa) – wheat system. *Indian Journal of Agronomy* **49**(4): 223–225.

Lal, R. 2005. Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degradation and Development* **17**: 197–209.

Le Bissonnais, Y. 2003. Aggregate breakdown mechanisms and erodibility. In: Lal R (ed) Encyclopaedia of soil science. Marcel Dekker Inc., New York.

Logsdon, S. and Karlen, D.L 2004. Bulk density as a soil indicator during conversion to no-tillage. *Soil and Tillage Research* **78**: 143–149.

Madari, B., Machado, P.L.O.A., Torres, E., de Andrade, A.G. and Valencia, L.I.O. 2005. No tillage and crop rotation effects on soil aggregation and organic carbon in a Rhodic Ferralsol from southern Brazil. *Soil and Tillage Research* **80**: 185–200.

Maurya, P.R. and Lal, R. 1980. Effect of no-tillage and ploughing on roots of maize and leguminous crops. *Experimental Agriculture* **14**: 341–358.

Meena, J.R. and Behera, U.K. 2008. Tillage and residue management effects on performance of greengram (*Vigna radiata*) and carbon sequestration in maize–based cropping system. Submitted for presentation in world conference on conservation agriculture.

Mohanty, M., Bandyopadhyay, K.K., Painuli, D.K., Ghosh, P.K., Mishra, A.K. and Hati, K.M. 2007. water transmission characteristics of vertisol and water use efficiency of rainfed soybean (*Glycine max*) under subsoiling and manuring. *Soil and Tillage Research* **93**: 420–428.

Nunan, N., Morgan, M.A. and Herlihy, M. 1998. Ultraviolet absorbance (280 nm) of compounds released from soil during chloroform fumigation as an estimate of the microbial biomass. *Soil Biology and Biochemistry* **30**(12): 1599–1603.

Obalum, S.E. and Obi, M.E. 2010. Physical properties of a sandy loam Ultisol as affected by tillage-mulch management practices and cropping systems. *Soil and Tillage Research* **108**: 30–36.

Ram, H., Kler, D.S., SINGH, Y. and Kumar, K. 2010. Productivity of maize (*Zea mays*)–wheat (*Triticum aestivum*) system under different tillage and crop establishment practices. *Indian Journal of Agronomy* **55**(3): 185–190.

Rasool, R., Kukal, S.S. and Hira, G.S. 2007. Farmyard and inorganic fertilization effects on saturated hydraulic conductivity of soil and performance of rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) systems. *Indian Journal of Agricultural Sciences* **77**(11): 768–771.

Roldan, A., Caravaca, F., Hernandez, M.T., Garcia, C., Sanchez-Brito, C., Velasquez, M. and Tiscareno, M. 2003. No-tillage, crop residue additions, and legume cover cropping effects on soil quality characteristics under maize in Patzcuaro watershed (Mexico). *Soil and Tillage Research* **72**: 65–73.

Shah, Z., Shah, S.H., Peoples, M.B., Schwenke, G.D. and Herriedge, D.F. 2003. Crop residue and fertiliazer n effects on Nfixation and yields of legume-cereal rotations and sopil organic fertility. *Field Crops Research* **83**: 1–11.

Singh, G., Marwaha, T.S. and Kumar, D. 2009. Effect of resource-conserving techniques on soil microbiological parameters under long-term maize (*Zea mays*)–wheat (*Triticum aestivum*) crop rotation. *Indian Journal of Agricultural Sciences* **79**(2): 94–100.

Six, J., Elliott, E. T. and Paustian, K. 2000. Soil macroaggregate turnover and microaggregate formation: A mechanism for C sequestration under no-tillage agriculture. *Soil Biology and Biochemistry* **32**: 2099–2103.

Sturz, A.V. and Christie, B.R. 2003. Beneficial microbial allelopathies in the root zone: the management of soil quality and plant disease with rhizobacteria *Soil and Tillage Research* **72**: 107–123.

Subba Rao, A., Muneswar, S., Reddy, D.D., Saha, J.K., Manna, M.C. and M.V. Singh. 1998. Integrated plant nutrient supply system to improve and sustain the productivity of soybean-wheat cropping system on Typic Haplusterts. *Bulletin No. 2*. Indian Institute of Soil Science, Bhopal, pp. 78–91.

Verhulst, N., Deckers, J. and Govaerts, B. 2009. Classification of the soil at CIMMYT's experimental station in the Yaqui Valley near Ciudad Obregón, Sonora, Mexico. CIMMYT Report. CIMMYT, Mexico, pp. 10.

Whalen, J.K., Hu, Q. and Liu, A. 2003. Compost applications increase water-stable aggregates in conventional and no-tillage systems. *Soil Science Society of America Journal* **67**: 1842–1847.

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Soft computing approach for optimal reservoir operation

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ABSTRACT

Soft computing techniques have been adopted widely in almost all sectors in decision making because of the ability to analyze and model the complex problem in the comprehensive manner for which conventional mathematical techniques have their shortcomings. Soft computing techniques provide better option for improving management of water resources. Optimal operating policies are very much essential for sustainable management of reservoir as poor operating policies may leads to over or under use of water. Due to huge amount of uncertainty involved in real time operation of reservoir, derivation of optimal operating rules with conventional techniques is tedious job. The soft computing tools like Fuzzy logic, Neural Networks, Nero-Fuzzy handle the uncertainty and unpredictability and helps in decision making to develop operating policies of reservoir. This paper briefly reviews the development of soft computing techniques like Fuzzy Logic (FL), Artificial Neural Networks (ANNs) and Neuro-Fuzzy System (NFS) and their application in deriving operating policies for the reservoirs.

Key words: Soft computing, Reservoir operation, Fuzzy logic, ANN, Neuro-Fuzzy system

INTRODUCTION

Soft computing is an approach to construct computationally intelligent techniques, such as Fuzzy Logic (FL), Artiûcial Neural Networks (ANNs), and Neuro-Fuzzy System (NFS). These techniques provides by and large inexact solutions of complex problems, unlike the hard computing in which one have to deal with a large set of conventional techniques such as mathematical, stochastic and statistical methods. In contrary, soft computing combines biological structures with computing techniques. FL refers to logical system that generalizes classical two valued logical reasoning with uncertainty (Yen and Langari 2003). ANNs made up of interconnecting artiûcial neurons that has natural property for storing experimental knowledge and making it available for use as human brain does. Integration of FL and ANN with certain derivative-free optimization technique gives the NFS.

Soft computing which is proposed by Dr. Lotfi Zadeh is simply a fusion of techniques that were designed to model and address the real world problems, which are difficult to model by existing techniques. The applications of soft computing have two main advantages. Firstly, the nonlinear problems can be solved easily, in which the mathematical modeling is not possible. Second and most important advantage is that, it incorporates human knowledge such as recognition, understanding, learning, and others into the computing. This leads in to the possibility of constructing intelligent systems such as autonomous and automated designed systems.

Among many natural resources on earth the water is a vital and most important resource. Now days there is ever increasing stress on available water resources as human population is growing at very high rate. Due to this reason, how such a rare and vital resource can best be utilized for human use and how efficiently this can be managed are the burning questions all over the world today. In India large part of population depends on agriculture. Under the present situations of its rapid population growth, there is always a heavy pressure on available water resource, to meet the increasing demand for food. There is ever increasing need for irrigation for better agricultural output. Not only

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in agriculture but water consumption has increased drastically in all sectors like domestic, industry etc.

Under these circumstances there is need to give the great importance to water resource management. This requires to find out better operating policies of storage reservoirs. It may be appropriate to mention here that no water resource system is free from problems. It may be due to the fact that water is often available at times; the amount of water available is not up to the demand. Besides, there is a misdistribution of water in space and time. Precise use of water available in reservoir is required for sustainable water management. The whole reservoir system has been developed by incurring a huge cost so it should be utilized optimally to serve its purpose. Many reservoirs may fail to serve their purpose unless they managed properly. This may be due to adopting poor operating policies. From this discussion it is clear that a reservoir system with efficient management and improved operational policy would lead to the water and energy conservation for sustainable water management.

Determination of reservoir or pond operating policies is a complex problem because of uncertainty involve in it. That is why the soft computing techniques have been used for deriving operating policies for reservoirs. These techniques can be gainfully employed to handle such problems when conditions of the systems are uncertain (Mehta and Jain 2009). Many researchers have found that soft computing techniques are very efficient in handling large uncertain data (Manikumari and Murugappan 2008). Operating policies developed by using soft computing techniques showed very good results. Not only water is saved but sustainable water management can also be ensured.

This paper briefly reviews some of the studies carried to develop operating policies for the reservoir using FL, ANN and NFS with the detail concepts, methods and applications. The future development in the same area has also been discussed.

Methods of soft computing

There are many methods for soft computing like FL, ANNs, NFS, Evolutionary Computing, Probabilistic Computing, Belief Networks, Chaotic Systems and parts of learning theory, Genetic Algorithm etc. out of which FL, ANNs and NFS have the significant utility in deriving the reservoir operating rules. All three are described below.

Fuzzy Logic

Fuzzy logic is used in two different senses. In narrow sense it refers to a logical system which generalizes classical two-valued logic for reasoning under uncertainty and in broad sense, FL refers to all the theories and techniques that employ fuzzy sets. It is obvious that broad sense of FL includes the narrow sense FL as branch (Yen and Langari. 2003). A fuzzy inference system is the non-linear mapping from a given input space to an output space. Fuzzy Set theory allows the user to deal with uncertainties in data. The basic notion of fuzzy systems is a fuzzy (sub) set. In classical mathematics we are familiar with crisp sets. FL provides a set of membership values inclusively between 0 and 1 to indicate the degree of truth (fuzzy). The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system. There are different membership functions associated with each input and output response. Triangular shape of the membership is common, but bell, trapezoidal, exponential etc. have also been used.

The fuzzy inference system should include the following functional steps:

- A fuzziûcation interface that transforms the crisp inputs into degrees of match with linguistic values;
- A knowledge base that includes,
  — A rule base containing a number of fuzzy 'IF–THEN' rules;

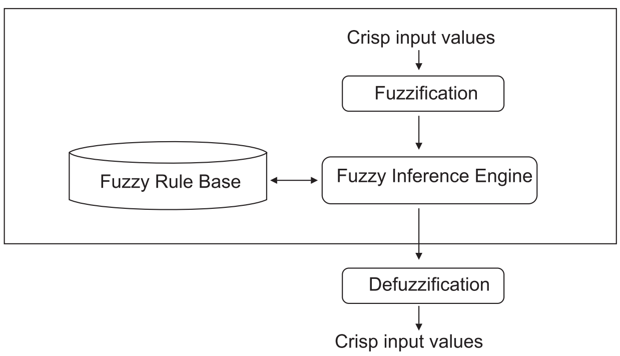

Fig 1: Functional blocks of fuzzy system.

— A database that defines the membership functions of the fuzzy sets used in the fuzzy rules;
- A decision-making unit that performs the inference operations on the rules;
- A defuzziûcation interface that transforms the fuzzy results of the inference into a crisp output. (Huang *et al*. 2010).

Application of FL in reservoir operating rules

Many research has been carried out to derive operating policies of reservoir using fuzzy logic, some of them are discussed below.

Panigrahi and Mujumdar (2000) developed the model for operation of single purpose reservoir using fuzzy logic for the Malaprabha irrigation reservoir in Karnataka. Following steps were followed in the modelling process.

- Fuzziûcation of inputs, in which the crisp inputs such as the inûow, reservoir storage and release were transformed into fuzzy variables,
- Formulation of the fuzzy rule set, based on an expert knowledge,
- Application of a fuzzy operator to obtain one number representing the premise of each rule,
- Shaping of the consequence of the rule by implication,
- Defuzziûcation.

Study underlined the advantage of the fuzzy rule based reservoir operation in which the complex optimization procedures were avoided. It was revealed that the linguistic statements such as 'low inûow' 'poor rainfall' etc. could be readily incorporated. As a result of these the operators feel ease in using such models. The fuzzy rule based model is easy to develop and adopt for operation which was proven to be true in case of study reservoir (Malaprabha irrigation reservoir).

Manikumari and Murugappan (2008) carried out similar study on the Veeranam irrigation tank system of Cuddalore district of Tamilnadu to derive operating guidelines which earlier was on adhoc basis. Tank of 41.6 MCM was being used for the irrigation purpose. The water release policy derived by using FL was compared with the actual historic water release. The water release of each month for the years from 1988-89 to 1996-97 was simulated using FL which gave the satisfactory result than that of adhoc policies. FL had proven to be efficient tool for decision making to meet irrigation requirements. The model enabled the operator to use release policy on day-to-day basis. The model had 84% accuracy when compared with actual historic water release and that led to increase in irrigation potential tremendously.

It has always been difficult to model the multi reservoir system using classical Stochastic Dynamic Programming (SDP), due to curse of dimensionality inherently associated with it. Owing to this, Jairaj and Vedula (2000) made an attempt to use Fuzzy Linear Programming (FLP) to solve such kind of problems. The fuzzy set theory was applied to a multi reservoir system with a number of upstream parallel reservoirs, and one downstream reservoir through the formulation of a fuzzy mathematical programming model. The objective of study was to minimize the sum of deviations of the irrigation withdrawals from target demands on a monthly basis, over the entire year. The SDP and FLP model were applied to three reservoir systems in the Upper Cauvery River basin, South India and the results obtained were compared. Though the data set and constraints were same in both the cases, fewer efforts generated the steady state solution for multi reservoir systems using FLP than that of SDP. The results revealed that SDP would not be feasible for large and complex multi reservoir systems because of dimensional considerations. In the present case, use of fuzzy linear programming in multi reservoir system optimization gave better results than SDP.

Artificial Neural Networks

Artificial Neural Networks (ANN) is very important aspect of soft computing. It is motivated by the recognition that the human brain computes in all the different ways from what the digital computer does. Neural network does not have real nerve cells; instead an artificial system of neurons carries out the computational work. So we can say that ANN is an artificial neural system.

It is difficult to define the neural network because of its multidisciplinary nature and its origin in biological science. But in simple way an ANN is a computational structure designed to mimic the human neural system. Neurons are the computational units of ANN, which are connected by means of weighted interconnections. Neurons have property of storing knowledge and making available for use as and when required. The weight of an interconnection is a number that expresses the strength of the associated interconnection. The important characteristic of ANNs is their ability to learn. This learning process is achieved by adjusting the weights of the interconnections between neurons according to applied learning algorithms.

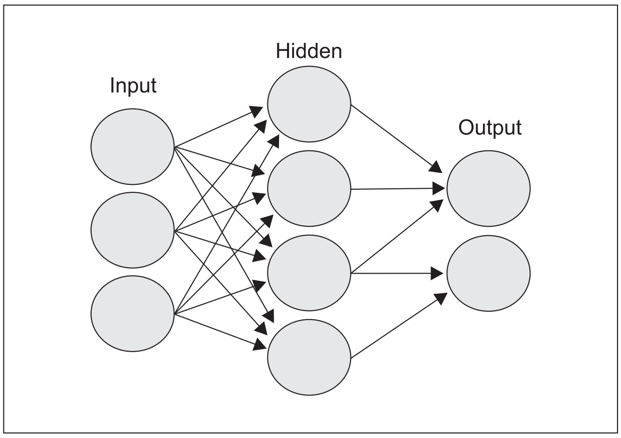

Fig. 2. Structure of neural network

The structure of neural network consists of three basic layers, input layer, hidden layer and output layer. The manner in which the neuron layers are structured to learn the algorithm is called as 'Network architecture'. There are three types of architecture. 1. Single layer feed forward networks; it is the simplest structure in which only one hidden layer is present along with the other layers. 2. Multilayer feed forward networks; it consists of more than one hidden layer. 3. Recurrent network; it can be distinguished from feed forward neural network in a way that it has at least one feedback loop. The flow chart for the working of ANN is given in fig. 3.

The ability of ANN to learn gives the power of generalizing the output during training. This main advantage has made ANN to solve large scale complex problems that are traceable. Due to this advantage many researchers have used ANN for deriving reservoir operating rules.

Application of ANNs in reservoir operating rules

Cancelliere *et al.* (2002) applied approach of ANNs for deriving the operating rules for an irrigation reservoir. To determine operating rules a two step process was used. In first step, a dynamic programming technique in which sum of squared deficit, assumed as objective function subject to various constraints, were applied to derive operating rules. In second step, the water releases resulting from the reservoir were expressed as a function of signiûcant variables by neural networks. Neural networks were trained for a long period and also for the period of severe droughts. Validation of operating rules determined was carried out for different shorter period. Performance indices of the reservoir and crop yield through soil water balance model were used to assess the behavior of different operating rules. Validation of selected neural networks over seven year period showed the superiority and also improved the reservoir performances during drought conditions. The operating rules based on an optimization with constraints resembling real system operation led to a good performance of reservoir both in normal and in drought periods by reducing water spill and maximum deûcit.

Chandramouli and Deka (2005) developed the Decision Support System (DSS) for optimal operation of Aliyar reservoir in South India using combination of a rule based expert system and ANN models. The models were trained using the results from deterministic single reservoir optimization algorithm. The DSS based on trained neural network models, used the real time data of previous time for deciding the operating policies. Results revealed that the operating policies developed by ANN improved the reservoir operation in significant way. It was also found that the application of ANN was suitable for field problems.

Neuro-Fuzzy System (NFS)

Neuro- Fuzzy refers to combinations of artificial neural networks and fuzzy logic. The need of combining these two techniques was realized because the neural network can approximate a function, but the interpretation of results in terms of natural language cannot be obtained. A neural network uses nonlinear regression to model dynamic plant in the discrete time domain. The result is a network, with adjusted weights and approximation. The learning results in a large set of parameter values which would be very difficult to interpret in words. Conversely, a fuzzy rule base consists of readable IF-THEN statements which are almost natural language, but drawback is that, it cannot learn the rules by itself. To overcome the drawbacks of these techniques and to achieve readability and learning ability at the same time, both are combined to give new system of computation called as Neuro-Fuzzy. The fusion of ANN and FL in neuro-fuzzy models provides learning as well as readability. This combination results in a hybrid intelligent system that has human-like reasoning power, learning and reading abilities. Arun Raj Kumar and Selvakumar (2013) have given the architecture of Neuro-Fuzzy system which is show in fig. 4. Combination of FL and ANN can be observed in the following NFS architecture.

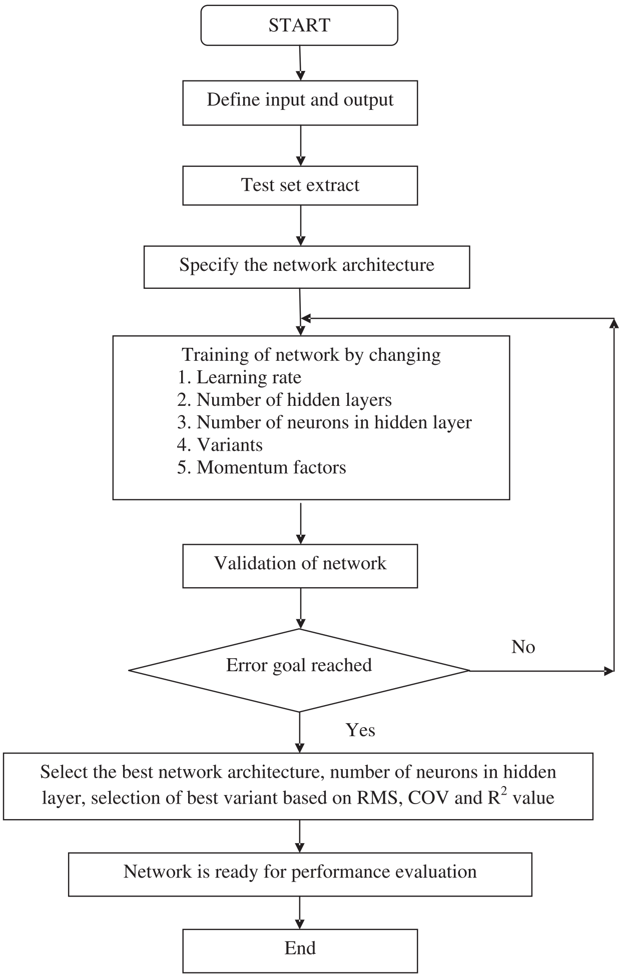

Fig. 3. Flow chart for ANN

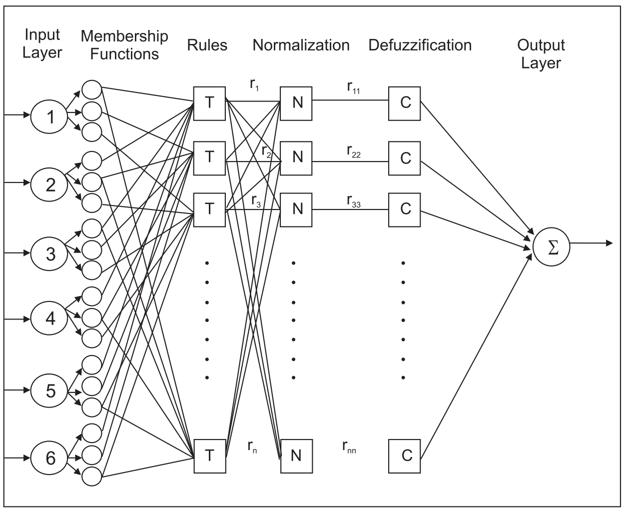

Fig. 4. Architecture of NFS

Application of NFS in reservoir operating rules

Very few studies have been carried out to develop the operating policy using NFS; some of them are reviewed below.

Mehta and Jain (2009) developed operating policies for Ramganga multipurpose reservoir located at Kalagarh, India by using NFS. The study showed that the developed policies minimized the damage caused due to ûoods and droughts. The operating policies also determined the optimum outflow in response to the demand of water for domestic supply, irrigation and hydropower generation for monsoon and non-monsoon periods. In present study three models based on Fuzzy rule were developed, each for monsoon and non monsoon period and same were tested. Actual releases were used to formulate the general operation fuzzy. Comparison of the releases computed from all models using Fuzzy Mamdani (FM) and ANFIS (Adaptive Neuro-Fuzzy Interactive System) – Grid and Cluster carried out. The results showed that model developed using ANFIS gave the best results which had highest value of correlation coefficient though FM was more user-friendly. Model efficiency was found to be more than 90% in both the cases.

Chang and Chang (2006) used a neuro-fuzzy hybrid approach to construct a water level forecasting system during flood periods for predicting the water level. ANFIS was used to build a prediction model for reservoir management to test the applicability and capability of ANFIS for the Shihmen reservoir, Taiwan. Data sets for 132 typhoons and heavy rainfall events with 8640 hourly data of past 31 years were collected and used in model development. The developed neuro-fuzzy model was tested for accuracy with and without human knowledge input. The results showed that the ANFIS could be applied successfully and can provide high accuracy and reliability for reservoir water level forecasting for the next three hours. Also the model with human decision as input variable was found to have consistently superior performance with regards to all used indexes than the model without this input.

Hasebe and Nagayama (2002) compared the operation of reservoir using FL and NFS and the traditional method by using examples of floods in flood and non flood period. The practical utility of the system for reservoir operation was also evaluated. The results showed that the NFS was very effective than the FL during flood season, however it was not so effective when water use was the objective, where FL had its effectiveness.

CONCLUSIONS

Soft computing techniques are robust and can handle uncertainty in cost effective manner. The operation of the reservoir involves huge uncertainty as demand and supply are highly instantaneous. Therefore the techniques like Artificial Neural Network, Fuzzy Logic and Neuro-Fuzzy are employed for modeling the reservoir application. Each of the techniques has its own peculiarity to handle the uncertain data. There is a huge scope for advancement in the application of these techniques for the sustainable water management.

REFERENCES

Arun Raj Kumar, P. and Selvakumar, S. 2013. Detection of distributed denial service attacks using an ensemble of adaptive and hybrid Neuro-Fuzzy system. *Computer Communications*. 36:303-311.

Cancellirre, A., Giuliano, G. and Rossi, G. 2002. A neural network approach for deriving irrigation reservoir operating rules. *Water resource management*.16:71-88.

Chandramouli, V. and Deka, P. 2005. Neural network based decision support model for optimal reservoir operation. *Water resource management*. 19: 447-464.

Chang, F. and Chang, Y. 2006. Adaptive neuro-fuzzy inference system for prediction of water level in reservoir. Advances in Water Resources. 29:1-10.

Hasebe, M. and Nagayama, Y. 2002. Reservoir operation using the neural network and fuzzy systems for dam control and operation support. *Advances in Engineering Software.* 33(**5**):245-260.

Huang, Y., Lanb, Y., Thomsona, S. J., Alex, F.A., Hoffmannb, W. C. and Lacey, R. E. 2010. Development of soft computing and applications in agricultural and biological engineering. *Computers and Electronics in Agriculture.* 71:107-127.

Jairaj, P.G. and Vedula, S. 2000. Multireservoir system optimization using fuzzy mathematical programming. *Water Resource Management.* 14: 457-472.

Manikumari, N and Murugappan, A. 2008. Fuzzy logic based model for optimization of tank irrigation. *Journal of engineering and applied science*. 3(**2**): 199-202.

Mehta, R. and Jain, S. K. 2009. Optimal operation of a multipurpose reservoir using Neuro-fuzzy technique. *Water resource management*. 23: 509-529.

Panigrahi, D. P. and Mujumdar, P. P. 2000. Reservoir operation modeling with fuzzy logic. *Water resource management*. 14: 89-109.

Yen, J. and Langari, R. 2003. Fuzzy logic: Intelligence, Control and Information. Pearson Education Pvt. Ltd., New Delhi.

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Effect of different farm holding size on cropping pattern and soil characteristics of farmer's field of Meerut district

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ABSTRACT

The field survey of farm families was conducted in three villages namely Alipur, Madarpur and Kulanjanpur of Sardhana Tehsil of Meerut district during December 2011 to study the effect of different farm holding size on cropping pattern and soil characteristics of farmer's fields. The results indicated that large and medium categories of farmers adopting Sugarcane – ratoon - wheat cropping sequence with mechanized farming whereas small and marginal farmers were practicing diversified cropping patterns giving more emphasis on vegetables and fodder crops besides cultivation of cash crop marigold. The Organic Carbon and available N P K of marginal and small farmer's fields found 31.62, 20.42, 23.56, 20.72% and 18.81, 28.26, 27.76, 03.70% higher than medium and large categories of farmer's fields respectively.

Key words: Farmers categories, Cropping sequences, Holding sizes and Soil Characteristics

INTRODUCTION

There are various categories of farmers as per their holding sizes viz. marginal having land size < 1 ha., small (1- 2 ha), medium (2- 4 ha) and large category (>4 ha). But the numbers of marginal and small farmers are increasing rapidly year after years due to fragmentation of large families, rapid industrialization, urbanization, and various development activities viz. construction of dams, roads and railways. Under such situation, marginal and small farmers are compelled to take up some other secondary and third enterprises such as dairy, fisheries, poultry, piggeries, bee keeping, mushroom cultivation, vermicomposting, horticulture and forestry as per their suitability in the areas concerned and circumstances in order to generate employment through out the year and increase the overall income and ultimately adopting diversified agriculture. As these categories farmers are economically and technologically poor, the use of organic sources of nutrient for crop production is a very common practice in their limited land resources.

On the other hand medium and large farmers are taking up remunerating cropping system like sugarcane – ratoon – wheat, rice- wheat – sorghum and maize – wheat etc. with proper crop management practices and improved seeds, fertilizers, irrigation, plant protection measures and mechanized farming. The variations in cultural practices for crops and soil management greatly influence soil health (Sharma et. al. 2000). However, very meager information is available on this aspect. Therefore, there is an urgent need to initiate the study on impact of farm holding sizes, various cultural practices and fertilizers use adopted by different categories of farmers on their cropping pattern and soil health.

MATERIALS AND METHODS

The survey of farm families was conducted in three villages namely Alipur, Madarpur and Kulanjanpur of Sardhana Tehsil of Meerut district during December 2011. The climate of area falls in semiarid subtropical and characterized by hot summer and cold winter. May and June are hottest and December and January are the coldest months of the year. The area is situated at latitude of 29° 09' N and longitude of 77° 39' E and at an altitude of 210.60 m above mean sea level. The average

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annual rainfall of the areas is approximately 720 millimetres. The July and August are the main months of maximum rainfall. There were 6 farmers selected randomly from each category ie large, medium, small and marginal from each village and made total number of 72 farmers. All the farmers were systematically interrogated to record the holding size, cropping sequences, fertilizer used and number of animals reared by them and presented in table1. Besides the above information, 72 composite soil samples were collected from each category of farmers of all the villages. These samples were processed and analyzed for various physico chemical properties.

The pH was determined by following standard method prescribed by (Jackson, 1973). The organic carbon content of the soil was measured by the chromic digestion method (Walkley and Black, 1934). The available N was determined by the method of Subiah and Asija (1956), available P was estimated by the procedure of Olsen *et al.* (1954) and available K was measured by neutral ammonium acetate method. The average value of all the soil properties and available nutrients of each location of all the fields were worked out and presented in table 2.

RESULTS AND DISCUSSIONS

It was observed from the survey work that 100 % large and medium categories of farmers were adopting fully mechanized farming and 90% taking Sugarcane- ratoon - wheat cropping sequence and rest of the 10% area was under forage (Lucerne Sorghum and Bajra) and other crops like Potato, Maize, Onion and Marigold. Small and marginal farmers were practicing traditional farming and mostly taking vegetable crops such as Potato, Onion, Peas, Chilies, Bhindi ,Cauliflower Cabbage, cash crop such as Marigold and fodder crops such as Sorghum and Bajra besides Rice, Wheat, Mustard and Greengram for their own consumption in a different cropping sequences (Table 1). Almost all the categories of farmer's maintain 5-6 milch animals and using their excreta as source of manures in an alternative year but quantum of application was higher in categories of small and marginal farmers because of their small holding size in comparison of large number of animals. Application of nitrogenous fertilizer (Urea) @ 375 kg and phosphatic fertilizer (DAP) @ of 150 kg/ha was routine fertilization to each crop like Sugarcane, wheat Maize and Rice in Sugarcane- ratoon- wheat, Rice-wheat-green gram and Maize- potato onion cropping sequences where as potato crop was cultivated with 250 kg Urea and 125kg DAP/ha along with 25.0 tones FYM while hardly 5-10% farmers applied potassium fertilizer (Muriate of Potash) @ 125 kg /ha to Potato crop on an average (Table-1). However, there was no systematic fertilization to

Table 1. Survey of Farm families of different categories of farmers

Alipur				
Parameters	Large categories	Medium categories	Small categories	Marginal categories
Holding Size	12.80 Acre	5.02 Acre	4.80 Acre	0.88 Acre
Cropping Sequence	Sugarcane- ratoon- wheat, Rice-wheat, Sorghum-potato- lucerne.	Sugarcane- ratoon - wheat, Sorghum-potato- lucerne, Maize potato- marigold.	Maize-potato- onion- chilies, Sorghum-peas- marigold, Sorghum- potato-bhindi, Rice- wheat-green gram.	Rice-potato- onion- chilies, Sorghum - peas- marigold, Rice-potato- marigold.
Fertilizers Used	375 kg Urea, 150kg DAP/ha. for each cropping sequence in a year viz Sugarcane- Ratoon – Wheat and Rice – Wheat, 250 kg , 125.0kg DAP and 25 tones FYM/ ha for Potato.	375 kg Urea, 150kg DAP/ ha for each cropping sequence viz Sugarcane- Ratoon – Wheat and 50% doses same fertilizer were given to Maize crop,250 kg urea, 125.0kg DAP and 25 tones FYM/ ha for Potato.	375 kg Urea, 150 kg DAP/ha for each cropping sequence viz Rice-Wheat-Greengram and 50% doses same fertilizer were given to Maize crop, 250 kg urea, 125.0 kg DAP and 25 tones FYM/ ha for Potato whereas 25-30 tones F. Y. M. /ha to other crops.	180 kg urea and 75 kg DAP/ha for Rice crop and 250 kg urea, 125.0 kg DAP and 25.0 tones FYM/. ha for Potato where as 25-30 tones F. Y. M. /ha to other crops.
Animals Kept.	5.0	5.0	6.0	5.0

Madarpur				
Parameters	Large categories	Medium categories	Small categories	Marginal categories
Holding Size	9.0 Acre	5.1 Acre	2.9 Acre	1.02 Acre
Cropping Sequence	Sugarcane- ratoon-wheat, Rice-wheat, Sorghum- potato-lucerne.	Sugarcane-ratoon-wheat, Maize-wheat, Sorghum-potato-lucerne, Maize-potato-marigold.	Maize-potato- Onion-chilies,Maize-wheat – bajra. (fodder), Rice-wheat- marigold, Maize-potato-onion.	Maize-wheat-dhania,Sorghum - wheat-bhindi,Rice-potato-marigold, Rice-wheat-marigold.
Fertilizers Used	375 kg Urea and 150kg DAP/ha for each cropping sequence in a year viz - Sugarcane-Ratoon -Wheat, Rice – Wheat, 250 kg urea, 125.0 Kg DAP and 25.0 tones FYM /ha for Potato.	375kg Urea and 150kg DAP/ha for each cropping sequence in a year viz Sugarcane-Ratoon - Wheat,Maize-Wheat. 250 kg urea, 125.0 Kg DAP and 25.0 tones FYM /ha for Potato.	375 kg Urea, 150 kg DAP / ha for each cropping sequence in a year viz Rice- Wheat, Maize-Wheat, 250 kg urea, 125.0 Kg DAP and 25.0 tones FYM / ha for Potato and 25-30 tones FYM/ha to other crops	375 kg Urea, 150 kg DAP /ha for each cropping sequence in a year viz Rice, Wheat, Maize-Wheat, 250 kg urea, 125.0 Kg DAP and 25.0 tones FYM /ha for Potato. and 25-30 tones F Y M /ha to other crops
Animals Kept.	5.0	6.0	6.0	5.0

Kunjalpur				
Parameters	Large categories	Medium categories	Small categories	Marginal categories
Holding Size	5.33 Acre	4.22 Acre	2.85 Acre	1.08 Acre
Cropping Sequence	Sugarcane- ratoon-wheat, Rice-wheat, Sorghum- potato-lucerne.	Sugarcane- ratoon -wheat, Sorghum- potato-lucerne, Maize-potato-onion.	Sorghum-potato-marigold chilies,Maize-potato-marigold-bajra (fodder), Maize-mustard greengram	Sorghum-potato-marigold- chilies, Sorghum-potato-marigold-cabbage, Sorghum -pea-marigold, Maize-potato-merigold-bajra (fodder).
Fertilizers Used	375 kg Urea and 150kg DAP/ha for each cropping sequence in a year viz, Sugarcane – Ratoon -Wheat, Rice-Wheat, 250 Kg urea and 125Kg DAP- and 25 tones FYM /ha for Potato.	375 kg Urea and 150kg DAP/ha for each cropping sequence in a year viz Sugarcane-Ratoon- Wheat and 50% doses were given to Maize and Onion crops. 250 Kg urea and 125Kg DAP- and 25 tones FYM /ha for Potato.	250 Kg urea and 125Kg DAP- and 25 tones FYM /ha for Potato, 120 kg Urea and 75kg DAP/ ha. for Maize crop and 25-30 tones/ ha. F Y M to other crops.	250 Kg urea, 125.0 Kg DAP/ha and 25 tones FYM / ha for Potato. and 25-30 tones/ha. F Y M to other crops
Animals Kept.	5.0 crops	5.0	6.0	6.0

any other crops. Anyway, these fodder and other miscellaneous crops (except potato) are being cultivated with variable (25-30 tones /ha) application of Farm Yard Manures.

As per soil health of the farmer fields is concerned, the pH value of all the categories of the farmers fields ranged from 6.34 to 7.16 and attains the level of neutral range. The status of organic carbon and NPK of large category of farmers was lowest and varied from 0.21 to 0.48 %, 137 to 238 kg/ha, 10.24 to 17.5 kg/ha and 126 to 149 kg/ha followed by medium farmers field which ranged from 0.45 to 0.56 %, 216 to 274 kg/ha, 12.5 to 18.2 kg/ha and 130 to 146 kg/ha and small farmers field varied from 0.46 to 0.58 %, 257 to 285 kg/ha, 13.5 to 20.50 kg/ha and 130 to 150 kg/ha whereas marginal farmers field had higher values of organic carbon ranged from 0.56 to 0.68, available N 256 to 322 kg/ha, available P_2O_5 15.2 to 22.5kg/ha and available K_20_5 145 to 192 kg/ha. It may be due to more addition of organic manures into the soil which results higher amount of organic carbon and

Table 2. Soil characteristics of farmer's fields under different categories.

Locations	Farmers Categories	Soil pH	O C (%)	Available N (Kg/ha)	Available P_2O_5 (Kg/ha)	Available K_2O (Kg/ha)
Alipur	Large	7.12	0.31	178.0	12.15	128.0
	Medium	7.00	0.45	216.0	12.50	130.0
	Small	6.50	0.46	257.0	13.50	130.0
	Marginal	6.30	0.56	256.0	15.20	145.0
Madarpur	Large	6.80	0.21	137.0	10.24	126.0
	Medium	7.10	0.55	232.0	15.10	138.0
	Small	6.70	0.57	268.0	16.80	140.0
	Marginal	6.40	0.62	291.0	18.10	162.0
Kunjalpur	Large	7.16	0.48	238.0	17.50	149.0
	Medium	6.70	0.56	274.0	18.20	146.0
	Small	6.40	0.58	285.0	20.50	150.0
	Marginal	6.34	0.68	322.0	22.50	192.0

more availability of N P and K in the soil. These results are in agreement with the findings of Sharma and Bali (2002) The village wise nutrient status of the farmers field of large category of the farmers showed that percentage of Organic Carbon and available N P K were higher in fields of village Kulanjanpur followed by Alipur and Madarpur whereas rest of the categories of farmers recorded little bit different trend in respect of organic Carbon and available N P K. The values were higher in farmers fields of village Kulanjanpur followed by Madarpur and Alipur except in case of small farmers where values of Organic Carbon was highest in soils of village Kulanjanpur followed by Alipur and Madarpur. These variations in Organic Carbon and available N P K might be due to higher application of organic manures and diversification in cropping sequence. These findings corroborate the observations of Sharma and Bali (2002) and Tolanur and Badanur (2003).

CONCLUSIONS

It is revealed from the study that large and medium categories of farmers adopting Sugarcane –ratoon- Wheat cropping sequence with mechanized farming whereas small and marginal farmers were practicing diversified cropping patterns. The OC, and NPK values fall in categories of low to medium range and overall soil health of the marginal and small farmer's fields are better than medium and large categories of the farmers.

REFERENCES

Jackson, M.L. 1973. Soil chemical analysis Prentice-Hall of India Pvt. Ltd., New Delhi.

Olsen, S.R., Cole, V.C., Watanabe, F.S. and Dean, L.A. 1954.Estimation of available phosphorous in soil by extension with $NaHCO_3$. USDA. Circ. 939 : 19-33.

Sharma,M.P.Bali, S.V.and Gupta, D.K. 2000. Crop yield and properties of inceptisol as influenced by residue Management under Rice-Wheat Cropping sequence. *Journal of the Indian Society of Soil Science* **48** (3) : 506-509.

Sharma,M.P. and Bali, S.V. 2002 Effect of different cropping system on physico-chemical properties and soil fertility. Journal of Indian Society of Soil Science. 48: 181-83.

Subbiah, B.V. and Asija, G.L. 1956, A rapid procedure for estimation of available nitrogen in soils. *Current Sciences* **25**:259-260.

Tolanur, S.L. and Badanur, V.P. 2003. Changes in Organic Carbon, Available N, P and K under integrated Use of Organic Manure, Green Manure and Fertilizer on Sustaining Productivity of Pearl Millet-Pigeonpea System and Fertility of an Inceptisol. *Journal of the Indian Society of Soil Science.* **51** (1) : 37-41.

Walkley, A. and Black, I.A. 1934. An examination of the detgaulf method of determining soil organic matter and proposed modification of chronic and titration methods. Soil Science. 37: 29-30.

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Optimum size of agricultural land holdings for economic sustainability-Policies on land utilization & succession laws on inheritance

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ABSTRACT

Agriculture is and will continue to be the main theme for all strategies for planning of socio-economic developmental interventions across the country. The rapid growth in this sector is essential to meet increasing demands of over one billion population, which is feasible by increasing extent of cultivable land or by enhancing productivity of existing agricultural land on sustainable basis. For enhancing productivity, the land/soil management, optimum water resource development, soil health management, reclamation of problem soils, addressing the issues of climate change by adaptation and mitigation, harnessing the productive potential of rainfed areas, timely availability of inputs, support for marketing infrastructure, credit flow to the farmers etc. would further boost economic sustainability. Land holding while undertaking above interventions plays a significant role, therefore, ensuing optimum size of agricultural land holding becomes a key factor. For this purpose, bringing suitable statutory reforms/ laws relating to land utilization, policies on prevention of agricultural land for non-agricultural uses, succession laws of inherent properties etc. need to be analyzed & modified for economic sustainability of farming systems.

An attempt is made to take a stock of various survey reports in the area of land holding to study the optimum size of land holding. Outcomes of analysis of data of National Sample Survey Organization (NSSO) on income and consumption per farm household by size category of farmers, reveals that national average income per household farmer in case of large farmers is higher and the same is lower as holdings decrease, whereas difference in income and consumption increases as land holding increases. In case of marginal and small farmers' difference in income and consumptions are negative which reveals that these two categories of farming systems are in loss and not able to sustain until and unless some non-farm employment opportunities are made available. Difference in income & consumption only in case of semi-medium farmer's household is minimum which reveals that if little efforts with appropriate technologies and packages of practices are extended to this category, they can sustain with farming systems. Although, empirical studies have demonstrated that agricultural productivity is size neutral, but analysis of NSSO data reveals that optimum size of agricultural land holding may be 2 to 4 ha in India.

Key words: Climate change adaptation & mitigation, Succession laws, Intestate, Archaic & anachronistic, Inheritance, Contract farming

INTRODUCTION

Agriculture is a way of life, a tradition, which, for centuries, has shaped the thought, the outlook, culture and economic life of the people of India. Agriculture, therefore, is and will continue to be central theme for planned socio-economic development of the country. Growth in agriculture sector is essential to meet increasing demands of over one billion population of the country. This challenging task is feasible; firstly by increasing extent of cultivable land and secondly by enhancing the present level of productivity of agricultural land. The structural reforms and stabilization policies introduced in 1991 mainly focused on industry, tax reforms, foreign trade and investment, banking and capital markets; however, did not include any package specifically designed for agriculture. Real development in terms of

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growth of all sections of the population has not taken place and therefore, problems of poverty, unemployment, inequalities in access to health and education opportunities and poor performance of agriculture sector continue to exit in large section of the population.

Land is a means of earning income and of providing for one's needs. Land has meant social position and power as well as of great economic advantage. Social systems, laws, and customs are concerned with one way or other to land. The man-land ratio is very adverse and the availability of land per person in India is much below the world average. Also, land is far less productive than land in most of the other countries of the world and is being further degraded due to lack of land uses as per land capabilities. The question of the utilization of 328.73 million hectare of the country's land area in a manner in which the maximum area is brought under productive use has to be devised in a pragmatic and scientific way. Land use is a multi-faceted subject and is the concern of many disciplines. The higher economic growth of land is concern of the scientists, ecologists, planners, politicians, business and industry, trade and commerce groups, administrators, farmers and all concern.

The economic, political and social factors are the root of the land degradation problem. Human interaction with the land can depend critically on whether the land is leasehold, freehold or a common property resource and whether government regulations or fiscal measures restrict or encourage user activities. Land users in India are often constrained in their ability to invest in land improvement for several factors such as (i) capital for the development of land may not be available and therefore, land users may not perceive the full economic benefits, (ii) technical and managerial knowledge may be inadequate, and (iii) income may not be high enough to serve the cost of borrowing. The responsibility for ensuring that land is not over-exploited cannot be left entirely to individuals. Therefore, policies designed to arrest and reverse the processes of degradation must be aimed at people who use the land and they should have access to the right technology to suit their particular economic needs.

Land serves as storage for water and nutrients required for different crops, and meet the demand for food, energy and other human requirements. As per "Land Use Statistics at a Glance(2013) of Government of India, Ministry of Agriculture, New Delhi, out of total geographical area of 328.73 million ha, area under forest cover is 70.01 million ha, area under non-agricultural uses is 26.51 million ha, barren land is 17.05 million ha, total fallow land is 26.17 million ha (Permanent pastures is 10.30 million ha, culturable waste land is 12.66 million ha, land under miscellaneous tree crops and groves is 3.21 million ha) and net sown area is about 141.00 million ha.

Cultivable land has reduced from 185.09 million ha(1980-81) to 182.03 million ha (2010-11). During same period, land under non agricultural uses has increased from 19.66 million ha to 26.51 million ha During the Eighties (between 1980-81 and 1990-91), annual average increase in non-agricultural use was 0.15 million ha, during 1991-92 to 2000-2001 it is 0.23 million ha whereas during the period, 2001-02 to 2010-11, the annual average increase in non-agricultural use became 0.26 million ha Thus, pace of conversion is higher above 73% between 2001-02 to 2010-11 as compared to the period of 1980-81 to 1990-91.

Objectives

The major objectives of the study are as under:

a. Suggest optimum land holding size for ensuring sustainable farm income;
b. Promotion of crop diversification, changing region-wise cropping pattern based on location specific needs, including emphasis on cultivation of short duration high yielding varieties of seeds & other advance technologies;
c. Suggest interventions for non- farm activities for off season means by development of rural-agro industries, road transport and communication services to induce more income and employment; and,
d. Statutory amendment for prevention of land fragmentation.

MATERIALS AND METHODS

Average land holding has reduced from 1.84 ha in 1980-81 to 1.16 ha in 2010-11, resulting increase in percentage of operational holders in category of marginal & small by 1% whereas; during same period, it has marginally decreased in case of medium & large holder. The Indian agriculture is dominated by small and marginal farmers (80%) and therefore proper management of these holdings is important for raising agriculture growth, food security and livelihoods in India.

Above facts, indicate that our country is facing twin problems, firstly, reduction in availability of cultivable land due to diversion of such land for non-agricultural purposes, secondly reduction in average land holding mainly due to fragmentation and division in farm families, resulting in increase of small and marginal farmers to about 80% of the total farmers population. As regards the value of cultivable land in urban and rural areas is concerned, value of urban land is now about 15 to 20 times greater than rural land due to ever increasing demands of land for housing and other basic amenities. Therefore, achieving maximum efficiency in urban land uses have become an important area needing higher attention to improve productivity and alleviating growth of poverty. State-wise land holding under various categories of farmers are given in table 1.

Productivity of major crops in selected counties

Indian agriculture is overmanned & only few farmers are able to produce major agricultural commodities and depends on Government policies to support prices of the commodities. Furthermore, average yields are low not only in comparison to many food producing countries, but also yields at research stations. The productivity of major crops

Table 1. Average size of holdings by size group, in India as on 2010-11 *(Area in hectare)*

S. N.	Name of the States/UTs	Average size of holdings by size group(2010-11)					
		Marginal	Small	Semi-Medium	Medium	Large	All Holdings
1.	Andhra Pradesh	0.44	1.41	2.63	5.56	15.50	1.08
2.	Arunachal Pradesh	0.55	1.34	2.76	5.54	14.90	3.51
3.	Assam	0.42	1.38	2.69	5.15	68.11	1.10
4.	Bihar	0.25	1.25	2.59	5.09	14.45	0.39
5.	Chhattisgarh	0.44	1.42	2.68	5.71	16.30	1.36
6.	Goa	0.31	1.40	2.74	5.57	22.91	0.93
7.	Gujarat	0.49	1.45	2.77	5.71	19.54	2.11
8.	Haryana	0.46	1.47	2.87	6.09	17.95	2.25
9.	Himachal Pradesh	0.41	1.39	2.72	5.66	15.44	0.99
10.	Jammu & Kashmir	0.35	1.40	2.68	5.43	22.34	0.62
11.	Jharkhand	0.41	1.38	2.74	5.63	15.35	1.17
12.	Karnataka	0.48	1.41	2.68	5.69	14.71	1.55
13.	Kerala	0.13	1.57	2.79	5.32	64.58	0.22
14.	Madhya Pradesh	0.49	1.42	2.73	5.76	15.77	1.78
15.	Maharashtra	0.47	1.42	2.67	5.62	16.07	1.45
16.	Manipur	0.52	1.28	2.48	4.86	11.00	1.14
17.	Meghalaya	0.56	1.58	2.75	5.49	17.24	1.37
18.	Mizoram	0.60	1.27	2.42	5.13	15.09	1.14
19.	Nagaland	0.51	1.14	2.59	6.13	17.54	5.99
20.	Odisha	0.57	1.63	2.95	5.99	25.46	1.04
21.	Punjab	0.61	1.38	2.64	5.74	14.75	3.77
22.	Rajasthan	0.49	1.43	2.83	6.14	17.45	3.07
23.	Sikkim	0.37	1.20	2.49	5.44	15.77	1.42
24.	Tamil Nadu	0.37	1.39	2.70	5.63	20.13	0.80
25.	Tripura	0.27	1.39	2.59	4.81	14.29	0.52
26.	Uttarakhand	0.44	1.43	2.71	5.45	23.11	0.89
27.	Uttar Pradesh	0.37	1.39	2.72	5.52	15.01	0.75
28.	West Bengal	0.49	1.59	2.73	4.85	338.58	0.77
29.	A & N Islands	0.44	1.43	2.63	4.34	36.88	1.85
30.	Chandigarh	0.46	1.43	2.86	5.70	11.08	1.29
31.	D & N Haveli	0.51	1.37	2.77	5.74	15.46	1.38
32.	Daman & Diu	0.23	1.36	2.56	6.27	19.97	0.38
33.	Delhi	0.42	1.32	2.69	5.56	15.13	1.45
34.	Lakshadweep	0.17	1.36	2.50	6.11	24.00	0.27
35.	Pondicherry	0.35	1.46	2.86	5.72	16.90	0.66
	Total average	0.38	1.42	2.71	5.76	17.37	1.16

Source: Land Use Statistics at a Glance-(2001-02 to 2010-11), Directorate of E&S, DAC, MOA, GOI, New Delhi, April 2013.

in different countries of the world compared to India are as under:

The data on the productivity of paddy, wheat and maize of other countries indicate that there is scope to increase the productivity of the cultivated land by intensive cropping with the use of high-yielding varieties and by adopting new production technologies developed for each region by ICAR and SAUs. More emphasis is also needed for horticulture and floriculture development. Land reforms need to be introduced for (i) the elimination of intermediaries between the cultivator and the state, (ii) the implementation of ceilings on individual holdings and (iii) protection of tenants by providing security and fair rents.

Land fragmentation and its impact on foodgrain production

Agrarian problems such as fields being often fragmented, loss of fertility of soil by erosion, tilled for long without replenishment of nutrients appears to have reached the ultimate base level of infertility. The rehabilitation of agriculture is by far the most pressing problem facing India. Scientific soil and water conservation programmes, management of soil to replenish the nutrients, rural credit, agricultural education and advice, regeneration or forests, conservation of fish and wild life resources make it possible to survive from natural disasters such as droughts and floods.

Communication Systems in rural areas are inadequate. Market facilities are poor for agricultural produce. The farmer, usually have little storage capacity and have no holding power. They are exploited in the receipt of income for their output. The farmers are often without access to reliable market intelligence which is a major factor of lower incomes especially from dairy, fruit and vegetable crops. Landless poor and unemployed youths of the villages run towards for job opportunities resulting city slums which are unhygienic to live. In order to control such mindless migration of poor to the urban areas, rural development is an essential prerequisite of urban development in India.

While some of the natural resources are not fully utilized, others are being dissipated, wasted and in some cases destroyed. There are strong linkages between soil and water conservation, farm and livestock production practices, road construction, soil erosion, etc. For reversing back the ecological disaster urgent developmental efforts are needed on a long term planned measures. The heritage of future generations depends on the adoption and implementation of policies designed to conserve natural resources and create the physical environment in which progress can be enjoyed. The thoughtless destruction of productive land threatens our future and must be brought under control.

Strength of smallholders and their livelihood

The contribution by marginal and small farmers is higher as compared to their share from land output. The share of these farmers is 46.1% in land possessed but they contribute 51.2% to the total output of the country at all India level in 2002-03. In terms of production, small and marginal farmers also make larger contribution to the production of high value crops. They contribute around 70% to the total production of vegetables, 55% to fruits against their share of 44% in land area. Their share is 52% in cereal production and 69% in milk production. Thus, small farmers contribute to both diversification & food security. Only in cases of pulses & oilseeds, their share is lower than other farmers.

Agricultural Census data shows that there has been debate in India on the relationship between farm size and productivity. The results of NSS 2003 Farmers' survey has empirically established that small farms continue to produce more in value terms per hectare than the medium and large farms. Value of output per ha was Rs.14854 for marginal farmers, Rs.13001 for small farmers, Rs.11332 for medium & large farmers and Rs.12535 for all holding farmers.

Policies and succession laws relating to lands

Policies on Protection of Agricultural Lands**:** Following major policy initiatives have been taken by Government of India for protection of prime agricultural land for non-agricultural purposes are as under:

i. National Policy for Farmers, 2007 (NPF 2007): National Policy for Farmers, 2007 (NPF 2007) formulated by Ministry of Agriculture (MoA) has recommended that 'Prime farmland must be conserved for agriculture except under exceptional circumstances, provided that the agencies that are provided with agricultural land for non-agricultural projects should compensate for treatment and full development of equivalent degraded / wastelands elsewhere. For non-agricultural purposes, as far as possible, land with low biological potential for farming would be earmarked and allocated'. State governments have been advised to 'earmark lands with low biological potential such as uncultivable land, land affected by salinity, acidity, etc., for non-agricultural development activities, including industrial and construction activities.

ii. National Rehabilitation & Resettlement Policy, 2007(NRRP, 2007): National Rehabilitation and Resettlement Policy, 2007 (NRRP, 2007) formulated by Ministry of Rural Development, Department of Land Resources has recommended that 'only the minimum area of land commensurate with the purpose of a project may be acquired. Also, as far as possible, projects may be set up on wasteland, degraded land or un-irrigated land. Acquisition of agricultural land for non-agricultural use in the project may be kept to the minimum; multi-cropped land may be avoided to the extent possible for such purposes and acquisition of irrigated land, if unavoidable, may be kept to the minimum.' These policies have been sent to States/UTs for implementation.

iii. The Right to Compensation, Transparency in Land Acquisition, Rehabilitation and Resettlement Act: Recently, Parliament passed the Right to Compensation, Transparency in Land Acquisition, Rehabilitation and Resettlement Act, which encompasses proper rehabilitation & resettlement, fair compensation and some extent of restriction in diversion of agricultural land. Presently, this Act is in process of Gazette Notification & will be effective from the date of notification.

Existing land/ property succession laws

Succession and inheritance can be of two kinds- Testamentary or testate inheritance which means inheritance as per the Will of the deceased and Non Testamentary or intestate succession, where the deceased dies without making a Will. The law on intestate succession for different communities in India is governed by different succession laws applicable for that particular community i.e. Hindu Succession Act (1956), Indian Succession Act (1925) including succession for Christians, Muslim Succession Act(1956) etc. The laws on testate succession are governed by the Indian Succession Act, 1925 for all communities except Muslims. However, the Muslims shall be bound by the Indian Succession Act, 1925 for the purpose of testamentary succession, if the will relates to immovable property situated within the State of West Bengal and within the jurisdiction of the Madras and Bombay High Courts. Applicability of the Succession law to a person belonging to a particular community is explained in the following diagram.

RESULTS & DISCUSSIONS

Optimum size of land holdings

As per available estimates, out of total 120 million farm holdings, about 98 million are of small and marginal farmers. The sustainability of these farmers is crucial for livelihoods in rural areas and for the entire country. It is true that small holdings have higher productivity than medium and large farms, however, it is not enough to compensate for the disadvantage of the small area of holdings. The cost of cultivation per hectare is high on small and marginal farmers than medium and large farms. At the all India level, net farm income per hectare for small holdings is higher than large holdings table 2. The data at state level shows that in 9 out of 20 states, the reverse is true i.e.net farm income per hectare is higher in large holdings than small holdings.

The cost of cultivation and net farm income per hectare (table 2), as per Review of Agriculture (June 2011) are as under:

On perusal of value of output, cost of cultivation and net income, it is evident that small holdings are equal or better than large holdings from efficiency point of view. There are large regional variations, in the value of output per hectare. For marginal farmers, it varies from Rs. 29,448 in Punjab to Rs.7,177 in Rajasthan. This is also true for medium and large farmers. It ranges from Rs.28,983 in Punjab to Rs.4,213 in Rajasthan. In many States, small holdings have higher value of output per hectare than large farms. However, in the case of States like, Kerala, Madhya Pradesh, Uttar Pradesh, Himachal Pradesh and Tamil Nadu, the large farms have higher productivity (in value terms) than marginal farmers.

The information available on input use and other variables and structure of holdings in the input survey and agriculture census cannot be used to establish the relationship between farm size and productivity. However, this type of information is available in the situation assessment survey of farmers conducted by the National Sample Survey Organization (NSSO) in 59^{th} round on "Income Expenditure and Productive Assets of Farmers Households". In this report the average were computed from the unit level data available from

Table 2. Net farm Income per-hectare of crop area and cultivation

S. N.	Name of the State	Net farm Income per-hectare of crop area & cultivation				
		Marginal	Small	Marginal & Small	Medium & Large	All Holdings
1.	Andhra Pradesh	4224	5073	4637	5359	5047
2.	Assam	15765	14682	15269	15238	15260
3.	Bihar	7997	7566	7834	8479	8032
4.	Chhattisgarh	5317	5157	5227	4468	4809
5.	Gujarat	5717	5875	5806	5536	5630
6.	Haryana	9922	9151	9523	8155	8567
7.	Himachal Pradesh	7887	11674	9157	11785	9707
8.	Jammu & Kashmir	20330	20295	20317	13079	18067
9.	Jharkhand	10655	9406	10169	8898	9854
10.	Karnataka	5695	6333	6028	5672	5796
11.	Kerala	16829	18109	17216	15799	16921
12.	Madhya Pradesh	5294	4060	4531	5203	5001
13.	Maharashtra	6547	5712	6032	3653	4232
14.	Odisha	3448	3096	3306	2939	3204
15.	Punjab	18582	15780	16701	16615	16632
16.	Rajasthan	2651	1392	1962	1345	1499
17.	Tamil Nadu	6088	3658	5120	7723	6295
18.	Uttarakhand	11286	8527	10730	64752	21358
19.	Uttar Pradesh	6700	7399	6998	8281	7421
20.	West Bengal	9528	9444	9503	9512	9503
	All India	7809	6955	7414	6080	6694
	Cost of Cultivation per ha	6975	6046	6530	5252	5841
	Benefit (in %) as compared to cost of cultivation per ha	112	115	114	116	115

Note: All India includes small States Goa, Delhi, Pondicherry, NE-States & Uts.
Source: Computed using NSS unit level data 59th Round on Situation Assessment Survey of Farmers-Ministry of Statistics & Programme Implementation, New Delhi.

NSSO. Value of output per household was divided by average size of holding to arrive at the value of output per hectare for various size classes. Situation Assessment Survey, NSSO 59th Round, Report No.497 indicates that land productivity was inversely related to farm size class. Per hectare value of crop output was Rs.25,173 at holdings below 0.4 ha and Rs.18,921 at holdings of size 0.4 ha to 1 ha As the farm size increased towards 2 ha productivity declined to less than Rs.17,000 per hectare. In large farms (4 ha to 10 ha) the value of aggregate crop production declined to Rs. 13,500 per hectare. Farmers operating on landholdings above 10 ha (the very large size category) were found to have very low productivity (Rs.7,722) which was about half of the productivity at large holdings and less than one third of the productivity in the bottom farm size category. Productivity in marginal and small holdings was found to be much higher than the average productivity for all size categories. Per capita output is low on smallholdings despite higher productivity, due to lower per capita availability of land.

As per the nationwide surveys of farm households conducted by NSSO, it is evident that the lower size of holdings in India have been using higher dose of inputs, making more intensive use of land and adopting new technology on a much larger scale compared to farms in the larger size categories. These patterns of negative association between farm size and productivity enhancing variables have not diluted over time with the advancement of technology or modernization of agriculture. The negative relationship between farm size and aggregate productivity is quite pronounced even in the recent years. It seems that emerging changes in labour market and the rising demand for labour will further increase advantage of smallholders over large size holdings. The much vaunted scale advantage has not provided any edge to larger size holdings, nor has it constrained production in marginal and smallholdings. On the contrary, the available evidence suggests that productivity of Indian agriculture may rise significantly if land inequality is reduced in favour of lower size holdings.

Despite a strong advantage in land productivity and much better production performance, smallholders earn an awfully low amount of income from agriculture on a per capita basis primarily due to very adverse land man ratio. As per available estimates (2010-11), per capita availability of land in marginal holdings (<1 ha) is 0.38 ha, small holdings (1 to 2 ha) it is 1.42 ha, medium (4 to 10 ha) is 5.76 ha and large (10 ha and above) is 17.37 ha As such, there is a need to work out whether such a tiny piece of land can generate enough income to take care of the livelihood needs of a farm family.

The average consumption per farmer household per month in all categories is Rs.2,770 which is higher than income (Rs 2,115), leading to shortfall of about Rs.655 in India. As such there is high need to create employment outside agriculture sector in rural areas itself for sustaining income of farmers and also to support their livelihoods. Taking into account the size of the family, average net farm income per hectare from agriculture per hectare of land comes to Rs. 6,694. *"This income was compared against the Planning Commission norm of poverty line for rural areas which shows that a farmer operating less than 0.64 ha area will be under poverty, while as per the Tendulkar Committee norms, a minimum 0.8 ha of land area is needed to keep a farm family above the poverty line, if this family lives only on agricultural income. This implies that 62% of farmers in India, who own less than 0.80 ha of cultivable land, would be under poverty if they do not have an opportunity to earn income outside agriculture"(Chand et al, 2011, p.10).*

It is also evident that with the present level of productivity three-fourths of the population of smallholders cannot meet their livelihood from farm income alone. There are mainly two ways to improve their income and livelihoods. Firstly, an increase in the land-man ratio, which is possible only if a sizeable segment of smallholders is moved out of agriculture and secondly, to provide alternative sources of employment to smallholders in or around their habitation to supplement their farm income. The experience of past six decades in India and China show that the strategy of raising the land-man ratio by shifting a sizeable number of farmers cultivators away from agriculture has not worked in the Asian region. Despite the rapid growth of the economy during the last three decades, the size of landholding in China is only 0.6 ha similarly, the acceleration in India's economic growth after the early 1990 could not check the growth in population of smallholders. Based on these experiences and those of other countries in Asia, the option of raising the income of smallholders by increasing the land-man ratio was not found workable. Another strong factor against the first option is that an increase in the size of land holdings results to lower productivity. Therefore, there is need to create employment avenues for smallholding cultivators outside agriculture within the countryside itself so that workforce in smallholder households partly works on the farm and partly outside farm. This model of development has helped China to improve livelihood and eliminate poverty in small farm households.

Driving elements for sustaining land holdings and foodgrain production

The major natural resources/ inputs required for enhancing agricultural production are land/soil management, water resource development, soil health management, reclamation of problem soils, addressing the issues of climate change adaptation and mitigation, capacity building & training for harnessing the productive potential of rainfed areas along with timely availability of inputs, support for marketing infrastructure, increase in flow of credit particularly to the farmers may further boost economic sustainability.

Agrarian reforms

Identification of need-based technological interventions

Previous *agrarian reforms* have lessened the inequality in access to land, water, credit, knowledge, and markets, and in income distribution; simultaneously, they have increased agricultural productivity. Such reforms must be adopted to the widest possible extent. Secure access to natural resources encourages sustainable production; it also helps in insulating the small-holders against displacement from their holdings as a result of encroachment by agricultural or non-agricultural entities. There are, however, opportunities in Indian agriculture where investment to gain benefit from economies of scale is both feasible and worthwhile. Notable such opportunities arise in processing, value-addition, and distribution of produce. There are successful experiences of large-scale (co-operative) milk processing in Gujarat and of sugarcane processing in Maharashtra. Such examples should be replicated in other states, and the methodology adopted for should be adopted for other commodities and products.

Farming education and awareness

It is correspondingly significant that almost one-half of the heads of India's farm households lack formal education and awareness; it is pertinent that more than four-fifths of India's child labour work in the agricultural sector, and that most of those children belong to small-holder families. Educational attainment is similarly important in helping narrow the yield gaps and productivity gaps that persist throughout much of India's agriculture, and correspondingly in helping raise total factor productivity. There are indeed proven methodologies for meeting the some of those gaps and for raising factor productivity; adoption of those methodologies shall be more rapid when the agricultural population is better educated.

Development and diffusion of appropriate technologies

Improved agricultural technologies are "size-neutral"; however, some of them are not "resource-neutral". Hence in generating improved agricultural technologies, small-holder-oriented research and extension should emphasize "cost reduction without yield reduction". This might be pursued through integration of non-monetary inputs, low-cost technologies such as integrated pest management, integrated plant nutrition systems, water harvesting and recycling, and monitoring of efficient use of natural and purchased resources. There shall thus be need for enhanced and sustained investment in research, technology development, human-resource development, and especially extension. These investments have diminished in recent years, and there is urgent need for re-invigoration and for a paradigm shift towards farmer participation - particularly in relation to non-monetary technologies. *Livestock* have a major and increasing role in small-holder mixed-farming systems. To enhance labour productivity on small-holdings, priority needs are *tools* - small, but perhaps mechanized - wherewith drudgery can be lessened but employment maintained. Such tools will add value to the work hours. In *post-harvest* handling, agro-processing, and value-addition activities, the priority intervention has to be to disseminate more widely various available, proven technologies. These available technologies serve not only to reduce post-harvest losses, but also to improve product quality through effective storage, packaging, handling, and transport, such that export-quality items can be marketed.

Contract farming

Contract farming system may help the small and marginal farmers to overcome constraints in accessing inputs, credit, extension and marketing. In recent years, there has been some form of contract arrangements in several agricultural crops such as tomatoes, potatoes, chilies, baby corn, rose, onions, cotton, wheat, basmati rice, groundnut, flowers, and medicinal plants and is spreading throughout India in states like Andhra Pradesh, Tamil Nadu, Karnataka, Punjab and Maharashtra. Contract farming in India is neither backed up by law nor by an efficient legal system. This is the single most constraint to widespread use of contract farming in India. The legal system may improve with legislative measures like the model contract and code of practice, registration of contracts with marketing committees and tribunals for efficient, speedy and corrupt-free dispute resolutions.

On farm water management

The availability of water for irrigation is decreasing, and therefore, there is need for improving water use efficiency to make best use of available water resources for enhancing water productivity. With this in view a Centrally Sponsored Scheme on micro-irrigation was launched in January, 2006 during the XI Plan for implementing drip and sprinkler irrigation system, which is now transform as National Mission on Micro Irrigation (NMMI). As NMMI enhances scope for area coverage with same quantum of conserved water leading to saving of irrigation water, fertilizers & electricity and increases production & productivity, therefore, highest thrust has been given for NMMI under National Mission for Sustainable Agriculture (NMSA) during XII Plan to address the issues of enhancing water using efficiency.

Co-operative farming and farming co-operatives

India has a long and successful history of farmers' co-operatives, through which small-holders increased their bargaining power as buyers of inputs and sellers of products. Such bargaining power shall become increasingly important as trade globalization expands. A newer development is the *co-operative group-farming* enterprise, wherein households retain their land-ownership rights, but pool and share their farming resources, operations, and benefits. In appropriate circumstances, such group-farming has potential to transform subsistence agriculture to demand-driven, commercial agriculture, and perhaps to increase rural-community post-harvest enterprise, employment, and income.

Institutional and infra-structural supports

As discussed in the preceding para, the proposed large-scale rural co-operatives would expect to provide a cost-effective "single-window-delivered" array of technical and financial services. For the *individual* small-holder producers of primary products, the technical services would expect to include custom-hire facilities and operators wherewith to undertake timely and efficient pre- and post-harvest *field-crop*-production activities, and on-farm guidance and assistance in *horticultural* and in *livestock* husbandry. For contiguous small-holdings, *community* services would include crop- and livestock-marketing support, and irrigation-water supply - in partnership with water-users' associations where appropriate. It is thus re-confirmed that institutional and initial financial support - from national or/and state agencies – need to be provided to the embryonic large-scale co-operatives.

Non-farm employment for ensuring economic sustainability

On the perusal of the various data and its analysis, it is observed that with present level of land holding and system of cultivation, majority of the farmers are not getting proper income. This calls for the introduction of other various interventions for creation of additional employment, outside agriculture sectors for livelihood support. Such interventions may include off-farm employment. For this purpose small-holders who are under continuous pressure to increase production from their limited land resources. Policies and strategies, existing and new, must help to diversify on-farm and off-farm activities and thereby enhance sustainability and productivity. The income from off-farm and non-farm employment assists the small-farm households to become or remain hunger-free. For the rural poor, strengthened rural infra-structures-particularly connections to major roads and highways-would facilitate the development of small enterprises, agro-based activities, and markets, and increase off-farm and non-farm employment opportunities.

SUMMARY & RECOMMENDATIONS

Analysis of various data and survey reports on ensuring economic sustainability of the farmers with various type land holdings in the present statutory provisions lead to following recommendations:

Difference in income and consumption of different category of farmers reveals that semi-medium farm householders are having little loss and are efficiently managing the available resources for sustaining their income. Therefore, optimum size of agricultural land holding could be about 2.0 hectare to 4.0 hectare (semi-medium farm holding) for economic sustainability of farmers, adoption of mechanization, conservation agriculture, micro irrigation systems etc.

Policies and strategies, existing and new, must help to diversify on-farm and off-farm activities and thereby enhance sustainability and productivity. Small farmers are engaged in off-farm paid work in Peri-urban areas and such work may be in the tourism and eco-tourism industry, or in various agriculture or non-agriculture-related enterprises. In comparison to rural area, the peri-urban areas are usually better endowed with road, transport, market and other infra-structures; they thereby have easier access to off-season employment opportunities, and poor people are less poor than the rural poor. Under this situation for the rural poor, strengthening rural infra-structures would facilitate in development of small enterprises, agro-based activities leading to increase in off-farm employment opportunities.

Various Succession Acts for transfer of inheritable of properties reveals that Hindu Succession (Amendment) Act, 2005 passed by the Parliament, has comprehensive systems for transfer of parental properties with special empowerment of Hindu females, who have been allowed to be absolute owner of the inheritable properties and can dispose it by will as they like. However, large scale capacity building and awareness amongst the stakeholders, monitoring of such provisions besides ensuring easy assessment of such land records of Indian Farmers will create higher transparency and adoption.

As per Seventh Schedule of the Constitution of India, land including transfer and alienation of agricultural land, falls under the purview of the State Governments and, therefore, it is for the State Governments to frame suitable Policy / enact

Legislation to prevent diversion of agricultural land for non-agricultural purposes which also results in land fragmentation and reduction in size of land holding. Government of India role, in these areas are limited to advisory and accordingly National Policy for Farmers, 2007 (NPF-2007) and National Rehabilitation and Resettlement Policy, 2007(NR&RP-2007) have been formulated and circulated to the States for adoption. These policies envisage, minimum acquisition of agricultural land for non-agricultural purposes. Besides, there is need for effective implementation of various provisions of these policies and its online monitoring for ensuring optimum size of land holdings for economic sustainability of farmers.

National Mission on Micro Irrigation (NMMI) which is mainly for enhancing large area coverage with minimum water leads in improvement of water and chemical fertilize use efficiencies, besides, enhancement in production & productivity. Therefore, during XII Plan has to be accorded for adoption of NMMI to address the issues of climate change adaptation and mitigation.

Contract farming in India is neither backed up by law nor by an efficient legal system, which is the single most constraint in widespread use of contract farming in India. As such, improvement in legal system with suitable legislative measures like, model contract & code of practice, registration of contracts with marketing committees and tribunals for efficient, speedy dispute resolutions.

REFERENCES

Anonymous, "Land Use Statistics at a Glance, 2001-02 to 2010-11. Directorate of E&S, DAC, MOA, GOI, New Delhi, April, 2013".

Anonymous, "Computed using National Sample Survey Organization (NSSO). 59th Round on Situation Assessment Survey of Farmers.

Chand, R., P.A. Lakshmi Prasanna and Aruna Singh, 2011. "Farm Size and Productivity: Understanding the strengths of smallholders and improving their livelihoods", Economics and Political Weekly, Vol. 46, Nos. 26 and 27.

Dev, S. Mahendra, "Small Farmers in India, Challenges and Opportunities"-Indira Gandhi Institute of Development Research, Mumbai June, 2012.

Lipton, M., 2006. "Can Small Farmers Survive, Prosper, or be the Key Channel to cut Mass Poverty". Journal of Agricultural and Development Economics, Vol.3, No. 1, 2006.

Rao, CH, Hanumatha, 2005. Agriculture, Food Security, Poverty and Environment" Oxford University Press, New Delhi.

Singh, Ajit Kumar, "Income and Livelihood Issues of Farmers: A Field Study", Agricultural Economics Research Review, Vol. 26-2013 pp 89-96.

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