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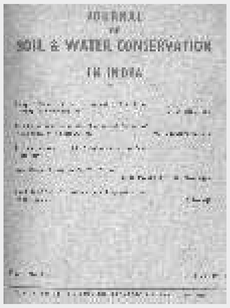

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Contents

Pledge

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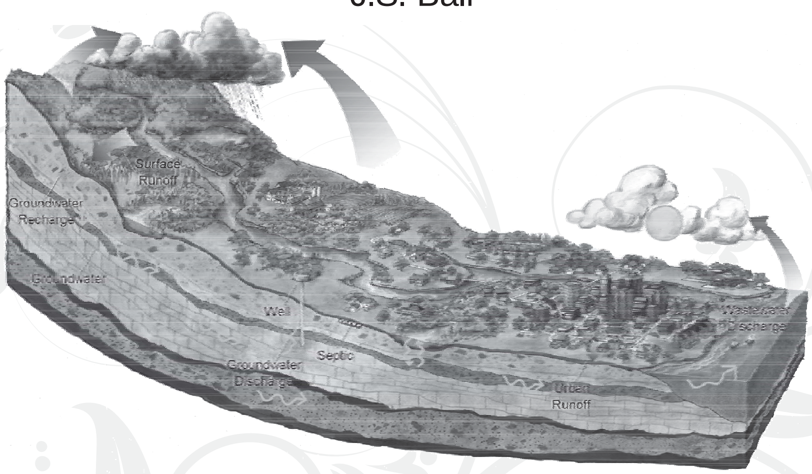

I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
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which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,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

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Effect of topography and vegetation on soil development in Kumaon hills of North Western Himalayas

TAPAN GORAI[1], N. AHMED[2], S. K. MAHAPATRA[3], S. C DATTA[4], R D SINGH[5] and R. K. SHARMA[6]

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ABSTRACT

Four representative pedons, Airideo on hill top (P1), Basauli on side slope (P2), Someswar on broad valley (P3) and Kosi on narrow valley (P4) in a toposequence in Kumaon region (Almora district) of Uttarakhand, were studied for their characterization and soil development. The hilltop is moderately dense forest with *Pinus roxburghii* and the side slope (Basauli) is covered with mixed vegetation. Soils of Someswar and Kosi are cultivated. In general, the soils were moderately deep in the hill top, shallow in the side slope and narrow valley, and deep in the broad valley. Soil dry colour ranged from grayish brown (10 YR 5/2) to very pale brown (10 YR 7/4) with texture varying from sandy clay loam, sandy loam to clay loam and bulk density increased with increase in depth. These soils were non saline, moderately acidic (pH 5.5 to 6.4) and increased in pH with depth, except P3 soils where the pH decreased (5.8 to 5.5) from the surface (Ap) to surface horizon (Bw1). Organic carbon decreased with increase in depth except in P2 and P3 soils. In P3 soils, a marked increase in CEC with increase in depth (13.7 to 16.8 cmol (p+) kg^{-1}) may be due to enrichment of fine clays transported from higher elevation whereas lower CEC was due to sandy loam texture in P4 soil. The soils in the toposequence in the Kumaon region of lesser Himalayas has been classified as fine loamy kaolinitic thermic Typic Dystrudepts (P1, hill top), fine loamy illitic thermic Lithic Udorthents (P2, side slope), fine loamy mixed thermic Fluventic Dystrudepts (P3, broad valley) and coarse loamy mixed thermic Typic Udorthents (P4, narrow valley) respectively.

Key words: Toposequence, Kumaon hills, soil morphology, soil classification, soil development

INTRODUCTION

Soils are indispensable resource but their multipurpose and long-term exploitation has serious consequences on the overall ecology of a particular region. Inappropriate agricultural practices, overgrazing of grassland and indiscriminate deforestation cause soil degradation, decline in soil fertility, productivity and soil quality besides environmental hazards (Blum, 1997). The sustainable use of soil resource requires an extensive knowledge about its genesis, morphology and other properties. The landform analysis of Almora district, which falls in Kumaon region of north western Himalayas, was carried out by Martin *et al.* (2007) in 1:50,000 scale with the help of IRS 1D remote sensing. Verma *et al.* (2008) reported the effect of slope and aspect on soil formation like Mollisols on northern slopes and Inceptisols on southern slopes of Tehri Garhwal region of Uttarakhand. Panwar and Pal (2010) assessed soil fertility in relation to altitude, slope and aspect in a hilly micro-watershed of lower Shiwalik. Saran *et al.* (2011) also reported the variation of soil and land characteristics along the slope transects in micro-catchments of Shiwaliks in lower Himalayas. Bell *et al.* (1994) analyzed landform-soil relationship to understand spatial patterns of soil attributes in similar geological and climatic conditions. Several authors (Mishra and Ghosh, 1995 and Pai *et al.* 2007) analysed soils on

[1]Assistant Professor cum Junior Scientist, Bhola Paswan Shastry Agricultural College, Purnea-854302; [2] Principal Scientist & Corresponding author (email: nay_ssc@yahoo.com); [3] Principal Scientist, National Bureau of Soil Survey and Land Use Planning, Delhi Regional Centre, IARI Campus, New Delhi-110012. [4]Principal scientist; [5]Professor, [6]Technical Officer, Division of Soil Science and Agricultural Chemistry, IARI, New Delhi-110012

the toposequence basis which provides a useful paradigm to understand relationships between soil and land cover at a spatial dimension. The classification of soils according to internationally accepted systems is also helpful for soil conservation, transfer of technology and facilitates land use planning (FAO-ISRIC-ISSS, 1998). The varied geological, physiographic, climatic and vegetation characteristics have given rise to a variety of soil types in this Himalayan region. Mountainous lands are known be prone to severe soil degradation and exhibit differences in their characteristics because of their complex physiography and altitudes. Knowledge of these soils in respect to characteristics, classification, use potential and their limitations is extremely important for optimizing land use. There is no earlier report of soil study on toposequence basis in this region in respect to their characteristics and classification which is extremely important for optimizing land use. Therefore, an attempt was made to study the morphological, physical and chemical characteristics of the soils along a toposequence in Almora district of Uttarakhand for detailed characterization and classification.

MATERIALS AND METHODS

The study area belongs to Kumaon hill region of Western Himalayas, in Almora district, Uttarakhand and lies between 29º 37' N to 29º 49' N latitudes and 79º 37' E to 79º 44' E longitudes and covers an area of about 5385 sq.km. Four representative pedons of distinct physiography from the locations namely Airideo (P1, hill top), Basauli (P2, side slope), Someswar (P3, broad valley) and Kosi (P4, narrow valley) with altitudes of 2000 m, 1400 m, 1200 m and 1100 m above mean sea level respectively (Fig 1), were studied for morphological characteristics. Basuli soils occur on very steep slopes (30-50%), Airideo and Kosi soils on moderate steep slopes (8-15%) whereas Someswar soils on gentle slope (3 to 5%). In the lesser (mid) Himalayas, the parent rocks include mica schists, granite, gneisses, slates, phyllites, sandstones, quartzites and limestones.

The climate is warm subhumid (to humid with inclusion of perhumid) and the mean annual precipitation (both rainfall and snowfall) ranges from 1100 to 1700 mm. Mean annual minimum and maximum temperature is about 2 ºC and 24 ºC respectively. The soil moisture and temperature

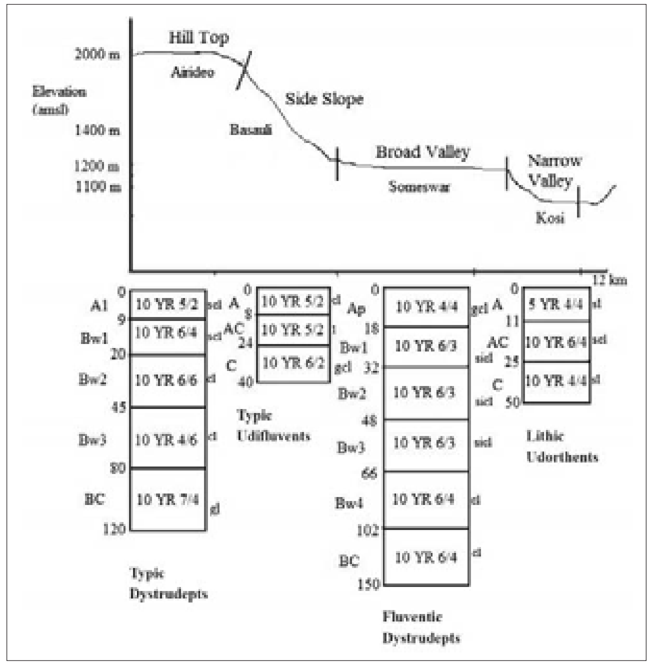

Fig. 1. Schematic diagram of landscape- soil relationship of the study area

regime are udic and thermic. The hilltop (Airideo region) is moderately dense forest with *Pinus roxburghii* and the side slope (Basauli) is covered with mixed vegetation like oaks - *Quercus incana, Quercus dialta,* and conifers - *Cedus deodara, Pinus wallichiana, Picea smithiana* and *Abies pindrow*. Someswar and Kosi are cultivated with paddy, jowar, bajra, maize, sunflower, wheat, mustard and horticultural plantation such as pears, plum and peach.

Mechanical composition and textural class of the soil was determined as per the USDA textural diagram (Soil Survey Staff, 2006). Bulk density of soil was estimated by clod method (Prihar and Hundal, 1971). Soil pH was measured in 1:2.5 soil water suspensions and suspension and soil: 1N KCl solution using a combined electrode (glass and calomel) in a digital pH meter and electrical conductivity was measured in the supernatant liquid of the soil water (1:2.5). Soil organic carbon was determined by wet oxidation method (Walkley and Black, 1934). Cation exchange capacity (CEC) of soil was determined by centrifuge method using 1N sodium acetate (pH 8.2) and after extracting exchangeable cations with neutral normal ammonium acetate, exchangeable calcium and magnesium were analysed by versenate method and exchangeable sodium and potassium were measured in flame photometer. Semi quantitative estimates of clay minerals were made using XRD technique following standard methods (Gjems, 1967). The soils were classified up to family level as per soil taxonomy (Soil Survey Staff, 2006).

RESULTS AND DISCUSSION

Morphological characteristics of the soils

The depth of soils along the toposequence in Almora District was found to vary from shallow to deep. Moderately deep soil on the hill top was found with relatively flat topography. The soils in broad valley were found to be deep which were developed on comparatively stable landform of alluvium and colluviums. Shallow soils in side slope and narrow valley near Kosi River were due to higher gradient of slope and erosion and less chance for soil developments. Rao *et al*. 1997 had reported variation of soil depth with physiographic variations. The BC horizon of Airideo soil and regolith of Basauli soil had 15 to 20% coarse fragments and so modifier group gravelly was used in texture. The presence of gravels in surface soil of Airideo may be attributed to colluvial movement of rock and coarse fragments. In general, the hue of soil matrix in dry soil was 10YR with value ranging from 7 to 4 and chroma from 4 to 2 whereas in moist condition, hue varied from 5YR to 10YR along with value ranging from 3 to 5 and chroma from 1 to 6 (Table 1). Singh *et al*. (1993) studied a toposequence in central Himalayas and reported that generally 10YR was found to be common hue in moist and dry conditions for upland soils but only in moist conditions for the midland region. The surface soil structure in Airideo and Someswar was crumb due to leaf litter deposition in the forest whereas the sub-soil structure was medium moderate sub-angular blocky. The soil structure in Basauli and Kosi was observed to be fine weak granular in the surface as well as in the sub-surface soil.

Physical characteristics

The Airideo soil (P1) had 34 to 52% sand, 22 to 34% silt and 26 to 34% clay y in soil profile (Table 2). The A1 and Bw1 horizons of Airideo soil in hill top was sandy clay loam in texture whereas Bw2 and Bw3 horizons was clay loam in texture indicating vertical migration of finer fractions through profile and also removal of finer fractions from surface soil through water because of high rainfall (Sarkar *et al.* 2002). In Someswar (P3), soil texture varied from clay loam in surface soil to silty

Table 1. Morphological characteristic of soils on the toposequence

Profile	Depth (cm)	Horizon	Matrix colour		Texture[a] (USDA)	Structure[b]	Coarse fragments(%)
			Dry	Moist			
Airideo	0-9	A1	10 YR 5/2	10 YR 3/2	scl	f2 cr	-
	9-20	Bw1	10 YR 6/4	7.5 YR 5/6	scl	m2 sbk	5-10
	20-45	Bw2	10 YR 6/6	7.5 YR 5/6	cl	m2 sbk	5-10
	45-80	Bw3	10 YR 4/6	10 YR 3/6	cl	m2 sbk	10-15
	80-120	BC	10 YR 7/4	10 YR 4/6	gl	m2 sbk	15-20
Basauli	0-8	A	10 YR 5/2	10 YR 3/1	cl	f1 gr	-
	8-24	AC	10 YR 5/2	10 YR 4/2	l	f1 gr	10-15
	24-4040+	CR	10 YR 6/2	10 YR 4/2	gcl	f1 gr	15-20
Someswar	0-18	Ap	10 YR 4/4	7.5 YR 4/4	gcl	f2 cr	15-20
	18-32	Bw1	10 YR 6/3	7.5 YR 4/4	sicl	m2 sbk	10-15
	32-48	Bw2	10 YR 6/3	10 YR 4/2	sicl	m2 sbk	-
	48-66	Bw3	10 YR 6/3	10 YR 4/2	sicl	m2 sbk	-
	66-102	Bw4	10 YR 6/4	10 YR 3/2	cl	m2 sbk	-
	102-150	C	10 YR 6/4	10 YR 4/2	cl	m2 sbk	-
Kosi	0-11	A	10 YR 4/4	5 YR 4/4	sl	f1 gr	-
	11-25	AC	10 YR 6/4	5 YR 4/4	scl	f1 gr	-
	25-50	C	10 YR 5/4	5 YR 4/4	sl	f1 gr	5-10

[a] scl-sandy clay loam, cl-clay loam, l-loam, gl-gravelly loam, gcl-gravelly clay loam, sicl-silty clay loam
[b] f-fine, m-medim, 1-weak, 2-moderate, cr-crumb, gr-granular, sbk-subangular block

Table 2. Physical properties of different soils along the toposequence

Soil depth (cm)	Bulk density (Mg m^{-3})	Clay%	Silt%	Sand%	Sand / Silt	Silt / Clay	Texture
Airideo (P1, hill top)							
0-9	1.33	26	22	52	2.34	0.83	Sandy clay loam
9-20	1.46	32	22	46	2.07	0.68	Sandy clay loam
20-45	1.49	34	32	34	1.05	0.93	Clay loam
45-80	1.44	32	34	34	0.99	1.05	Clay loam
80-120	1.65	26	30	44	1.45	1.13	Loam
Basauli (P2, side slope)							
0-8	1.33	26	36	38	1.04	1.36	Clay loam
8-24	1.38	24	40	36	0.89	1.63	Loam
24-40	1.46	30	40	30	0.74	1.31	Clay loam
Someswar (P3, broad valley)							
0-18	1.40	36	32	32	0.99	0.88	Clay loam
18-32	1.47	36	44	20	0.44	1.21	Silty clay loam
32-48	1.60	38	44	18	0.40	1.14	Silty clay loam
48-66	1.47	36	48	16	0.32	1.32	Silty clay loam
66-102	1.69	30	36	34	0.93	1.18	Clay loam
102-150	1.45	32	40	28	0.69	1.23	Clay loam
Kosi (P4, narrow valley)							
0-11	1.65	18	16	66	4.10	0.87	Sandy loam
11-25	1.65	20	18	62	3.42	0.88	Sandy clay loam
25-50	1.55	18	18	64	3.53	0.97	Sandy loam

clay loam in subsurface soil, which is due to the fluvial action and / or eluviations of fine silt and clay during puddling in rice-wheat cropping system (Maity *et al.* 2006). Kosi soil(P4) in the narrow valley contained weighted average of 63% sand, 18% silt and 19% clay in 0-50 cm soil depth which could be attributed to dominance of physical weathering and washing out of finer soil fractions by run-off water (Vara Prasad Rao *et al*. 2008). Bulk density in different horizons of soils along the toposequence ranged from 1.33 to 1.69 Mg m^{-3} (Table 2). Bulk density (BD) of Airideo and Basauli soils increased with depth due to the filling of pores by eluvial finer particle fraction and also over-burden pressure causing compaction of finer particles in deeper horizon, whereas surface soils were less compact probably due to high amount of organic matter and plant root concentration (Coughlan *et al.* 1986). The Someswar soils of the broad valley had bulk density ranging from 1.40 to 1.69 Mg m^{-3} which varied irregularly with depth corresponding to variation in the composition of alluvial and colluvial materials in different layers along with different compaction levels (Walia and Rao, 1996). Bulk density in different horizons of Kosi soil ranged from 1.55 to 1.65 Mg m^{-3}, which was slightly higher than that of other surface soils due to coarser soil texture.

Chemical characteristics

Airideo (hill top), Basauli (side slope) and Kosi soils (narrow valley) were slightly acidic (6.0-6.4) but in Someswar (broad valley) there was further decrease in pH (5.8-5.5) between 0-50 cm depths. In hill top, soil was acidic due to coniferous vegetation and acidic litter material, high rainfall and leaching of bases (Gangopadhyay *et al.* 2001). Someswar soil in the broad valley had pH varying from 5.5 to 6.4 with a weighted average value of 5.7 i.e. moderately acidic. Overall, the soils were non-saline, slightly acidic and pH difference (pH_{KCl}-pH_{H2O}) was always negative indicating that the soil colloids had a net negative charge and considerable amount of exchangeable acidity. The range of soil CEC was 8.5 to 16.8 cmol (p^+) kg^{-1} (Table 3) with comparatively higher CEC (13.7 to 16.8 cmol (p^+) kg^{-1}) in Someswar and lower CEC ranging from 8.5 to 8.7 cmol (p^+) kg^{-1} in Kosi soil.

Stepwise multiple regression equation of soil

Table 3. Chemical properties of different soils along the toposequence

Soil depth (cm)	pH (1:2.5)		EC (dS m^{-1})	WBC (%)	CEC [cmol (p^+) kg^{-1}]	Exchangeable cations [cmol (p^+) kg^{-1}]				Base saturation (%)
	water	1 *N* KCl				Ca^{2+}	Mg^{2+}	K^+	Na^+	
Airideo (hill top)										
0-9	6.0	4.7	0.09	2.1	16.6	8.62	2.00	0.55	0.99	73
9-20	6.2	4.3	0.05	0.4	10.6	2.87	1.38	0.35	0.78	51
20-45	6.2	4.4	0.05	0.4	11.0	4.25	1.50	0.40	0.78	63
45-80	6.2	4.4	0.05	0.2	12.9	3.75	2.13	0.35	0.71	54
80-120	6.2	4.5	0.09	0.2	10.2	4.00	1.75	0.35	0.90	69
Basauli (side slope)										
0-8	6.0	4.6	0.10	1.5	13.9	5.37	2.50	0.26	0.91	65
8-24	6.4	4.7	0.06	0.9	12.9	6.37	1.50	0.17	0.76	68
24-40	6.3	4.6	0.09	1.3	14.8	5.12	4.63	0.19	0.81	73
Someswar (broad valley)										
0-18	5.8	4.4	0.07	1.4	13.7	4.50	3.75	0.24	0.64	67
18-32	5.6	3.9	0.05	0.9	15.6	6.00	2.38	0.13	0.62	59
32-48	5.5	3.9	0.05	1.1	16.8	6.25	2.63	0.15	0.68	58
48-66	6.0	4.2	0.04	1.0	16.2	6.75	2.75	0.14	0.73	64
66-102	6.4	4.5	0.04	0.8	15.6	6.25	3.75	0.15	0.71	70
102-150	6.3	4.8	0.05	0.7	14.3	5.50	0.50	0.12	0.68	57
Kosi (narrow valley)										
0-11	6.4	4.9	0.07	0.6	8.7	2.75	2.25	0.16	0.69	67
11-25	6.4	4.7	0.07	0.4	8.5	2.87	1.88	0.12	0.68	65
25-50	6.3	4.6	0.05	0.2	8.7	3.37	2.13	0.10	0.62	71

CEC was derived as:

Soil CEC = 3.148 + 3.156 × WBC (%) + 0.249 × Clay (%);

R^2 = 0.761 and partial regression coefficients are significant at 1% level of significance.

The sequence of exchangeable cations was exch. Ca > exch. Mg > exch. Na > exch. K and similar trend was also reported by Sarkar *et al.* (2001). These soils were moderately base saturated with values ranging from 51 to 73%, which is due to the high rainfall and slightly acidic soil nature of the region. Comparatively higher base saturation in the sub-surface layers of Basauli and Kosi soils may be attributed to the weathering and subsequent leaching of cations while the lowest base saturation observed in the sub-surface horizons (18 to 48 cm) of Someswar soil was attributed to the corresponding low pH due to rice cultivation.

Organic carbon in surface soils of Airideo (hill top), Basauli (side slope) and Someswar (broad valley) was observed to be high (2.1 to 1.4 %) whereas in Kosi (narrow valley) soil, organic carbon was medium (0.6%). The higher organic carbon in surface horizon of Airideo in hilltop and Basauli on hill slope is due to addition of large amounts of leaf litter through leaf fall and also due to absence of intensive cultivation of field crops in hilltop and on hill slope leading to low removal or depletion of organic carbon from the surface soil; consequently the surface soils recorded higher organic carbon. The high soil organic carbon content in Basauli (side slope soils) under mixed vegetation of oak and pine forest is in contrast with the low oak litter deposition, but this might be due to the low C:N ratio of oak litters which is indicative of its fast decomposition (Singh and Bhatnagar, 1997). Organic carbon gradually decreased with depth in all soil profiles except Someswar soils where organic carbon distribution was irregular due to fluvial and colluvial nature of parent material.

Toposequence variability of different soil properties

The statistical analysis (Table 4) of horizon thickness showed a consistently wide range of variability within the different landscape position as indicated by low standard deviations (4.6 to 13.9)

Table 4. Mean (M), standard deviation (SD) and coefficient of variation (CV) of soil properties

	Horizon thickness (cm)	Clay (%)	Silt (%)	Sand (%)	Soil pH	Bulk density (Mg m^{-3})	CEC {cmol (p^+) kg^{-1}}	WBC[1] (g kg^{-1})
Airideo (hill top)								
Mean	24.0	31	28	42	6.2	1.5	12.3	6.7
SD	13.9	3.7	5.7	7.9	0.1	0.1	2.6	8.1
CV (%)	57.9	12.3	20.2	19.0	1.3	7.9	21.6	119.8
Basauli (side slope)								
Mean	13.3	27	39	34	6.2	1.6	13.9	12.7
SD	4.6	3.1	2.3	4.2	0.2	0.3	0.9	3.2
CV (%)	34.6	11.3	6.0	12.2	3.4	20.5	6.8	24.7
Someswar (broad valley)								
Mean	25.0	35	41	24	5.9	1.6	15.4	9.9
SD	13.8	3.0	5.9	7.7	0.4	0.1	1.2	2.4
CV (%)	55.1	8.6	14.5	31.7	6.1	8.2	7.5	24.5
Kosi (narrow valley)								
Mean	16.7	19	17	64	6.4	1.6	8.7	4.1
SD	7.4	1.2	1.2	2.0	0.1	0.1	0.1	1.7
CV (%)	44.2	6.0	6.7	3.1	1.4	3.4	1.4	40.3

[1]WBC-Walkley and Black Carbon

and high coefficient of variation (34.6 to 57.9). The soils developed on the Someswar (broad valley) showed thicker horizons (25 cm) because of frequent deposition from upper topographic positions. Basauli and Kosi soils showed thinner horizons with minimum solum thickness due to steep slope gradient and higher erosion restricting soil development. Kosi soil showed highest amount of sand content (mean value 63.5%) with a narrow range of variability amongst the horizons and consistent with physiographic position. Airideo soils occur on flat topography in hill top, have higher clay content in subsoil and thus are relatively stabilized. Someswar soil was found to have highest silt (mean value 41%) and clay (mean 35%) due to alluvial and colluvial parent material. A fairly constant increase in the mean and weighted mean values of CEC was observed from hilltop to broad valley as controlled by organic matter, clay content and its constituent clay minerals. Organic carbon had highest coefficient of variation (119.8%) in Airideo soil (Table 4) due to forest litter deposition and higher grass root in surface soil, followed by Kosi soil (40.3%), Basauli soil (24.7%) and Someswar soil (24.5%). Similar results of soil spatial variability among certain soil properties developed on hill top, side slope, broad valley and narrow valley in Siwalik hill areas of Punjab was also reported by Sawhney *et al.* (1996, 2005).

Soil classification

Airideo soils are relatively stabilized as they occur on flat topography and have cambic diagnostic horizon, 57% base saturation, udic moisture regime, 31% clay on weighted average basis, 72% kaolinite in the clay fraction in the soil control section (25 to 75 cm) and was classified as fine loamy kaolinitic thermic Typic Dystrudepts (Soil Survey Staff , 2006). Someswar soil also qualified for Dystrudepts great group with an irregular decrease of organic carbon between depths of 25 cm and 125 cm of the soil profile and having mixed type of mineralogy (45% kaolinite, 22% mica and 25% hydroxy interlayered vermiculite). So this soil was classified as fine loamy mixed thermic Fluventic Dystrudepts. Basauli soil, which lacked any evidence of soil profile development with unweathered parent material with unconsolidated bedrock below 50 cm and dominant illite mineral in the clay fraction, was classified as fine loamy illitic thermic Lithic Udorthents. Kosi soil, which is moderately shallow in depth with moderately steep slope and somewhat excessive drainage, was classified as coarse loamy mixed thermic Typic Udorthents. Mahapatra *et al*. (2002) also reported similar type of soils in Almora district.

Constraints and potentials

Proper soil and water conservation practices including engineering and agronomic measures should be adopted to arrest the soil loss and sustain the fertility status from the steeply sloppy areas (side slope, narrow valley). Basauli soils with slopes ranging from 30-50% should be brought under permanent forest vegetation of suitable fuel-fodder plant species and grasslands along with soil conservation measures like contour trenching / staggered trenching / contour furrows. Airideo soils with 15-30% slopes, terrace benches, bunds and risers may be utilized for suitable forest species, buffer hedgerows, shrubs, forage grasses and horticultural plantations i.e. agro-forestry using the concepts of biodiversity and principles of landscape ecology, serving to generate a diverse array of plants, a semi-forested area and to stabilize terrace, bunds and riser (Singh *et al*. 1990, Cao *et al*. 2007). Someswar and Kosi soils with having less than 15% slope may be cultivated for agricultural crops using engineering conservation techniques like contour bund, graded bund, bench terrace and agronomic practices like contour farming, mulching, intercropping with legumes, manures, fertilizers etc. on watershed management basis.

CONCLUSION

The soils in toposequence of Kumaon region of North Western Himalayas in Almora district of Uttarakhand show that the soils of the side slopes and narrow valleys are prone to erosions and have limited soil depth. There is a tendency of increase in bulk density with depth in the profiles of all physiographic units except in the narrow valley soils. The high rainfall and cold climate prevailing in the region is conducive for high leaching of the bases and slower decomposition of organic matter. The low base saturation values are indicative of high leaching of bases and dominance of mica and kaolinite. Airideo soils on hill top and Someswar soils on broad valley were well developed and belong to Inceptisols soil order while Basauli soil on side slope and Kosi soils on narrow valley were found to be relatively less developed and are classified as Entisols. Proper soil and water conservation measures can enhance soil fertility and productivity in this region.

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Soil carbon sequestration in different land use systems

M. C. MANNA[1], A. MANDAL[2] and Y.V. SINGH[3]

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ABSTRACT

The soil organic carbon is highly sensitive to changes in land use and management practices. The build-up of soil organic carbon has a direct impact on soil health. An inverse relationship was speculated between the soil organic carbon and global warming which is caused by an increase in the concentration of greenhouse gases (GHG) in atmosphere at the rate of 0.5% yr^{-1} (3.2 Pg C yr^{-1}) for CO_2, 0.6% yr^{-1} for CH_4 and 0.25 ppb yr^{-1} for N_2O. Contribution of these three GHGs to global warming is to an extent of 20% due to agricultural activities and 14% to change in land use and attendant deforestation. Principal agricultural activities that contribute to emission of GHGs include ploughing, application of fertilizers and manures, soil drainage, biomass burning and residue removal. The loss of soil C is accentuated by soil degradation (soil erosion, compaction, salinization *etc*.) and the assisted decline in soil quality. Historic global C loss due to agricultural activities is estimated as 55 to 100 Pg from soil C pool and 100 to 150 Pg from the biotic C pool. The long-term solution to the risk of potential global warming lies in finding alternatives to fossil fuel. Therefore, the strategy of soil C sequestration is a bridge to the future. Over the short-time horizon of 25 to 50 years, it is the simplest and most cost-effective option, and a win-win strategy.

Key words: carbon sequestration; land use systems; soil organic carbon

INTRODUCTION

Climate change involves alternations in temperature, precipitation, increase in sea level and increase in UV-B radiation in the atmosphere of Earth results in degrading environment, changing the growing rate of extinction of species, declining availability of water, loss of fertile land and so on (Basu 2008). The planet Earth is at this moment, radiating back to space a little bit less energy than what it receives from the Sun. The result is a small energy imbalance, amounting to roughly one watt of heat for every square meter of our planet's surface. This means that the Earth is now like a house which is being heated so efficiently that the production of new heat is more than the amount which escapes through the windows, walls and the roof. Sooner or later a new balance will be found and the amount of escaping heat will again be equal to the production. But until this new equilibrium is reached the planet will keep on heating. The build up of soil carbon is also intimately depending on the conservation agriculture practices. In this paper we have discussed the dynamics of soil carbon sequestration under different land use management systems.

Global warming

Where does this approximately 5000000 Gigawatt imbalance in our planet's energy budget come from? One reason is the so called greenhouse gases, water vapour, methane, carbon-dioxide, nitrous oxide, tropospheric ozone, the freons (or chlorofluorocarbons or CFCs) and some of the substances which have now largely replaced them (like the HCFCs). The greenhouse gases are able to "catch"' infrared or heal radiation before it escapes back to space from the surface of our planet, like an invisible glass of a greenhouse. Human activities are increasing the concentrations of greenhouse gases in the atmosphere, and by-doing this we are

[1]Principal Scientist, Division of Soil Biology, Indian Institute of Soil Science, Bhopal 462 038 (M.P.)
[2]Scientist, Division of Soil Biology, Indian Institute of Soil Science, Bhopal -462 038 (M.P.)
[3]Department of Soil Science & Agril. Chemistry, Institute of Agricultural Sciences, B.H.U., Varanasi, U.P

heating the planet. Another factor is the so called black aerosols, small soot particles, and tar balls which are produced when something is burned. They do not stay in the atmosphere for a very long time, but they absorb sunlight efficiently. Most scientists think that between 0.1 and 0.2 degree Celsius of the 0.8 degree warming which has already taken place, this far, has probably happened because the Sun has been a little bit more active than what is its long-term average. The home planet Earth is also overheating because of its albedo or reflectivity - its capacity to reflect sunlight directly back to space - is diminishing. Open water surfaces, forests, other vegetation and dark soils absorb most of the sunlight falling on them like a sponge, so when the ice and snow cover retreats in the Polar Regions the surface of the planet becomes darker. If the climate heats by a couple of degree centigrade, the average strength of hurricanes, and typhoons should increase by 50 per cent or more, which would make them much more destructive. The annual number of cyclones might also increase if the warming amounts to 6 degree or even much more intense.

Carbon sequestration

Sink of carbon from atmosphere to either plant into soil or from atmosphere into soil is called as soil carbon sequestration. Excluding carbonate rocks (inorganic carbon path), a soil represents the largest terrestrial stock of carbon, holding 1500 Pg (1Pg = 10^{15} g), which is approximately twice the amount held in the atmosphere and three times the amount held in terrestrial vegetation (McCarl *et al.* 2007). Soil inorganic carbon (SIC) pool contains 750 - 950 Pg C. Terrestrial vegetation is reported to contain 600 Pg C. The majority of carbon is held in the form of soil organic carbon, having a major influence on soil structure, water holding capacity, cation exchange capacity, the soils ability to form complexes with metal ions to store nutrients, improve productivity, minimize soil erosion *etc.* This organic carbon is highly sensitive to changes in land use systems (Post and Kwon 2000, Lakaria *et al.* 2012, Guimaraes *et al.* 2013) and management practices such as increased tillage, cropping systems, fertilization *etc.* leading to changes of status of soil organic carbon (Purakayastha *et al.* 2008). The land use with different cropping systems changes the soil organic carbon content in the soil (Table 1).

Table 1. Organic carbon in soil after six years of plantation with different land use options

System	Organic C (%)	
	0-15 cm	15-30 cm
Sole cropping	0.42	0.37
Agro- forestry	0.71	0.73
Agro- horticulture	0.73	0.74
Agro-silviculture	0.38	0.56

Source: Das and Itnal (1994)

Consequences of soil erosion on C-sequestration

Soil erosion indeed can cause a rapid depletion of the soil organic carbon (SOC) pool. Accelerated soil erosion, affecting 1094 million ha (Mha) by water erosion and 549 Mha by wind erosion (Oldeman 1994), has local, regional and global impacts (Lal 1998a). Estimates of contemporary rates of soil erosion show total sediment discharge of 15 billion tonnes for the world comprising 7.6 billion tonnes from Asia, 2.4 billion tonnes from South America, 2.1 billion tonnes from North America, 1.7 billion tons from Africa and 1.2 billion tonnes from elsewhere (Lal 1994; Walling 1987). In addition to effects on crop productivity, soil erosion also profoundly impacts the environment. Two principal impacts of erosion on environment include reduction in quality of water and air through pollution and eutrophication of surface water, and emissions of radioactively-active gases (*e.g.*, CO_2, CH_4 and N_2O) to the atmosphere. Increasing atmospheric concentration of radioactively-active gases (0.5% yr^{-1} for CO_2, 0.6% yr^{-1} for CH_4, 0.25% yr^{-1} for N_2O) (IPCC 1995) necessitates identifying sources and sinks for developing potential interventions towards mitigating the greenhouse effect. While the impact of land use change on soil C pool and fluxes is being widely recognized (Lal *et al.* 1995a; b; Janzen *et al.* 1998) that of soil erosion on C dynamics is not properly understood. Soil erosion, both by water and wind, causes decline in SOC content on-site. Preferential removal of clay and soil organic matter content reduces SOC pool, lowers soil quality and declines biomass productivity. Several experiments have documented reduction in SOC content of soils subjected to moderate and severe soil erosion. In Canada, Gregorich *et al.* (1995) observed a rapid decline in SOC on an eroded compared to an uneroded cropland. The SOC content in the top 30-cm layer decreased by 20% in an uneroded soil and it was further declined by 70% in eroded soil following 80 years of cultivation. Several experiments conducted in North America have demonstrated the adverse impact of accelerated erosion on SOC pools (Gregorich and Anderson 1985; Gregorich *et al*. 1998). In Ohio, USA, Fahnestock *et al*. (1996) observed that SOC pool in the top 0-10 cm depth was 39.8 Mg C ha^{-1} for the uneroded soil, 15.6 Mg C ha^{-1} for slightly eroded, 14.6 Mg C ha^{-1} for moderately eroded, 13.4 Mg C ha^{-1} for severely eroded and 17.0 Mg C ha^{-1} for the depositional phases. The drastic reductions were observed in SOC pool by accelerated soil erosion on bare fallow soil. The rate of SOC loss ranged from 20 to 700 kg C ha^{-1} yr^{-1} on cultivated land with improved cropping practices of grass barriers and intercropping. Taking into consideration the land area affected, the historic C loss is estimated at 21.2 Pg by water erosion and 3.7 Pg by wind erosion (Lal 1999). The total historic C loss of 24.9 Pg due to accelerated erosion is 45% of the estimated 55 Pg of C lost from world soils (IPCC 1995).

Impact of land use and management practices on SOC storage

Land use and soil management systems, which enhance the amount of biomass returned to the soil, also accentuate the terrestrial C pool. Different technological options for biotic and soil C sequestration include afforestation, and restoration of degraded ecosystem, establishment of bio-energy plantations with a large potential for biomass production, establishing perennials with a deep and prolific root system, growing species containing high cellulose and other resistant species containing high cellulose, and developing appropriate land use systems. Similarly, strategies for soil C sequestration include adoption of conservation tillage and mulch farming techniques, maintenance of soil fertility, soil and water conservation, and adoption of complex rotations (Table 2 & 3). The total potential of SOC sequestration through restoration of degraded soils in India is 10-14 Tg C yr^{-1}.

Major changes in land use occurred in the forests and grassland with 39.9 and 37.5 % of total land use change (Lal *et al.* 1998c, 1999). Change in land

Table 2. Long-term effect of cropping system on C- sequestration in an alkaline soil of India

Location	Soil type	Tree species	Study period	Sampling depth (cm)	Initial SOC (Mg ha^{-1})	Final SOC (Mg ha^{-1})	C-sequestration (kg ha^{-1} yr^{-1})
Haryana	Alkaline soil	*Acacia nilotica*	1970-1989	0-120	4.03	12.3	413
CSSRI, Karnal		*Eucalyptus tereticornis*	1970-1989	0-120	4.03	7.4	168
		Prosopsis juliflora	1970-1989	0-120	4.03	13.0	448
		Terminala arjuna	1970-1989	0-120	4.03	12.9	443
		Albizzia lebbek	1970-1989	0-120	4.03	10.5	323

Source: Singh (1994). After 20 years of tree plantation in alkaline soils at CSSRI, Karnal C- sequestration was least under Eucalyptus plantation (168 kg ha^{-1} y^{-1}).

Table 3. Long-term effect of Rice-based cropping system on C- sequestration in an Alluvial soils of India

Location	Cropping system	Study period	Sampling depth (cm)	Initial SOC (Mg ha^{-1})	Final SOC (Mg ha^{-1})		C-sequestration (kg ha^{-1} yr^{-1})	
					NPK	NPK+ FYM/ compost	NPK	NPK+ FYM/ compost
Gayeshpur (W.B.)	Rice-mustard-sesame	1998-2004	0-20	37.3	39.1	40.2	257	414
Mohanpur (W.B.)	Rice-wheat-fallow	1986-2004	0-20	34.0	35.2	37.2	63	168
Barrackpur (W.B.)	Rice-wheat-jute	1971-2004	0-20	27.9	30.1	46.09	64	535
CRRI,Cuttack (Orissa)	Rice-fallow-rice	1969-2004	0-20	31.6	39.7	46.1	225	402

Source: Mandal *et al*. (2008)

use contributes C to the atmosphere in two principal ways: (i) release of C in the biomass which is either burnt or decomposed, and (ii) release of SOC following cultivation enhanced mineralization brought about by change in soil moisture and temperature regimes and low rate of return of biomass to the soil. Carbon contained in the biomass of the climax vegetation is in the order: tropical rainforest > temperate forest > temperate deciduous > boreal forest > tropical woodland > temperate woodland > tropical grassland > temperate grassland > desert scrub > alpine tundra and meadow. After forest, introduction of improved pasture in natural grassland and savanna ecosystem is another major option of carbon sequestration in soil. Adoption of appropriate farming systems and use of cover crops provide another option of C-sequestration with in terrestrial ecosystems (Table 4). Mixed crop rotations and use of cover crops improve SOC contents and enhance aggregation. Diversified cropping systems with better management substantially improved SOC in semiarid-tropic soils of India (Manna *et al*. 2003) (Table 4). Adoption of conservation tillage increases C-sequestration in soil (Karlen 1994). Lal (1989) estimated that widespread adoption of conservation tillage on soil in 400 million ha crop land by the year 2020 may lead to C-sequestration of 1481 to 4913 Tg (1 Tera gram= 10^{12} g). It is estimated that agricultural intensification in India results in C-sequestration of about 12.7 to 16.5 Tg yr^{-1}. There was a great potential for carbon sequestration through secondary carbonates; especially in irrigated soils, at about 21.8 to 25.6 Tg C yr^{-1} (Pal *et al*. 2000; Nordt *et al*. 2000). The total potential of SOC sequestration in India is 77.9 to 106.4 Tg yr^{-1} (92.2 ± 20.2 Tg yr^{-1}). Of this potential, 12.9% is through restoration of degraded soils and 45.6% through erosion prevention and management, 15.8 % through agricultural intensification and 25.7 % through secondary carbonates.

Impact of soil conservation and SOC pool

Soil conservation implies reducing risks of soil erosion to the tolerable limit, which in most soils of the tropics and sub-tropics may be as low as 1 to 2 Mg ha^{-1} yr^{-1} (Lal 1998b). In a broader context, soil conservation may also imply improving soil quality through controlling erosion, enhancing SOC content, improving soil structure, accentuating activity of soil fauna *etc*. Soil conservation may be achieved through reduction of soil detachment and its transport by agents of erosion. Improving soil's resistance to forces causing detachment and transport involves enhancing soil structure. Some agricultural practices with favourable impact on soil structure include growing cover crops, sowing crops with conservation tillage, maintaining required level of soil fertility, and converting

Table 4. Identifying cropping systems for C-sequestration in semi-arid topic (SAT) regions of India

Location	Soil type	Cropping system	Study period	Sampling depth (cm)	Initial SOC (Mg ha^{-1})	Final SOC (Mg ha^{-1})	C-sequestration (kg $ha^{-1}y^{-1}$)
Madhya Pradesh	*Typic Haplusters* (Kheri)	Paddy-Wheat	1982-2002	0-30	19.8	22.5	135
Maharashtra	*Typic Haplusterts* (Linga)	Citrus	1982-2002	0-30	22.0	36.9	745
Maharasthra	*Typic Haplusterts* (Asra)	Cotton / Greengram+ Pigeon pea	1982-2002	0-30	17.3	35.0	885
Gujarat	*Typic Haplusterts* (Semla)	Groundnut-Wheat	1978-2002	0-30	27.3	31.9	209
Karnataka	*Typic Haplusterts* (Teligi)	Paddy-paddy	1974-2002	0-30	18.61	43.6	861
Karnataka	*Typic Haplustalf* (Vijapura)	Finger millet	1982-2002	0-30	19.3	21.9	130
Andhra Pradesh	*Typic Halplustalf* (Kaukuntala)	Castor + Pigeonpea	1978-2002	0-30	14.5	35.1	936

Source: (Manna *et al*. 2003)

marginal and degraded lands to restorative land uses. All these practices lead to C sequestration through improvement of soil structure and enhancement of soil quality.

Knowledge gaps and future research in carbon sequestration

Soils are one of our most important natural resources. Increasing carbon content in the soil, through better land use management practices, produce a number of benefits in terms of soil biodiversity and soil health sustenance. Soil carbon sequestration through the restoration of soil organic matter can further reverse the process of land degradation and restore soil health through restoring soil biota and soil ecological processes. In particular, through improved management and conservation of natural resources contribute to stabilizing or enhancing food production and optimizing the input use efficiency, thereby reducing emissions of GHGs from agricultural land. Under climate change scenarios, increased temperature may enhance soil organic matter mineralization in colder regions of the world, releasing carbon dioxide from soils. Improved soil management will mitigate the effects of global warming by improved and permanent soil cover. Carbon storage assists climate change mitigation and provides other ecosystem benefits. Changes in land use management causing CO_2 release to the atmosphere can alter ecosystems, reducing their carbon storage and sequestration capacity. There is a huge technological option for biotic and soil C sequestration includes afforestation, and restoration degraded land. There is lack of comprehensive knowledge about the carbon dynamics and potentials of carbon sequestration in tropical ecosystems, frozen soils, wetlands, Histosols, Andisols, Aridisols and Alfisol, Vertisol as well. There is also insufficient knowledge about the potentials carbon sequestration in subsoils, soil erosion and carbon dynamics, plant nutrients and their interaction with soil carbon, and soil structure and soil quality indices.

Some future lines of work in the domain of soil carbon sequestration are mentioned below.

- Research on determining maximum attainable carbon content of soil for different agro-ecological regions of country should be taken on priority basis.
- The soil carbon map of country depicting the current status and attainable deficit must be prepared.
- In order to attain the maximum C content in different soil and climatic conditions, there is a need to devise the suitable agronomic practice taking into account of organic resources availability.
- Emphasis should be given on increasing carbon content of resistant pool rather than total organic carbon per se.
- Soil carbon stabilization mechanism as influenced by different factors must be ascertained.
- Research for characterization of different functional pools of carbon should be undertaken in different soil types and cropping systems.
- Research work should be undertaken for evaluating the effect of surface applied organic materials on carbon sequestration, soil water conservation, and water stabile aggregates which greatly influence SOC dynamics.
- There is a need for research on the introduction of legumes or forage crops in the context of judicious land management under different crop rotations for improving soil physical health, and maintaining SOC levels.
- Strategies need to be developed for subsurface placement of organic residues to improve SOC level in different soils.
- Effort should be made to sequester carbon in stable pool than that involves short-term storage of carbon in vulnerable compartments.
- There is a need for better understanding of microbial mechanisms involved in the complex relationship between C input and soil C sequestration.

CONCLUSIONS

Adoption of conservation effective farming practices can lead to reduction in soil erosion, improvement in soil quality, and enhancement of SOC pool. Important agricultural practices with potential for C sequestration include conservation tillage, crop residue mulch, conservation research programme and conservation buffers including management of riparian zone, elimination of summer fallow, soil fertility management and adoption of recommended cropping systems. While being highly labile pool of carbon, this sink can be filled over a 25 to 50 year period. Thus, soil C sink is a short-term solution to the serious problem of greenhouse effect. The long-term solution of the potential global warming threat lies in finding alternatives to fossil fuel. There is also urgent is need of adoption of best land use practices (conservation tillage, mulch farming techniques, complex crop rotation, and soil and water conservation) in a long run that could enhance the to SOC sequestration and a reduction of GHGs. Nonetheless, soil C sequestration buys us the much-needed time during which other energy-related alternatives take effect. Soil C sequestration is a win-win- win strategy. While enhancing soil productivity, it improves water quality and mitigates the greenhouse effect.

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Effect of tillage, crop establishment techniques and nutrient management on growth and productivity of tomato

U. K. BEHERA[1], ANCHAL DASS[2], BILLU SINGH[2] and B. PARIDA[2]

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ABSTRACT

A field experiment was conducted during the *rabi* season of 2008-09 at Indian Agricultural Research Institute, New Delhi to study the influence of tillage, crop establishment techniques and sources and levels of fertilizer on the growth and yield of tomato (*Lycopersicon esculentum* L). Plant height, number of fruits / plant and other growth parameters were maximum with the application of 100% recommended rate of fertilizers (RRF) through Yaramila (15-09-20) over other sources. Comparing the lower levels of fertilizer i.e. 50 % and 75% and 100% of RRF from Yaramila (15-09-20), it was observed that the performance of tomato with respect to number of fruits / plant was statistically similar with 75% RRF. This implies that at lower levels (75%) of Yaramila (15-09-20), the potentiality of the crop in terms of number of fruits / plant and fruit yield (0.83 kg / plant) was achieved. Among different sources of fertilizers, 100% RRF through Yaramila 15-09-20 produced 15 and 20.4% higher number of fruits / plant and yield, respectively than RRF applied through conventional fertilizers and combined application of straight fertilizers and Yaramila 15-09-20. The performance of tomato was similar in all tillage and crop establishment practices.

Key words: Tomato, Tillage, Crop establishment, Yaramila (15-09-20), IFFCO (10-26-26), Yield

INTRODUCTION

India is the second largest producer of vegetables in the world. It produces 146.6 million tonnes (m t) of vegetables from an area of 8.5 m ha (Kumar et al., 2011**)**. By the year 2025, India will require 225 m t of vegetables. Vegetables such as potato (*Solanum tuberosum*), tomato (*Lycopersicon esculentum* L), lady's finger (*Abelmoschus esculentus*), brinjal (*Solanum melongena L.*) etc. are widely grown vegetable crops in India. Tomato is extensible grown both under rain-fed and irrigated conditions in different regions of the country (Dass, 2008). However, the crop performs best at temperature 22-25^{O}C (Kalloo, 1986). Above this range the fruit-set is usually poor, due to poor pollen production, lack of anther dehiscence, poor pollen germination, drying of stigma, ovule abortion etc. One of the major constraints towards higher productivity and production of vegetables is the management of plant nutrients / fertilizers. Intensive agriculture results in multiple deficiencies of the nutrients. Excessive mining of the nutrients results in deficiency of NPK as well as secondary and micronutrients, which limits the crop production. It is well established fact that the soil in some parts of the country has shown deficiencies for various secondary and micronutrients. Imbalance fertilizer use has become a major problem to improve the crop productivity. Besides, mixed and complex fertilizers usually do not contain secondary and micronutrients, such as S, Mg, Mn, Zn etc. for which a large scale nutrient deficiency has been reported.

A soil fertility surveys by Singh (1999, 2006) based on the analysis of 60,000 soil samples have shown S deficiencies to be a widespread problem. A soil is considered deficient in S, if it tests less

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110012
[1]College of Agriculture, OUAT, Chiplima-768025, Odisha. Phone: 09968130091, E-mail: ukbehera2008@rediffmail.com
[2]Green Fields International, C-174, Madhuvan, Shakkarpur, New Delhi-110092

than 10 mg S/kg soil extractable with 0.15% $CaCl_2$. The data generated by the ICAR project and the TSI-FAI-IFA project proved that S deficiencies are a critical problem in 40"45% of districts of the country affecting 57-64 m ha of net sown area. To overcome this problem, a product of 'YaraMila 15-09-20', which contains 3.8% sulphur and 1.8% magnesium can play a crucial role.

Increasing cropping intensity and accompanying changes in the soil and fertilizer management practices have altered the zinc status of soils and its availability, especially in the Indo-Gangetic plains of India, where on a large areas' rice-wheat cropping system is being practiced. As the plant demand for higher yield increases and plant requirement for macro-and micronutrient is increasing, S and Zn deficiency is likely to become more widespread and intense. Zinc and S deficiencies have developed to be a major constraint in Indian Agriculture. Cropping systems of 200 to 300% intensity deplete the soil S and Zn more due to higher production. Besides, there has been a need to diversify the rice-wheat cropping system with other remunerative crops, viz. vegetables and pulses. Farmers in this region are now growing tomato as a crop diversification measure. Resource conserving techniques involving furrow irrigated raised bed, broad bed and furrow, permanent bed etc. are getting popularity due to saving of inputs, such as water, nutrients etc. Therefore, the present investigation was carried out to evaluate the performance of tomato crop under different tillage and crop establishment techniques and determine the optimum level and suitable source of fertilizer to harness the yield potential of tomato.

MATERIALS AND METHODS

The field experiment was conducted during *rabi* 2008-09 at Indian Agricultural Research Institute, New Delhi (28.42 N latitude, 27.122 E longitude, and 228.6 m above mean sea level). Soil samples were taken before the start of the experiment and were analyzed (Table 1) by using the standard methods (Kanwar and Chopra, 1986). Soil of the experimental site was sandy loam in texture and slightly alkaline in reaction. The experiment was conducted in a split-plot design with three main-plot treatments and six sub-plot treatments. In all, there were 18 treatment combinations. A spacing of 0. 70 m x 0. 45 m was maintained with gross-plot area of 16.8 m^2 (6.0 x 2.8 m). The details of the experimental treatments are given as follows:

Main plots: Tillage and crop establishment

CT(F): Conventional tillage flat-bed

CT(B): Conventional tillage raised-bed

ZT(F): Zero tillage flat-bed

Sub-plots: Fertilizer levels and sources

Table 1. Mechanical, physical and chemical properties of experimental field soil

Particulars	Values	Method of analysis
Physical properties		
Sand (%)	61.7	Hydrometer method
Silt (%)	11.9	(Bouyoucos, 1962)
Clay (%)	26.4	
Textural class	Sandy loam	Triangular method (Bouyoucos, 1962)
Chemical properties		
Organic carbon (per cent)	0.38	Walkley and Black method (1934)
Total N (%)	0.041	Modified Kjeldahl's, method (Jackson, 1967)
Available N (kg/ ha)	145	Modified Kjeldahl's, method (Jackson, 1967)
Available P (kg/ha)	9.01	Olsen's method (Olsen *et al*., 1967)
Available K (kg/ ha)	250	Flame photometer method (Jackson, 1967)
Available S (kg/ha)	11.5	Williams and Steinbergs (1959)
pH (1:2.5 soil to water)	7.6	Beckman's pH meter (Jackson, 1967)
Electrical conductivity (dS/m)	0.32	USDA handbook No. 60 at 25 ^{0}C (dSm^{-1}) (Richards, 1954)
Bulk density (g/cm^3)		Core sampler method (Piper, 1950)
0-15 cm	1.56	
15-30 cm	1.59	

F_1 : 100% Recommended dose of fertilizer (RF) through YaraMila 15-09-20 fertilizer

F_2 : 50% RF from YaraMila 15-09-20 fertilizer

F_3 : 75% RF from YaraMila 15-09-20 fertilizer

F_4 : 50% RF from YaraMila 15-09-20 fertilizer + 50% RF from straight fertilizers (combined application)

F_5 : 100% RF from conventional fertilizer sources (IFFCO: 10-26-26) + addition of Mg and S to equate with F_1

F_6 : Control

The fertilizer YaraMila 15-09-20', which contains 3.8% sulphur and 1.8% magnesium was used as the test fertilizer. This 'YaraMila 15-09-20' fertilizer is based on nitrophosphate technology. It has both nitrate (44%) and ammonical (56%) form of nitrogen. The phosphorus is in the polyphosphate form having the advantage of less P-fixation to soil. The source of potash was potassium sulphate. The RRF for the test crop was 120:80:40 (120 kg N, 80 kg P_2O_5 and 40 kg K_2O). The tomato variety 'Pusa Rohini' was the test crop and 35-day old seedlings were transplanted. The recommended packages of practices were followed for raising the crop. The crop was irrigated at different intervals with a depth of 6 cm in each irrigation. In total 7 irrigations were applied upto 7 days before final picking. Data were recorded on different biometrical parameters, like plant height, number of fruits / plant, dry matter production and fruit yield, and were analysed using ANOVA technique as suggested by Rangaswamy (2006) using MSTAT-C software. The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Growth parameters

The flowering was significantly influenced by the levels and sources of nutrient application. Duration required from transplanting to 50% flowering was significantly longer under control, while it was similar for other fertility treatments. For 50% flowering, control treatment took 43 days, while for other treatments it varied from 37 to 39 days after transplanting (DAT) of crop (Table 2). Plant height at all the three growth stages was significantly influenced by the different level and sources of nutrients. The plant height for all the fertilizer treatments was statistically similar, except for control. The plant height in control was significantly lower than fertilizer treatments. Among the sources of nutrient, combined application of 50% amount of nutrient from

Table 2. Growth parameters of tomato as influenced by different tillage and crop establishment techniques, and sources and levels of fertilizer applications

Treatment	Days to 50% flowering	Plant height (cm)			Leaves / plant	Branches / plant
		3 0 DAT	60 DAT	90 DAT		
Tillage						
CT-Flat	38.05	20.28	36.83	37.19	20.0	5.8
ZT-Flat	39.83	20.97	36.54	38.31	20.0	6.0
FIRB	38.83	22.08	37.72	38.47	20.7	5.6
SEm±	0.58	0.34	1.09	0.70	0.63	0.29
CD (P=0.05)	NS	1.34	NS	NS	NS	NS
Fertilizer sources and levels						
100 % RRF from Yaramila	37.11	22.77	40.46	38.32	23.0	6.8
75 % RRF from Yaramila	38.88	21.84	38.55	39.13	22.2	6.4
50 % RRF from Yaramila	37.77	22.78	37.82	38.64	22.8	6.8
50 % RF from Yaramila+ 50 % straight fertilizer	38.33	21.21	38.24	38.37	19.3	5.6
100 % conventional source	38.11	22.33	38.77	38.00	22.3	6.2
Control	43.22	15.71	28.33	35.50	11.88	3.2
SEm±	0.33	0.64	1.10	0.93	0.89	0.31
CD (P=0.05)	0.96	1.86	3.18	2.70	2.58	0.91

DAT= days after transplanting; FIRB= Furrow irrigated raised bed; CT= conventional tillage; ZT= Zero-tillage conventional source (straight fertilizer) and 50% from 'YaraMila 15-09-20' proved inferior to other fertilizer treatments. Similarly, number of leaves/ plant and branches/ plant were significantly influenced due to different levels and sources of fertilizers. Both these traits were the maximum with application of 100% RRF from 'YaraMila 15-09-20', while these traits were the minimum for control. Among the other fertilizer treatments, combined application of 50% nutrient from conventional sources and 50% from 'YaraMila 15-09-20' resulted in significantly lower number of leaves and branches than 'YaraMila 15-09-20' at 100% and 75% of RRF.

Yield attributes

Fruits/cluster, fruit diameter and fruit height were significantly influenced due to fertilizer levels and sources (Table 3). These traits were the lowest in control plots. 'YaraMila 15-09-20' at 100%, 75% and 50% level were superior with respect to fruits/ cluster than other fertilizer sources and control. For fruit diameter and fruit height, no definite trend was observed. The plant dry matter production at the harvest of the crop was significantly influenced due to different fertilizer levels and sources. The maximum dry matter/plant was recorded in 'YaraMila 15-09-20' at 100% RF. This was followed by 'YaraMila 15-09-20' at 75% RF and conventional sources of nutrients at 100% RRF. Among the fertilizer treatments, the plant dry matter accumulation was the lowest at combined application of 50% from conventional sources and 50% from 'YaraMila 15-09-20' (Table 3). The lowest plant dry matter yield was recorded in control.

The number of fruits recorded per plant (Table 4) presents the number of fruits picked from these plants from 1st picking to 7th picking. Number of fruits picked/plant increased gradually from 1st picking to 5th picking. On an average, the maximum of 4.13 fruits/ plant were recorded at 5th picking and it was the lowest at 1st picking with 0.52 fruit/ plant. Taking the total fruits/plant into consideration, on an average 16 fruits/plant were harvested. The response of tomato to different levels and sources of nutrient application was significant. The maximum number of fruits/plant was recorded in 100% RRF from YaraMila 15-09-20 fertilizer (19.8 fruits/plant) and the minimum number of fruits of (6.93 / plant) was obtained from control plots. This showed that there was good response of the crop to fertilizer application. Comparing the lower levels of fertilizer doses i.e. 50% and 75% of RRF from 'YaraMila 15-09-20', with

Table 3. Fruits/cluster, fruit diameter, fruit height and dry matter accumulation in tomato as influenced by different tillage and crop establishment, and sources and levels of fertilizer applications

Treatment	Fruits/ cluster	Fruit diameter (cm)	Fruit height (cm)	Plant dry matter at harvest(g/ plants)
Tillage				
CT-Flat	3.3	4.94	4.29	298
ZT- Flat	2.9	5.03	4.28	238
FIRB	3.4	5.05	4.39	258
SEm±	0.16	0.04	0.04	014
CD (P=0.05)	NS	NS	NS	NS
Fertilizer sources andlLevels				
100 % RRF from Yaramila	3.5	5.10	4.43	307
75 % RRF from Yaramila	3.4	5.13	4.37	260
50 % RF from Yaramila	3.6	5.03	4.30	281
50 % RF from Yaramila+ 50 % straight fertilizer	3.2	5.08	4.44	259
100 % conventional source	3.2	4.94	4.25	275
Control	2.3	4.77	4.13	206
SEm±	0.17	0.08	0.07	25
CD (P=0.05)	0.50	0.24	0.22	72

DAT= days after transplanting; FIRB= Furrow irrigated raised bed; CT= conventional tillage; ZT= Zero-tillage

Table 4. Number of fruits / plant in tomato as influenced by different tillage and crop establishment, and sources and levels of fertilizer applications

Treatment	Picking							Total
	I	II	III	IV	V	VI	VII	
Tillage								
CT- Flat	0.40	1.11	2.35	2.61	4.02	2.81	2.55	15.88
ZT- Flat	0.57	0.95	2.13	3.28	4.25	2.95	2.26	16.41
FIRB	0.58	0.99	2.17	2.97	4.10	2.23	2.42	15.51
SEm±	0.10	0.06	0.19	0.33	0.38	0.21	0.27	1.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer sources and levels								
100 % RRF from Yaramila	0.87	1.26	2.41	3.60	5.08	3.64	2.95	19.82
75 % RRF from Yaramila	0.52	0.98	2.52	3.32	4.68	2.54	2.51	17.10
50 % RRF from Yaramila	0.68	1.53	2.80	3.53	4.98	2.64	2.56	18.76
50 % RRF from Yaramila+ 50 % straight fertilizer	0.44	1.01	2.30	3.33	3.94	3.03	2.38	16.46
100 % conventional source	0.46	1.10	2.34	3.47	4.31	2.64	2.87	17.22
Control	0.13	0.21	0.95	1.17	1.74	1.53	1.17	6.93
SEm±	0.06	0.08	0.13	0.14	0.18	0.12	0.10	0.72
CD (P=0.05)	0.18	0.25	0.39	0.42	0.54	0.35	0.29	2.07

DAT= days after transplanting; FIRB= Furrow irrigated raised bed; CT= conventional tillage; ZT= Zero-tillage

the 100% RRF from the same source, it was observed that the performance of tomato with respect to number of fruits / plant was statistically similar with 75% of RF, while it was significantly higher than 50% RRF. This implies that even at lower dose (75% RRF) of 'YaraMila 15-09-20' the potentiality of the crop with respect to number of fruits was achieved. Again, comparing the performance of tomato with respect to number of fruits / plant due to different sources of nutrient, 'YaraMila 15-09-20' at RRF produced 15.0% and 20.4 % higher number of fruits / plant than with RRF through conventional fertilizer source and combined application of straight fertilizer and YaraMila 15-09-20, respectively.

Fruit yield/plant

Fruit yield / plant exhibited a similar trend as with the fruit number. The fruit yield increased from 1st picking to 5th picking and there after the yield / plant declined. On an average, 0.710 kg fruit / plant was recorded. Among the different sources of nutrient, the fruit yield / plant (Table 5) was maximum (0.88 kg / plant) in 'YaraMila 15-09-20' followed by nutrient from conventional sources (0.74 kg / plant) and combined application of 50% from YaraMila complex and 50% from straight fertilizers (0.70 kg / ha) while the lowest yield (0.30 kg / plant) was recorded under control treatment. However, 'YaraMila 15-09-20' recorded 18.2% and 24.9% higher than the same doses applied from conventional sources and combined application of 50% amount of fertilizers from YaraMila complex and 50% from straight fertilizers. This also makes it clear that mixed application at 50% ratio from both the sources is not beneficial. The reason for this could not be understood. Taking relative performance of these 3 treatments into consideration, 'YaraMila 15-09-20' fertilizer application at 100, 75 and 50% RRF resulted statistically similar fruit yield, though 'YaraMila 15-09-20' at 100% RRF produced 7.6 and 5.0% higher fruit yield than 50% and 75% of RRF. Application of 100% RF from conventional sources produced 15.4% lower fruit yield / ha. Again combined application of 50% RRF from straight fertilizer and 50% from 'YaraMila 15-09-20' proved inferior to 100% RRF from 'YaraMila 15-09-20'. Combined application of fertilizer was not beneficial for tomato cultivation compared to their sole application.

Fruit and stover yields

On an average, total 23.7 t / ha of ripened fruits were harvested (Table 6). The performance of

Table 5. Weight of fruits (kg / plant) in tomato as influenced by different tillage and crop establishment, and sources and levels of fertilizer applications

Treatment	Picking							Total
	I	II	III	IV	V	VI	VII	
Tillage								
CT- Flat	0.01	0.06	0.13	0.14	0.19	0.10	0.02	0.68
ZT- Flat	0.02	0.06	0.13	0.17	0.21	0.09	0.02	0.73
FIRB	0.03	0.06	0.13	0.16	0.20	0.08	0.02	0.71
SEm±	0.004	0.005	0.013	0.016	0.0184	0.008	0.003	0.056
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer Sources & Levels								
100 % RRF from Yaramila	0.04	0.07	0.14	0.20	0.23	0.13	0.02	0.87
75 % RRF from Yaramila	0.02	0.06	0.16	0.19	0.23	0.09	0.02	0.81
50 % RRF from Yaramila	0.03	0.08	0.17	0.18	0.23	0.08	0.02	0.83
50 % RRF from Yaramila + 50 % straight fertilizer	0.01	0.05	0.13	0.15	0.20	0.10	0.02	0.70
100 % conventional source	0.02	0.06	0.14	0.17	0.21	0.09	0.02	0.74
Control	0.005	0.02	0.05	0.06	0.09	0.05	0.01	0.30
SEm±	0.004	0.01	0.01	0.01	0.02	0.01	0.003	0.06
CD (P=0.05)	0.01	0.03	0.05	0.05	0.06	0.03	0.008	0.19

DAT= days after transplanting; FIRB= Furrow irrigated raised bed; CT= conventional tillage; ZT= Zero-tillage

Table 6. Fruits and stover yield (t / ha) in tomato as influenced by different tillage and crop establishment, and sources and levels of fertilizer applications

Treatment				Picking				Total	Stover
	I	II	III	IV	V	VI	VII		
Tillage									
CT- Flat	0.64	2.20	4.62	4.72	6.45	3.38	0.85	22.88	9.93
ZT- Flat	0.85	2.07	4.44	5.83	7.16	3.32	0.75	24.46	7.93
FIRB	1.06	2.01	4.61	5.61	6.75	2.87	0.80	23.75	8.60
SEm±	0.14	0.17	0.44	0.53	0.61	0.25	0.09	1.87	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizer sources and levels									
100 % RRF from Yaramila	1.38	2.62	4.93	6.94	7.80	4.48	0.98	29.17	10.23
75 % RRF from Yaramila	0.96	2.23	5.53	6.37	7.85	3.28	0.83	27.00	8.66
50 % RF from Yaramila	1.23	2.93	5.88	6.09	7.88	2.87	0.85	27.85	9.36
50 % RRF from Yaramila+ 50 % straight fertilizer	0.60	1.94	4.51	5.04	6.83	3.58	0.79	23.33	8.63
100 % conventional source	0.77	2.15	4.67	5.84	7.25	3.00	0.95	24.68	9.16
Control	0.15	0.67	1.82	2.04	3.09	1.95	3.92	10.13	6.86
Mean	0.85	2.09	4.56	5.39	6.79	3.19	0.80	23.69	8.82
SEm±	0.17	0.39	0.59	0.63	0.72	0.42	0.94	1.27	0.44
CD (P=0.05)	0.51	1.14	1.70	1.83	2.10	1.22	0.27	3.68	1.26

DAT= days after transplanting; FIRB= Furrow irrigated raised bed; CT= conventional tillage; ZT= Zero-tillage

tomato was similar in all the tillage and crop establishment practices. The fruit yield was 22.88, 24.46, and 23.75 t / ha for conventional tillage flat-bed, zero tillage flat-bed and conventional tillage raised-bed system, respectively. Response of tomato to different levels and sources of fertilizer was significant. The highest fruit yield of 29.17 t / ha was recorded in 100% RRF through 'YaraMila

15-09-20', while the lowest fruit yield of 10.14 t/ha was recorded in control. Dass *et al.* (2008) recorded 19.1 t/ ha tomato fruit yield from RRF against 9.2 t/ha in control. There was 3-fold increase in tomato yield under recommended dose of fertilizer from 'YaraMila 15-09-20' than control, which shows that there was tremendous response of tomato crop to fertilizer application. The fruit yield for 50% and 75% RRF from 'YaraMila 15-09-20' was 27.00 and 27.86 t/ha, respectively. The combined application of 'YaraMila 15-09-20' and conventional sources, resulted in lower fruit yield of 23.33 t/ha, while sole conventional sources produced 24.68 t/ha of fruit yield. Stover yield (t/ha) at harvest was significantly influenced by different fertilizer treatments. The maximum stover yield of 10.23 t/ ha was recorded in YaraMila complex at 100% RRF. While the lowest stover yield of 6.867 t/ha was recorded in control. The stover yield for treatments receiving 50% and 75% RRF from YaraMila complex, and 50% RRF from YaraMila complex and 50% from straight fertilizer and 100% from conventional fertilizer were statistically similar.There were few positive indications on the quality of produce when Yaramila fertilizer was used. The reason for the better performance of this fertilizer in tomato is due to the form of major nutrients in the fertilizer and also the supply of secondary nutrients along with the NPK. This fertilizer contains more water-soluble phosphates and polyphosphates, which might have improved phosphorus availability to plants. Prilled form of fertilizers also helps in better distribution of fertilizers and hence absorption of nutrients. Due to this, tomato crop responded very well to 'YaraMila 15-09-20' than conventional fertilizers.

CONCLUSIONS

The study revealed that the performance of tomato under different tillage and crop establishment techniques was similar indicating that tomato crop can be successfully grown under zero tillage without yield losses. 'YaraMila 15-09-20' complex proved superior to other sources of fertilizer. A lower fertilizer level (75% of recommended rate) from 'YaraMila 15-09-20' was equally effective with 100% RRF, thus helping in bringing economy in fertiliser use and higher fertiliser use efficiency.

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Effect of pre-puddling tillage and puddling intensities on soil physico-chemical properties and rice-wheat system productivity on a Typic Ustochrept of Indo-Gangetic Plains

V.K. SINGH[1], B.S. DWIVEDI[2], ARVIND K SHUKLA[3] and M.C. MEENA[2]

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ABSTRACT

The pre-puddling tillage and puddling intensity has great significance in increasing rice (*Oryza sativa* L.) yields and N uptake but increasing intensity of these operations involves excessive energy and may have adverse effect on succeeding wheat (*Triticum aestivum* L.). Diagnostic surveys conducted in Upper Gangetic Plains reveal that in rice, farmers practice 4-6 pre-puddling tillage operations, followed by two puddling operations. The frequency of pre-puddling tillage was also greater in case of medium and large farmers (average 04) as compared to the small ones (average 03), whereas 02 puddlings was a common practice by all the farmers irrespective of their holding size. With these considerations, a 3-year field experiment was conducted on a sandy loam (Typic Ustochrept) soil of Modipuram to study the interactive effects of pre-puddling tillage and puddling intensity on soil physico-chemical properties, nutrient uptake and field water use efficiency in rice, energy use, and on the productivity of rice and wheat crops. Treatments included 03 levels of pre-puddling tillage-discing followed by a tine-cultivation and planking (T_1), discing followed by 2 tine-cultivations and planking (T_2), or discing followed by 4 tine-cultivations and planking (T_4); and 3 puddling intensities i.e., 1, 2 or 4 passess of puddler in ponded water (P_1, P_2 and P_4, respectively), each followed by planking. Increasing pre-puddling tillage from T_1 to T_4 decreased irrigation water requirement by 3 to 11%, and increased rice grain yield (459 to 801 kg/ha) and Field water use efficiency (FWUE) by 14 to 27%. Similar increase in puddling intensity from P_1 to P_4 decreased irrigation water requirement by 8 to 17%, and increased rice yield from 821 to 1058 kg/ha and FWUE by 32 to 45%. The post-rice available-N in soil at 0-15 cm profile-depth was greater under P_2 or P_4 compared with P_1, indicating the advantage of puddling in retaining greater available-N in upper profile zone. The intensive puddling (P_4) led to higher soil bulk density and decreased wheat grain yields. A combination of two dry tillage operations followed by two passes of puddler proved optimum with respect to rice and RWCS yields, energy and water use efficiency.

Keywords: Pre-puddling tillage; Puddling; Bulk density; N uptake; Energy use; Rice-wheat

INTRODUCTION

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L) rotation is the predominant agricultural production system in South Asia, providing food and job to millions of people (Timsina and Connor, 2001). It occupies nearly 13.5 million ha area in the Indo-Gangetic Plain region (IGP) of India, Pakistan, Bangladesh and Nepal, and another about 10 m ha in China (Ladha *et al*, 2003). In most of these countries, wet land tillage for rice puddling has become almost synonymous with rice culture, as apart from reducing percolation losses, it helps to control weeds and creates a soft medium for easy transplantation of rice seedlings (De-Datta, 1981). The process of puddling consists of pre-puddling tillage (dry tillage) and wet tillage (puddling) operations. The effect of puddling (wet tillage) on puddle quality and percolation rate depends on

[1]Project Directorate for Farming Systems Research, Modipuram, Meerut-250 110
[2]Division of Soil Science and Agricultural Chemistry, IARI, New Delhi-12
[3]Co-ordinator, AICRP on Secondary and Micro- Micro-nutrients and Soil Pollutants, IISS, Barasia Road, Bhopal (M.P.)

initial soil conditions created by pre-puddling (dry tillage) (Gajari *et al*, 1999). The extent of the reduction in percolation losses in rice depends on puddling intensity. Percolation losses in rice have been reported to vary from 0.1 to several hundred millimeters per day (Sharma and De-Datta, 1985; Aggarwal *et al,* 1995). These can be reduced by increasing the resistance to water flow in the soil and decreasing hydrostatic water pressure of the ponded water (Kukal and Aggarwal, 2002). An increase in puddling intensity decreases hydraulic conductivity of puddled layers, whereas hydraulic gradient between puddled and unpuddled layers increases with increase in puddling intensity. Diagnostic surveys conducted under major rice-wheat growing areas of IGPR revealed that more than 65% of the farmers apply 4 to 8 pre-puddling tillage operations (Sharma *et al,* 2004) in order to bury wheat stubble, reduce weed growth and provide favorable soil tilth for puddling. This is followed by 3 to 5 wet tillage operations using puddler or cultivator plus a wooden plank. Puddling is a labour, capital and energy intensive operation and repeated puddling deteriorates soil physical conditions by breaking soil aggregates in the puddled layer and compaction underneath (Kukal and Aggarwal, 2003), adversely affecting root growth and yield of subsequent crops (Tripathi, 2003). Thus, it is logical to know the appropriate number of pre-puddling tillage operations and puddling intensity in relation to change in physico-chemical characteristics of soil and productivity of rice-wheat system. We therefore, undertook present investigation to (i) optimize the pre-puddling tillage and puddling intensity for increasing yield, N uptake and water use efficiency in rice, and (ii) study the changes in soil physico-chemical properties, energy use and their subsequent effect on wheat productivity due to interactive effect of different tillage operations.

MATERIALS AND METHODS

The field experiments comprised three pre-puddling tillage treatments in main plot and three puddling intensities in sub plots in a split plot design with four replications for three consecutive years, (2000-03) in an undisturbed layout on a Typic Ustochrept soil at the research farm of Project Directorate for Farming Systems Research (Earlier PDCSR) Modipuram, Meerut ($29^{\circ}\ 4^{2}$ N, $77^{\circ}\ 46^{2}$ E, 237m amsl), India. The pre-puddling treatments were: (i) discing 01 week after wheat harvest + 01 harrowing with a tine cultivator and a planking (01 pre-puddling tillage, T_1); (ii) discing 01 week after wheat harvest + 02 criss-cross harrowing operations with a tine cultivator at weekly intervals after discing, each followed by planking (02 pre-puddling tillage, T_2); and (iii) discing 01 week after wheat crop harvest + 04 criss-cross harrowing operations with a tine cultivator, each followed by planking (04 pre-puddling tillage, T_4). Puddling was done by tractor-mounted puddler, once (01 puddling intensity, P_1), twice (02 puddling intensity, P_2) or four times (04 puddling intensity, P_4) in 8-10 cm pounding water followed by one planking. The plot size was 12 m x 12 m. Study site represents irrigated, mechanized and input-intensive cropping area of Upper Gangetic Plain Zone of IGP. The climate of Meerut is semi-arid subtropical, with dry hot summers and cold winters. The soil of experimental site was a sandy loam (16.5% clay, 18% silt, 65.5% sand) of Gangetic alluvial origin, very deep (>2m), flat (about 1% slope) and well-drained, representing one of the most extensive soil series i.e., Sobhapur series of north-west India.

Twenty-five day old seedlings of rice cv PR-106 were transplanted at 20 x 15 cm spacing during first week of July in all the plots. After rice harvesting in the first weak of November, the succeeding wheat crop (cv PBW-343) was sown in rows 20 cm apart on the same layout, using 100 kg seed /ha with uniform tillage, (02 discing +02 cultivations with tine cultivator). Wheat was harvested in the third week of April during all the years. Both the crops were grown under assured irrigated conditions. At maturity, 11 x 11 m net plot area of rice as well as wheat was harvested manually just above the ground level using sickles. After sun drying in the field the total biomass was weighed, threshed with a plot thresher and grain weight recorded. The aboveground biomass was removed from the plots and underground stubbles were disced into the soil. A uniform dose of 120 kg N, 26 kg P, 33 kg K to both rice and wheat, and 5 kg Zn/ ha to rice was applied through urea (46.4 N%), single superphosphate (6.99% P), muirate of potash (49.8% K) to rice crop.

Before commencement of the experiment in 2000-01, soil samples were collected for 0 to 15 cm profile depth from four places of the experimental field, using a core sampler. The samples were bulked, dried, and pulverized to pass through 8 mesh sieves for pH, EC and available nutrients and 32 mesh for organic carbon, and_analyzed for pH, EC, soil organic carbon, available N, P, K and Zn contents by standard analytical procedures (Page *et al*, 1982). At the onset of the field experiment, the surface soil (0-15 cm) was mildly alkaline (pH 8.3), non-saline (EC 0.21 dS/m), low in organic C (0.41%) and available N (kg/ha), medium in available P and K (0.5*M* $NaHCO_3$-extractable P 11 mg/kg and *N* NH_4OAc-extractable K 110 mg/kg) and low in available Zn (DTPA-extractable Zn 0.73 mg/kg). The post harvest soil samples (0-45 cm profile-depth at every 15 cm interval) from rice fields were also drawn during third rice crop (2002-03), following the same procedure and analyzed for available N. The bulk density (BD) was determined at 0-15, cm depth using brass soil cores before the start of experiment as well as after completion of the third rice-wheat cycle. The dry matter samples of rice grain and straw were collected from bulk of produce by each plot were dried at 70^0 C in a hot-air oven, ground in a stainless steel Wiley mill, and wet-digested in conc. H_2SO_4 for determination of total N content and determined by Kjeldahl method using a Kjeltec autoanalyser.

Irrigation water applied to rice crop was measured using parshall flume having 15 cm throat width. The discharge of flume was free flow condition (0.6, Hb/Ha) during all the irrigations. The amount of water used at each irrigation was recorded and the total irrigation water use for rice was worked out. The Field water use efficiency was computed by dividing rice yield with total irrigation water use. In order to explain the treatment effects in terms of energy requirement for rice production the assumptions made by Mittal *et al*, (1985) were used. For treatment comparisons in the field experiment the 'F test' was used, following the procedure of split-plot design (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

Diagnostic survey

Diagnostic surveys conducted in Upper Gangetic plain reveals that in rice, farmers practice 4-6 pre-puddling tillage operations, followed by two puddling operations. The frequency of pre-puddling tillage was also greater in case of medium and large farmers (average 04) as compared to the small ones (average 03), whereas 02 puddlings were commonly practiced by all the farmers irrespective of their holding size. Pre-puddling (dry) tillage included harrowing and cultivations, but the number of these operations varied in accordance with holding size and resources of the farmers (Table 1). Whereas medium and large farmers invariably practiced 1-2 harrowing, only three-forth of the small farmers could use harrow. The frequency of cultivation (tillage operation with

Table 1. Tillage practices and frequency of irrigation in rice-wheat system in Upper Gangetic Plain zone

Particulars	Small (<2 ha) and semi-medium (2-4 ha) farmers				Medium (4-10 ha) and large (>10 ha) farmers			
	No. of cases	Max.	Min.	Mean	No. of cases	Max.	Min.	Mean
Rice								
Pre-puddling tillage								
Harrowing	46	2	1	1	40	2	1	1
Cultivations	60	3	2	2	40	4	3	3
Puddling	60	2	-	2	40	2	-	2
No. of irrigations	60	18	12	14	40	18	10	15
Grain yield (t/ha)	60	6.10	3.21	4.36	40	6.42	3.95	5.12
Wheat								
Tillage Harrowing	52	2	1	1	40	2	-	2
Cultivations	60	4	3	3	40	5	3	4
Planking	60	2	-	2	40	3	2	2
No. of irrigations	60	4	2	3	40	5	3	4
Grain yield (t/ha)	60	4.49	2.85	3.80	40	5.18	3.65	4.92

cultivator) was also greater in case of medium and large farmers (on an average three cultivations) as compared to the small ones (on an average three cultivations). Puddling (wet tillage) was practiced by all the farmers irrespective of their holding size, because only transplanted rice is grown in entire area. For this, farmers use tractor-drawn cultivator along with wooden plank in the submerged field. In general, two passes of cultivator + plank is a common practice at all categories of farms.

In wheat, prevailing tillage practices with small farmers comprise on an average 01 harrowing + 03 cultivations. The medium and large farmers on the other hand adopt 02 harrowing + 04 cultivations. After harrowing and cultivations, farmers consider at least 01 planking essential. Also, after wheat sowing, 01 planking is invariably practiced on all the farms.

The average productivity levels of rice and wheat in the surveyed area were greater than state or national average. The productivity of rice ranged from 3.21 to 6.10 t/ha, with an average of 4.36 t/ha at small and semi-medium farms, and from 3.95 to 6.42 t/ha with an average of 5.12 t/ha.

On-station studies

Effect on rice yield

The grain yield of rice increased significantly with increasing levels of pre puddling (dry tillage) and puddling (wet tillage), though the magnitude of dry tillage and wet tillage differed markedly (Table 2). The main effects of dry tillage were significant up to the highest level i.e., four tillage operation. Compared with one tillage, the yield of rice under treatment receiving two tillage (one harrow+one cultivator) was greater by 0.46 t/ha. A further increase in tillage level i.e., two harrow+ two cultivator produced an additional yield of 0.45 t/ha. Two passes of puddler increased the grain yield significantly (18.3%), but the differences between two and four passes of puddler could not cross the level of significance. The dry tillage x puddling interaction was also significant on grain yield and a combination of two dry tillage operations followed by two passes of puddler proved optimum. This combination yielded 5.73 t/ha, and a further increase in puddling did not accrue significant additional yield advantage. These tillage operations (02 pre-puddling tillage and 02 passes of puddler) appeared to benefit rice yield on the coarse-textured soil of the experimental field mainly through an improvement in puddle quality i.e., increased puddling index (Data not shown) and consequent reduction in percolation losses, and also by minimizing downward movement of available-N beyond root zone (Fig. 1a, 1b and 1c). In fact, relatively greater churning of soil owing to higher levels of pre-puddling tillage followed by puddling and planking resulted in more dispersion of soil particles, which ultimately led to a higher puddling index. Findings of this study corroborated well with earlier work on sandy loam soils of Punjab (Kukal and Sidhu, 2004), wherein pre-puddling tillage and puddling intensity had significant positive effect on puddling index.

Table 2. Effect of pre-puddling tillage and puddling intensity on grain yield of rice and residual wheat (Pooled over 03 years)

Pre-puddling tillage	Puddling intensity			
	P_1	P_2	P_4	Mean
Rice yield (t/ha)				
T_1	4034	4850	5195	4680
T_2	4500	5322	5593	5139
T_4	4894	5729	5844	5489
Mean	4476	5297	5534	-
Residual wheat yield (t/ha)				
T_1	4290	4241	3927	4153
T_2	4375	3871	3858	4035
T_4	4023	3932	2859	3605
Mean	4229	4015	3548	
CD at 5%	Rice		Wheat	
	P=356, T= 317, P x T= 411		P=254, T= NS, P x T= 385	

T_1, T_2 and T_4 indicate 01 tillage, 02 tillage (01 cultivator+ 01 harrow) and 04 tillage (02 cultivator+ 02 harrow) operations, respectively. P_1, P_2 and P_4 stand for 01, 02 (criss-cross) and 04 (criss-cross) passes of puddler

Effect on total N uptake by rice

A marked increase in total N uptake was noted due to increasing dry tillage levels or puddling intensity (Table 3). Raising puddling level from one to four passes of puddler resulted in 17.5% and 22.3% increase in total N uptake. The corresponding increase due to pre-puddling (dry) tillage was 8.1% and 13.4%, respectively. The total N uptake followed a trend similar to grain yield, and increasing puddling intensity beyond two passes of puddler in treatments having conventional dry tillage could hardly bring improvement in total N uptake by rice. Possible reason for relatively higher

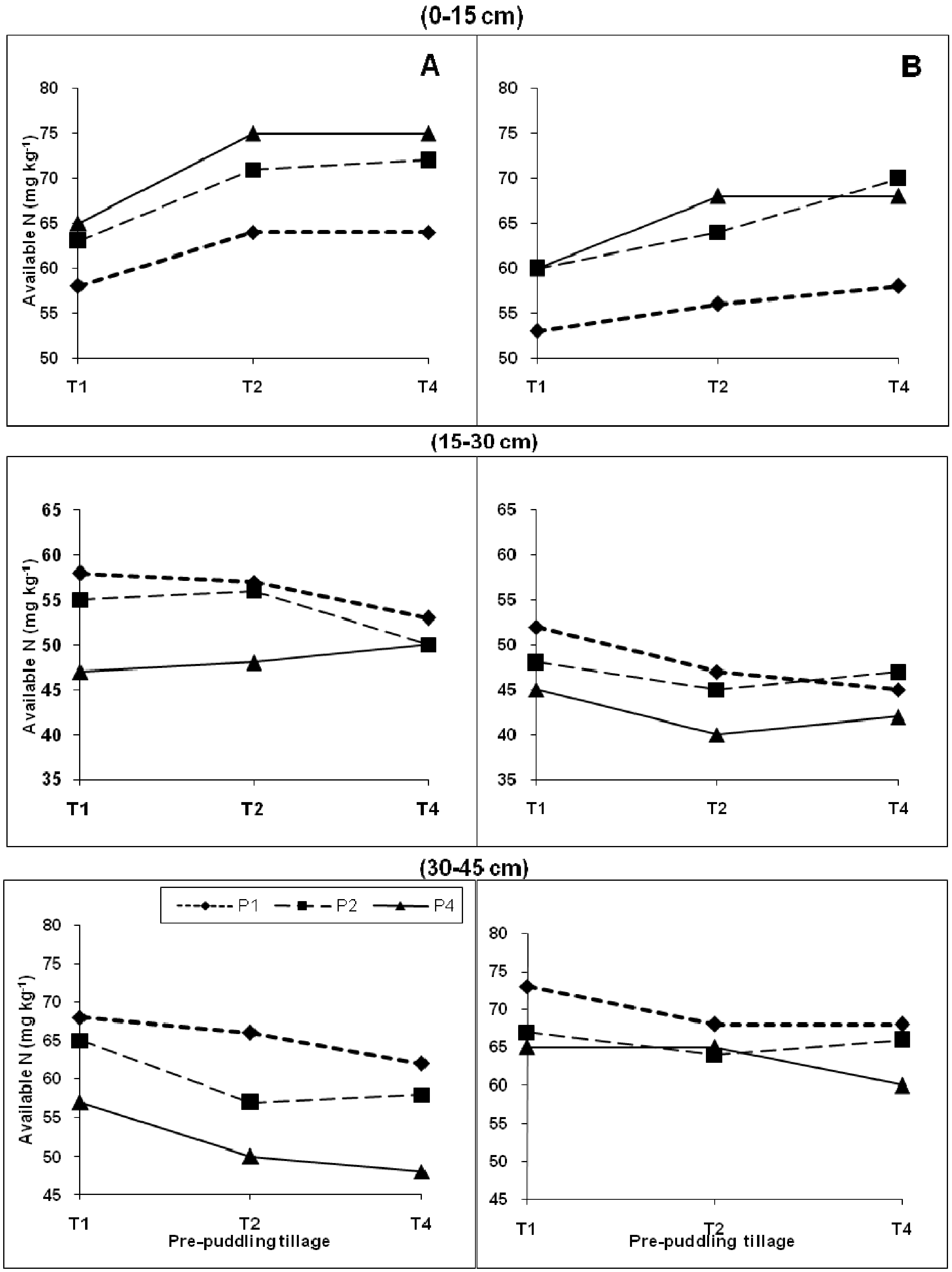

Fig 1a: Available N content of soil as influenced by pre-puddling tillage and puddling operations (A) 2-day and (B) 7-day after first top-dressing in rice

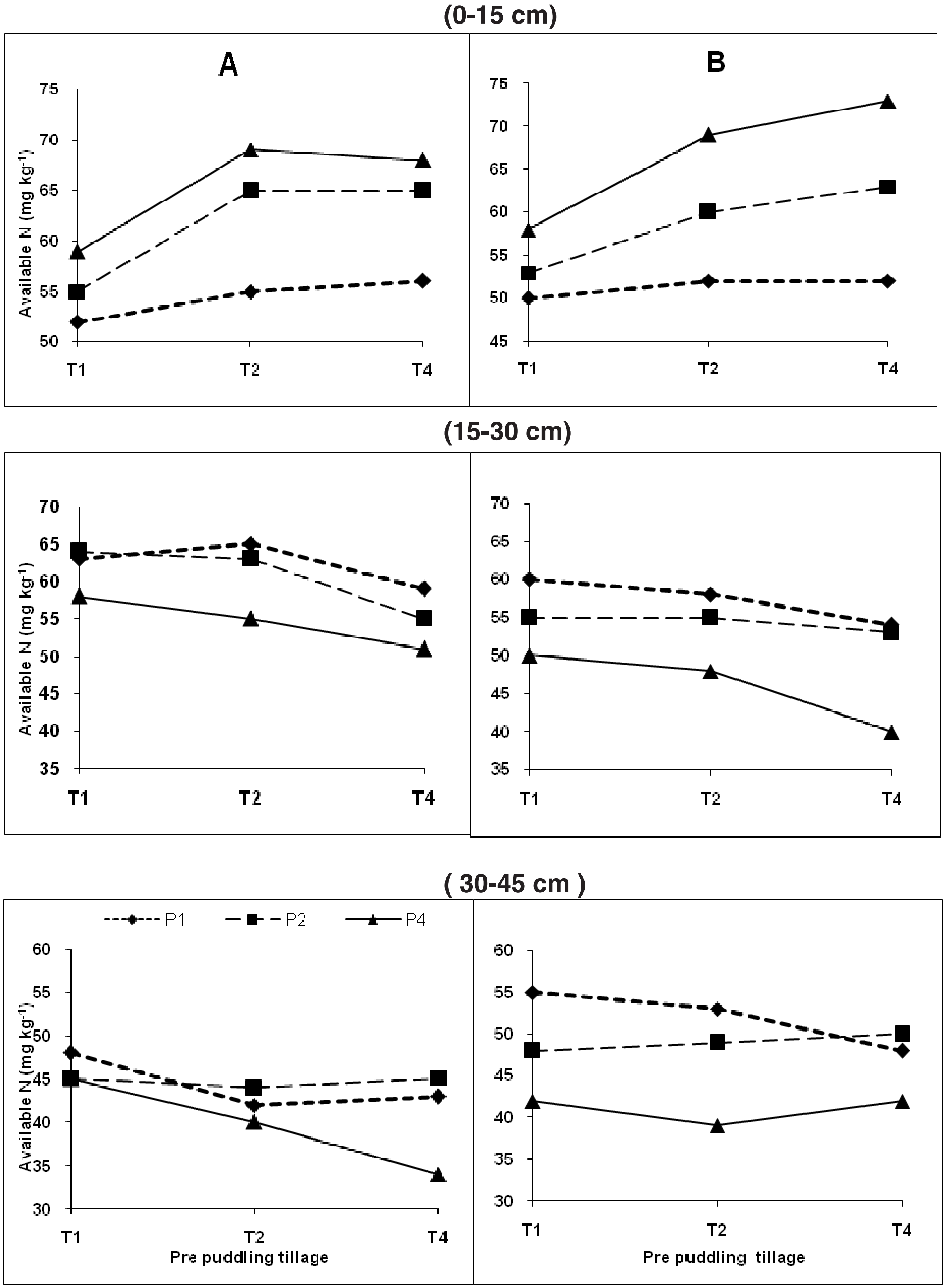

Fig 1b: Available N content of soil as influenced by pre-puddling tillage and puddling operations (A) 2-day and (B) 7-day after second top-dressing in rice

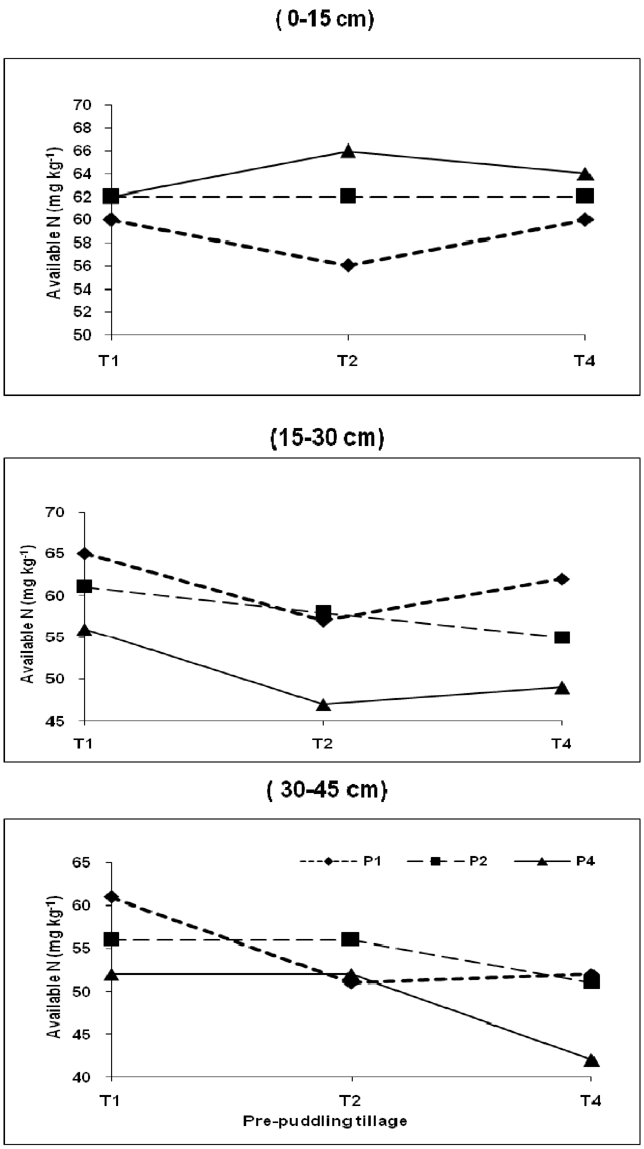

Fig 1c. Effect of pre-puddling tillage and puddling operations on available N content of soil after rice harvest

rice yields and N uptake in intensively puddle plot may be visualized that the restricted water movement to lower profile could have helped in minimizing the leaching losses and greater retention of available N in upper profile zone with intensive-puddling (Fig. 1, 2 and 3), and consequently higher N availability to rice occurred over the less-puddled ones.

Effect on irrigation water requirement in rice

The irrigation water input measured through parshal flume was greatest in treatments having one-dry tillage+one pass of puddler, and the smallest in treatments receiving four dry tillage+four passes of puddler (Table 4). Increasing dry tillage or puddling rates brought economy on irrigation water input. Raising puddling level from one to four passes of puddler economized water input by 17.0 ha-cm in rice crop, whereas the corresponding saving of irrigation water due to dry-tillage was 11.9 ha-cm. On average, the differences in water input in two or four passes of puddler were small. The increase in soil BD under intensively puddle plot could explain the saving of irrigation water and increase in Field water use efficiency (FWUE), and also a decrease in available-

Table 3. Effect of pre-puddling tillage and puddling levels on total N uptake (kg/ha) by rice (Pooled over 03 years)

Pre-puddling tillage	Puddling intensity			
	P_1	P_2	P_4	Mean
	Rice yield (t/ha)			
T_1	84.8	100.1	104.2	96.4
T_2	90.8	107.2	114.7	104.2
T_4	98.0	114.3	115.6	109.3
Mean	91.2	107.2	111.5	-
CD at 5%	P=7.1, T= 6.2, P x T= 11.9			

T_1, T_2 and T_4 indicate 01 tillage, 02 tillage (01 cultivator+ 01 harrow) and 04 tillage (02 cultivator+ 02 harrow) operations, respectively. P_1, P_2 and P_4 stand for 01, 02 (criss-cross) and 04 (criss-cross) passes of puddler.

Table 4. Effect of dry tillage and puddling on irrigation water requirement and field water use efficiency in rice (Pooled over 03 years)

Pre-puddling tillage	Puddling intensity			
	P_1	P_2	P_4	Mean
	Irrigation water input (ha-cm)			
T_1	120	115	110	115
T_2	119	110	102	111
T_4	115	102	92	103
Mean	118	109	101	-
	Field water use efficiency (kg/ha-cm)			
T_1	34	43	48	42
T_2	38	49	56	48
T_4	43	57	62	54
Mean	38	50	55	-
CD at 5%	Irrigation water input		Field water use efficiency	
	P=9.1, T= 8.2, P x T= 11.9		P=6.3, T= 5.6, P x T= 8.1	

T_1, T_2 and T_4 indicate 01 tillage, 02 tillage (01 cultivator+ 01 harrow) and 04 tillage (02 cultivator+ 02 harrow) operations, respectively. P_1, P_2 and P_4 stand for 01, 02 (criss-cross) and 04 (criss-cross) passes of puddler.

N leaching recorded at higher T and/or P levels. In the present study, the FWUE under T_4P_4 was greater by 81% compared with T_1P_1 (Table 4). The field water use efficiency (FWUE) increased markedly with increasing dry-or wet tillage and it was highest in the plot having four pre-puddling tillage + four puddling. Averaging across the dry tillage and different year or study, using two or four pass of puddler in rice brought 28% and 43% more FWUE, respectively than the one pass of puddler. Similarly, 2 or 4 dry tillage operations had 30% and 14.5% extra FWUE than one dry tillage operation (Table 4). It is pertinent to mentioned that the better nutrient availability in rhisosphere zone (For example available N in present case) ensures better rice yield and simultaneously lesser water requirement in intensively puddle plot were the important reason for higher FWUE.

Effect on bulk density of soil

The bulk density (BD) of surface soil layer as measured after rice harvest varied from 1.44 g/cc to 1.52 g/cc in different treatments. BD values averaged over puddling levels did not vary sizably due to dry tillage operations (Table 5). On the other hand, BD of the soil tended to increase with increasing puddling intensity. The dry tillage x puddling interaction was quite interesting in this context. Whereas soil BD decreased with increasing dry-tillage in less puddled (one pass of puddler) plots, the same followed an increasing trend with increasing dry-tillage levels under well puddled situations. Results of the present study corroborate the findings of Kukal and Aggrawal, 2003 that repeated puddling disrupt the soil aggregates and increased soil compaction and penetration resistance by the means of higher BD.

Table 5. Effect of pre-puddling tillage and puddling on bulk density (g/cc) after rice harvest (2002-03)

Pre-puddling tillage	Puddling intensity			
	P_1	P_2	P_4	Mean
T_1	1.46	1.44	1.49	1.46
T_2	1.46	1.47	1.50	1.48
T_4	1.43	1.49	1.52	1.48
Mean	1.45	1.47	1.50	-
CD at 5%	P=0.02, T= NS, P x T= 0.04			

T_1, T_2 and T_4 indicate 01 tillage, 02 tillage (01 cultivator+ 01 harrow) and 04 tillage (02 cultivator+ 02 harrow) operations, respectively. P_1, P_2 and P_4 stand for 01, 02 (criss-cross) and 04 (criss-cross) passes of puddler.

Changes in available N content of the soil

Soil analysis made during third rice (2002-03) crop at 0-15 cm, 15-30 cm and 30-45 cm profile depth after 2- and 7- days of first as well as second top-dressing indicated that available N content increased concomitantly with every increment in tillage or puddling regime (Figs. 1a and 1b), indicating thereby the advantage of these operations on retention of available N in plough layer in surface soil (0-15 cm depth). Contrary to this, a higher N content under lower puddling and tillage regimes was recorded in sub-surface soil layers, the treatment effect being more spectacular at 15-30 cm compared with 30-45 cm soil layer. Thus, the results suggested greater leaching losses of available N in the plots having one dry tillage and one puddling. The reverse was, however, true for plots having higher tillage and puddling levels. Since leaching of nitrogen (especially NO_3-N) at a given time depends on its concentration in solution and downward flux of water, a restricted water movement to lower profile under intensive puddling could have helped minimizing the leaching losses (Sharma and De-Datta, 1986). Thus, greater retention of available N in upper profile was observed under intensively-puddled plots. At all the three soil depths, available N content was higher at 2-day after top-dressing, as compared to 7- day after top-dressing. Such dynamic N availability in the rice soil may be envisaged due to its efficient utilization by the crop and reminder N movement beyond the studied zone (bellow 45-cm depth) (Singh *et al,* 2008). In post-rice soil samples, a similar treatment effect was noticed in different soil layers, particularly at 0-15 cm and 15-30 cm soil depth (Fig. 1_c).

Grain yield of residual wheat

The grain yields of wheat, raised with uniform tillage, fertilizer and water management practices on the undisturbed lay-out varied according to puddling intensity given in previous rice crop. The grain yield of wheat was smaller in the treatments having high pudding intensity, and vice-versa. When averaged over dry tillage treatment, wheat grain yield in P_2 and P_4 plot were 0.21 and 0.68 t/ha less than that in P_1 plots. This adverse effect of puddling might be associated with increased bulk density in P_4 plots (Table 5) caused wheat crop establishment and resulted in low yield. The BD of

Table 6. Effect of level of puddling and dry tillage operation on energy requirements (M J/ kg) in rice and rice-wheat cropping system (Pooled over 03 years)

Pre-puddling tillage	Puddling intensity			
	P_1	P_2	P_4	Mean
		Rice		
T_1	20360	21003	22887	21417
T_2	20699	21274	23090	21688
T_4	21349	21849	23620	22273
Mean	20803	21376	23199	
		Rice-wheat system		
T_1	36272	36915	38799	37329
T_2	36521	37186	39002	37570
T_4	37261	37761	39531	38184
Mean	36685	37287	39111	
CD at 5%	Rice		Rice-wheat system	
	P=372, T= 428, P x T= 547		P=1122, T= 1321, P x T= 1721	

T_1, T_2 and T_4 indicate 01 tillage, 02 tillage (01 cultivator+ 01 harrow) and 04 tillage (02 cultivator+ 02 harrow) operations, respectively. P_1, P_2 and P_4 stand for 01, 02 (criss-cross) and 04 (criss-cross) passes of puddler.

excessively-puddled soils increase upon drying of the soil after rice harvest (Sharma and De-Datta, 1985), leading to a soil condition that is less favourable for establishment of wheat crop in RWCS. Increased sub-surface soil compaction as indicated by an increased BD under intensive puddling resulted in restricted growth and penetration of wheat roots. Impaired soil structure of puddled and compacted sub-soil in rice-wheat system is the major impediment for establishment and growth of subsequent wheat crop (Gajri *et al,* 1992; Oussible *et al,* 1992; Aggarwal *et al,* 1995). On the other hand, compaaratevely better wheat yield under less puddle plots confirm the findings of earlier experiments on similar soils at Modipuram revealed that a deep and extensive root system of wheat helps to trap N and P from deeper profile and ensures an increase in wheat productivity (Dwivedi *et al*, 2003; Singh *et al*, 2005; Singh and Dwivedi, 2006). Although the wheat yield was not supposed to be influenced adversely due to nutrient stress *per se* as the fertilizers were applied at recommended rate, yet relatively greater wheat yields under less-puddled treatments could also be explained in the light of greater contact between absorbing root surface and available nutrient pool under an extensive root system (Tisdale *et al*, 1993).

Energy required for different tillage input in rice production increased with increasing pre-paddling tillage and also with paddling intensity up to T_4 or P_4. Although, the difference in energy requirement for pre-puddling tillage (T_1 to T_4) and puddling intensity up to 02 criss-cross pudding were not significant but increasing pudding intensity beyond P_2 to P_4 had pronounced effect on energy use (MJ/ ha). Further, P x T interactions were significant, and the maximum energy use was noticed with P_4T_4 (23,620 MJ/ha). Treatment having 02 pre- puddling tillage followed by 02 passes of puddler (T_2P_2) appeared energy efficient as this combination had optimal rice yield along with comparatively lesser energy use (21, 274 MJ/ ha). Explaining the treatment effect in terms of specific energy requirement (SE_R) further underlined the need for optimizing T and P combinations. The values of SE_R were lowest (3.84 MJ/kg) under T_4P_2, which were statistically similar to T_2P_2 (4.01 MJ/kg) (data not reported). The increase in tillage (dry or wet) beyond T_2P_2 was thus not advantageous with energy efficiency viewpoint. The cumulative energy use under rice-wheat system was also followed the similar tread to rice and T_2P_2 treatment was found optimal for energy input use and sustainable system annual productivity.

CONCLUSIONS

Both pre-puddling tillage and puddling played a significant role in water saving in rice by reducing percolation losses, restricting down word nitrogen movement, providing better environment for N uptake, and thereby increasing the grain yield. Optimization of pre-puddling tillage and puddling intensity is, therefore, essential in rice-wheat systems to overcome any adverse effect of puddling on the succeeding wheat crop following rice, as caused due to increase in sub-surface compaction. The present study suggested 2 pre-puddling tillage followed by 2 passes of puddler as an optimum tillage combination for rice on the coarse-textured (sandy loam) soils to achieve high annual RWCS productivity and efficient energy use view point.

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An application of classification and regression tree on qualitative soil survey data for land capability classification

NIRMAL KUMAR[1], G. P. OBI REDDY[2], S. CHATTERJI[3], JAGDISH PRASAD[4] and DIPAK SARKAR[5]

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ABSTRACT

Land capability classification (LCC) of a soil map unit is sought for sustainable use, management and conservation practices. High speed, high precision and simple generating of rules by machine learning algorithms can be utilized to construct pre-defined rules for LCC of soil map units in developing decision support systems for land use planning of an area. Decision tree (DT) is one of the most popular classification algorithms currently in machine learning and data mining. Generation of Classification and Regression Tree (CART) from qualitative soil survey data for LCC reported in reconnaissance soil survey data of Wardha district, Maharashtra has been demonstrated in the present study with soil depth, slope, and erosion as attributes for LCC. A 10-fold cross validation provided accuracy of 100%. The results indicated that CART algorithms had good potential in automation of LCC of soil survey data, which in turn, will help to develop decision support system to suggest suitable land use system and soil and water conservation practices.

Keywords: CART, Decision Tree, Land Capability Classification

INTRODUCTION

LCC - A qualitative system - developed by the US Department of Agriculture, as part of an erosion control programme (Klingebiel and Montgomery 1961) is undoubtedly the most used land classification system in the world (Rossiter, D.G. 1994). LCC provides information of the kind of soil, its location on the landscape, its extent, and its suitability for various uses, which is needed for conservation planning, environmental quality, and generation of interpretive maps (Fenton, 2005). The task of LCC occurs every time a soil surveyor identifies a map unit. A large and diversified dataset have already been generated through soil surveys. A pre-defined rule set learned on these data for automatically defining the LCC of the future map units being surveyed, will be of great help for developing decision support systems for land use planning and suggesting conservation and management practices. Machine learning and data mining techniques which gives computers the ability to learn based on the inherent characteristics of data, without being explicitly programmed (Fayyad et al., 1996; Diplaris *et al.*, 2006) may be utilized for generating these rule sets. DT is one of the most popular classification algorithms currently in machine learning and data mining (McQueen *et al.*, 1995; Gangrade *et al.*, 2009; Huang *et al.*, 2010; Debska *et al.*, 2011).

In their simplest form, DT classifiers successively partition the input training data into more and more homogeneous sub sets by producing optimal rules or decisions, also called nodes (Safavian and Landgrebe, 1991; 2003; Huang *et al.*, 2010; Trépos *et al.*, 2012). The rules or the splitting criteria at these nodes are the key to successful decision tree creation (Rattray et al., 1999). The most frequently used splitting criteria are the information gain, the information gain ratio (Quinlan, 1993), the Gini index (Breiman *et al.*, 1984), and the chi-square measure (Kass, 1980).

[1]GIS Section, National Bureau of Soil Survey and Land Use Planning (ICAR), Amravati Road, Nagpur – 440 033, India., Phone: 9595273046, Fax: (+91)0712 250534, e-mail: nirmalnbss@gmail.com
[2-5] National Bureau of Soil Survey and Land Use Planning (ICAR), Amravati Road, Nagpur

Some of the most popular DT methods are ID3, C4.5 (Quinlan, 1986, 1993, 1996), CHAID (Kass, 1980), and CART (Breiman *et al.*, 1984). The CART decision tree is a binary recursive partitioning procedure capable of processing continuous and nominal attributes both as targets and predictors. CART trees are grown using gini index for splitting procedure. CART classification method has been widely used for its advantages of high speed, high precision and simple generating model (Breiman *et al.*, 1984; Gahegan and West, 1998; Huang *et al.*, 2010). A detailed review of CART applications in agricultural and biological engineering may be found in McQueen *et al.*, (1995) and Huang *et al.*, (2010). In the field of applying DT algorithms for soil survey data, Tamboli *et al.*, (2012) evaluated ID3 DT for LCC with 12 simulated samples with soil depth, slope, and texture as attributes for LCC; however, model was not validated. Kumar *et al.*, (2013) applied ID3 DT method on soil survey data of Wardha district and got an accuracy of 86.84% on 10-fold cross validation.

MATERIALS AND METHODS

Training datasets used

By considering slope, soil depth and erosion as important attributes, LCC of 38 soil series of Wardha district, Maharashtra, India, was assessed as per the procedure laid down by Soil Survey Manual by All India Soil and Land Use Survey Organization (AISLUS, 1971).

Waikato Environment for Knowledge Analysis (WEKA) – an open source data mining tool – and SPSS® were used for generation of CART rules for comparison with the one manually generated.

CART Algorithm

CART is the most popular DT algorithm which constructs binary trees, i.e., each internal node has exactly two outgoing edges (Goel *et al.*, 2003). The CART (Breiman *et al.*, 1984) growing method attempts to maximize within-node homogeneity. The extent to which a node does not represent a homogenous subset of cases is an indication of impurity. For example, a terminal node in which all cases have the same value for the dependent variable is a homogenous node that requires no further splitting because it is "pure." The impurity measures for nominal dependent variables are gini index and towing. Gini is based on squared probabilities of membership for each category of the dependent variable. It reaches its minimum (zero) when all cases in a node fall into a single category. In case of towing, categories of the dependent variable are grouped into two subclasses. Splits are found that best separate the two groups. The measure used in this study is gini index.

f a data set S contains examples from *v* classes, gini index, gini(S) is defined as

$$gini(S) = 1 - \sum_{i=1}^{v} P_i^2 \qquad (1)$$

Where P_i is the relative frequency of class i in S.

If a data set S is split on attribute A into two subsets S_1 and S_2, the *gini* index $gini(S)$ is defined as

$$gini_A(S) = \frac{|S_1|}{|S|} gini(S_1) + \frac{|S_2|}{|S|} gini(S_2) \qquad (2)$$

Reduction in Impurity

$$\Delta gini(A) = gini(S) - gini_A(S) \qquad (3)$$

The attribute, which provides the largest reduction in impurity, is chosen to split the node. All the possible splitting points for each attribute need to be enumerated.

Accuracy Assessment

In machine learning methods, such as the DT, the classification accuracy is often predicted by stratified 10-fold cross-validation (Weiss and Kulikowski, 1991; Kohavi, 1995; Kirchner et. al., 2006). In the process, the whole dataset is split into 10 parts. Nine parts of the dataset is used for learning and 1 for testing. This procedure is repeated 10 times so that every part of the dataset is used for both training and testing (of course one at each time). Afterwards, the overall accuracy parameters were calculated as means from the evaluation of the individual cross-validation subset. A 10-fold cross validation was applied in CART model.

RESULTS AND DISCUSSION

Induction of CART

The LCC of soil series of the study area ranges from IIIs to Vies (Table 1). The same training dataset was used to evaluate CART in assessment of LCC.

Table 1. Soil series description and attributes for LCC

Soil series	Depth	Slope	Erosion	Capability class
Kolona series	d5	d	e2	IIIes
Karanja series	d5	d	e2	IIIes
Nagjhari series	d5	d	e2	IIIes
Nijampur series	d5	b	e1	IIIs
Pachod series	d5	b	e2	IIIse
Vagholi series	d5	b	e2	IIIse
Thar series	d4	c	e2	IIIse
Anjangaon series	d4	c	e2	IIIse
Takli series	d5	c	e2	IIIse
Arvi series	d4	b	e2	IIIse
Yakamba series	d4	b	e2	IIIse
Chamla series	d4	b	e1	IIIs
Sirasgaon series	d3	c	e3	IVes
Talani series	d2	c	e3	IVes
Panthargavda series	d3	d	e3	VIes
Parsodi series	d2	e	e3	VIes
Hridi series	d4	c	e3	IIIse
Chanakpur series	d3	b	e2	IVs
Wadner series	d2	b	e2	IVs
Pardi series	d2	b	e2	IVs
Lakhandevi series	d3	e	e3	VIes
Mahakali series	d3	e	e3	VIes
Karanii series	d3	e	e3	VIes
Ashti series	d3	d	e3	VIes
Kinala series	d2	e	e3	VIes
Sewagram series	d2	d	e3	VIes
Madni series	d2	d	e3	VIes
Hewan series	d5	b	e1	IIIs
Waigaon series	d4	b	e2	IIIse
Karla series	d4	b	e2	IIIse
Bothali series	d5	b	e2	IIIse
Kondhali series	d5	b	e2	IIIse
Wardha series	d5	b	e2	IIIse
Lasanpur series	d5	b	e2	IIIse
Malalpur series	d5	b	e2	IIIse
Malakpur series	d5	c	e2	IIIse
Sirpur series	d5	c	e2	IIIse
Talegaon series	d5	b	e2	IIIse

Depth classes: d2 – shallow (25-50 cm), d3 – moderately shallow (50- 75 cm), d4 – Moderately deep (75 – 100 cm), d5 – deep (100 – 150 cm)
Slope classes: b – very gently sloping (1-3%), c – Gently sloping (3-8%), d – Moderately sloping (8-15%), e – Moderately steep (15-30%)
Erosion classes: e1 – Slight erosion, e2 – Moderate erosion, e3 – Severe erosion

Based on the data (Table 1), gini index of the root node containing the whole training set as its subset is calculated as:

$$gini(S)=1-(3/38)^2-(3/38)^2-(18/38)^2-(2/38)^2-(3/38)^2-(9/38)^2 = 0.698 \quad (4)$$

Since, the CART algorithm finds binary splits to split a node let us consider the attribute *erosion*. If exhaustive search is used, the attribute has 3 possible splitting subsets (Figure 1).

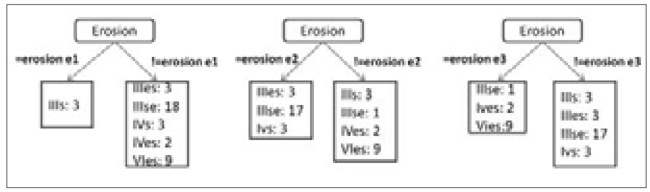

Fig. 1. Possible binary splits for erosion and their class distribution at the root node

In case of the first split in the figure 2, the gini values for two successor nodes are thus

$$gini(e1) = [1-(3/3)^2] = 0 \quad (5)$$

$$gini(!e1) = [1-(3/35)^2-(18/35)^2-(2/35)^2-(3/35)^2-(9/35)^2] = 0.651 \quad (6)$$

and gini index and gini gain for erosion e1 is calculated as

$$gini(erosion=e1) = 3/38*gini(e1)+35/38*gini(!e1) = 0.600 \quad (7)$$

$$gini\ gain(erosion=e1)= gini(S)- gini(erosion=e1) = 0.698 - 0.600 = 0.098 \quad (8)$$

Similarly, gini indices for all possible binary splits for the three attributes were calculated (Table 2). Attribute *depth* (binary split *d2-3:d4-5*) having maximum gini gain (0.250), will split the root node.

Table 2. Possible binary splits and gini gain at the root node

Binary Splits	Gini	Gini gain
Possible binary splits for depth		
d2 : !d2	0.608	0.090
d3 : !d3	0.590	0.108
d4 :!d4	0.636	0.063
d5 :!d5	0.607	0.091
d2-3 : d4-5	0.448	0.250
d2-4 : d3-5	0.691	0.007
d2-5 : d3-4	0.688	0.010
Possible binary splits for slope		
b :!b	0.592	0.106
c :!c	0.647	0.051
d :!d	0.591	0.107
e :!e	0.573	0.125

Binary Splits	Gini	Gini gain
bc : de	0.452	0.246
be : cd	0.672	0.026
bd : ce	0.672	0.026
Possible binary splits for erosion		
e1 :!e1	0.600	0.098
e2 :!e2	0.482	0.216
e3 :!e3	0.492	0.206

Child node of *depth d2-3* will be split by *slope b-c:d-e* having maximum gini gain (0.129) at this node (Table 3). In the same way child node of *depth d4-5* will be split by *slope b-c:d* having maximum gini gain (0.121) at this node (Table 4). Node *slope d-e* under the parent node *depth d2-3* and *slope d* under parent node *depth d4-5* will be truncated as there in no improvement in gini index further for any attribute. Gini gain at the child node *slope b-c* (0.063) under parent node *depth d2-3* (Table 5) suggests that *slope b:c* will be the next split for this node. Similarly, child node *slope b-c* (0.135) under parent node *depth d4-5* will be split by *erosion e2-3:e1* having maximum gini gain of 0.135 (Table 6). No further splitting occurs since the improvement in the gini gain comes down to zero in all child nodes.

Table 3. Possible binary splits and gini gain at the child node *depth d2-3*

Binary Splits	Gini	Gini gain
Possible binary splits for slope		
b : !b	0.086	0.106
c :!c	0.118	0.073
d :!d	0.163	0.029
e :!e	0.152	0.040
bc : de	0.063	0.129
bd : ce	0.165	0.026
be : cd	0.169	0.023
Possible binary splits for depth		
d2 : d3	0.188	0.004
Possible binary splits for erosion		
e2 : e3	0.086	0.106

Table 4. Possible binary splits and gini gain at the child node *depth d4-5*

Binary Splits	Gini	Gini gain
Possible binary splits for slope		
b : cd	0.232	0.025
c : bd	0.237	0.020
d : bc	0.135	0.121
Possible binary splits for depth		
d4 : d5	0.247	0.010
Possible binary splits for erosion		
e1 : !e1	0.135	0.121
e2 : !e2	0.174	0.083
e3 : !e3	0.254	0.003

Table 5. Possible binary splits and gini gain at the child node *slope b-c under node depth d2-3*

Binary Splits	Gini	Gini gain
Possible binary splits for slope		
B : !b	0.000	0.063
Possible binary splits for depth		
d2 : d3	0.061	0.002
Possible binary splits for erosion		
e2 : e3	0.000	0.063

Table 6. Possible binary splits and gini gain at the child node *slope b-c* under node *depth d4-5*

Binary Splits	Gini	Gini gain
Possible binary splits for erosion		
e1 : !e1	0.000	0.135
e2 : !e2	0.039	0.096
e3 : !e3	0.134	0.001
Possible binary splits for slope		
b : c	0.126	0.009
Possible binary splits for depth		
d4 : d5	0.135	0.000

The structure of the tree manually developed is found to be similar to that of WEKA (Figure 2) and SPSS (Figure 3). The accuracy of CART algorithm was assessed through a 10 - fold cross validation method. The confusion matrix has been shown in Table 7. The analysis shows that CART algorithm found to be 100% accurate with a kappa coefficient of 1.

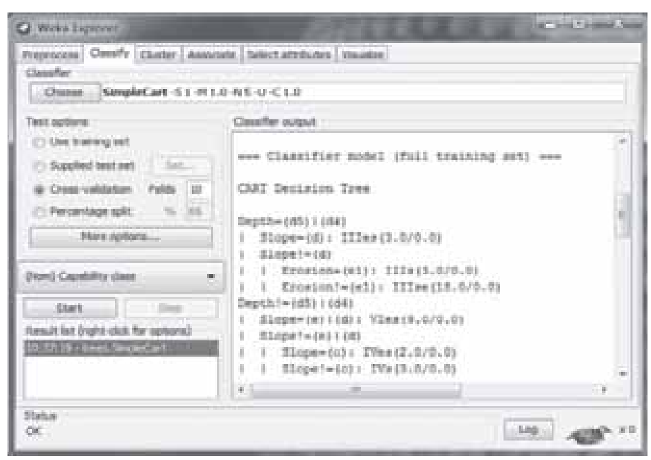

Fig. 2. Decision tree developed with CART module of WEKA

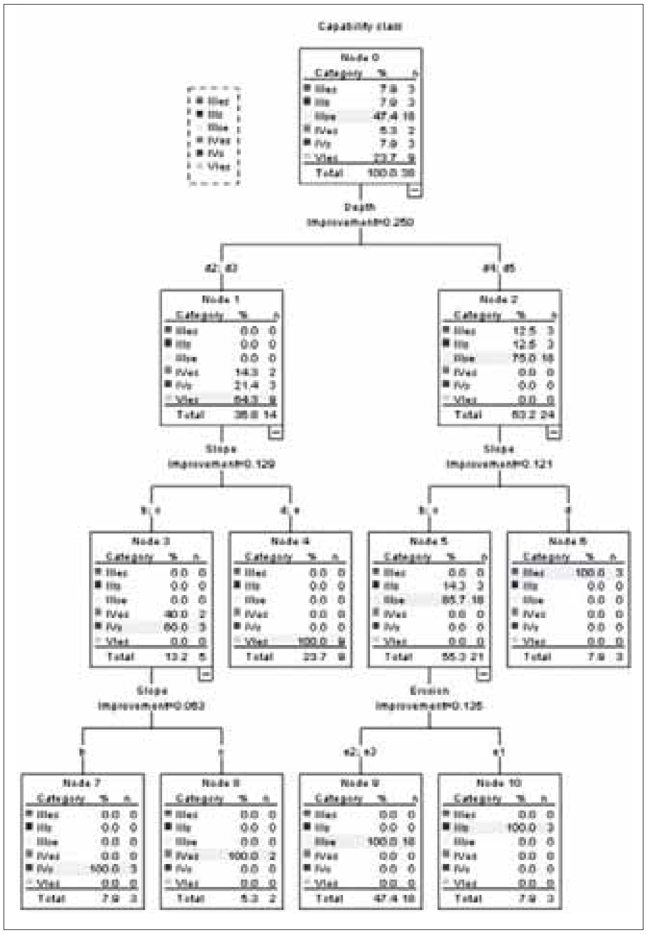

Fig. 3. Decision Tree developed with CART module of SPSS

Table 7. Confusion Matrix

Observed	Predicted						
	IIIes	IIIs	IIIse	IVes	IVs	VIes	Percent Correct
IIIes	3	0	0	0	0	0	100.0%
IIIs	0	3	0	0	0	0	100.0%
IIIse	0	0	18	0	0	0	100.0%
IVes	0	0	0	2	0	0	100.0%
IVs	0	0	0	0	3	0	100.0%
VIes	0	0	0	0	0	9	100.0%
Overall Percentage	7.9%	7.9%	47.4%	5.3%	7.9%	23.7%	100.0%

Growing Method: CRT

Dependent Variable: Capability class

CONCLUSIONS

The result indicates that decision tree algorithms have immense potential over the traditional procedures in LCC for their fast and easy rules generation. Explicit rules could be formulated with better accuracy for classifying complex soil-site data acquired over diversified landscapes. The large size training dataset with higher variability may produce a robust DT model for automation of LCC and their incorporation in decision support systems to suggest suitable land use system and soil and water conservation practices.

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Molybdenum status in mixed red and black soils of Balaghat and Chhatarpur districts of Madhya Pradesh

G.D. SHARMA[1], RISIKESH THAKUR[1], BRIJESH YADAV[2] and SOM RAJ[1]

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ABSTRACT

Status of acid ammonium oxalate extractable molybdenum content and effect of soil properties on its status were studied in mixed red and black soil of Balaghat and Chhatarpur districts of Madhya Pradesh. The findings of the present studies revealed that the acid ammonium oxalate extractable molybdenum content in Balaghat and Chhatarpur soils varied from 0.093 to 0.925 mg kg^{-1} with a mean value of 0.350 mg kg^{-1} and 0.093 to 0.925 mg kg^{-1} with a mean value of 0.355 mg kg^{-1}, respectively. Further, all the samples were found adequate in molybdenum content and some tehsils of both districts showed high content of molybdenum in soil. The pH, EC, $CaCO_3$ and OC of Balaghat soils ranged from 4.3 to 7.3, 0.10 to 0.35 dS m^{-1}, 10 to 80 g kg^{-1} and 1.29 to 7.16 g kg^{-1}, respectively. Whereas, the pH, EC, $CaCO_3$ and OC of Chhatarpur soils varied from 5.7 to 7.8, 0.10 to 0.30 dS m^{-1}, 10–60 g kg^{-1} and 0.79 to 5.20 g kg^{-1}, respectively. Correlation coefficients between soil pH, organic carbon and calcium carbonate content exhibited a significant and positive relationship whereas electrical conductivity was non-significantly correlated with available molybdenum in these soils. The value of correlation between soil and plant Mo was found to be positive and significant in case of Balaghat.

Key words : Molybdenum contents in soil and plant, mixed red and black soils, wheat and chickpea crops.

INTRODUCTION

The stagnation in crop productivity has been documented due to deficiency of some micro and secondary nutrients. Hence, micronutrients have been acknowledged for increasing importance in crop production under modern agricultural technology (Rattan *et al.*, 2009). Deficiency of micronutrients has become a major constraint to productivity, stability and sustainability in Indian soils (Sharma, 2008). Molybdenum is an important micronutrient found in the soil and is required for growth of most biological organisms including plants and animals. The element is a transition element, which can exist in several oxidation states ranging from 0 to VI, where VI is the most common oxidation state found in most agricultural soils. The vital roles played by the nutrient in plant nutrition is of fundamental importance and hence it has become necessary to assess the status of molybdenum in soils. In soils of Balaghat and Chhatarpur districts of Madhya Pradesh molybdenite and ferrimotybdite minerals are also found, which are rich in molybdenum content (Khamparia *et al*. 2010). Looking to the intimate relationship between soil properties and molybdenum availability and its rather scanty information availability, the present study was under taken to analyze the influence of soil properties on availability of Mo for better management in mixed red and black soils of Balaghat and Chhatarpur districts of Madhya Pradesh.

MATERIALS AND METHODS

The area of Balaghat district is spread between latitude 21^0 30' 18, 744" N to 22^0 11' 00, 369" N and longitudes 79^0 47' 29, 424" E to 80^0 32' 34, 224" E and the area of Chhatarpur district is spread between

[1]Department of Soil Science and Agril. Chemistry, JNKVV, Jabalpur, Madhya Pradesh
[2]SRF, Division of Agronomy, IARI, New Delhi

latitude 24 15' 23,190" N to 25^0 15' 57, 036" N and longitudes 79^0 12'02, 124" E to 80^0 06' 40, 008" E. The agro- ecological zone of Balaghat district is an Eastern plateau and hill with agro- climatic regions of sub humid region. While the agro-ecological zone of Chhatarpur district is a Bundelkhand agro-climatic zone with sub-humid climate. From these regionsof Balaghat and Chhatarpur districts, about three hundred samples of soil, grain and straw (wheat and chickpea) were collected with the help of staff members under Micronutrient Project during 2007-08 (Table 1). The samples were analyzed for different soil properties like soil pH, EC, $CaCO_3$, organic carbon and available molybdenum and data was processed statistically to obtain the proposed objectives.

The soil pH was determined by glass electrode pH meter in 1:2 soil water suspension (Govindrajan, 1970). Electrical conductivity was measured in supernatant liquid of 1:2 soil water suspension using a solu-bridge (Jackson, 1965). Analysis of calcium carbonate was carried out by the rapid titration method as described by Jackson (1965). Organic carbon content was determined by Walkey and Black method as described by Jackson (1965). Determination of available molybdenum in soil was performed by Acid Ammonium Oxalate Extractable Molybdenum method (Johnson and Arkley, 1954). While, the molybdenum content in grain and straw samples was estimated by Thiocyanate-Acetone method described by Ellis and Olsen (1950).

Table 1. The details of samples of soil, grain and straw collected from Balaghat and Chhatarpur districts.

Tehsils		Balaghat district			
	Soil	Plant samples			
	samples	Wheat		Chickpea	
		Grain	Straw	Grain	Straw
Waraseoni	40	20	20	20	20
Katangi	05	0	0	5	5
Lalbarra	10	7	7	3	3
Balaghat	06	4	4	2	2

RESULTS AND DISCUSSION

Soil properties of the Balaghat and Chhatarpur districts (Table 2) exhibited a considerable variation. The ranged of soil pH was between 4.3 to 7.3 with a mean value of 6.1 in case of Balaghat soils while the pH ranged from 5.7 to 7.8 with a mean value of 6.9 in case of Chhatarpur soils. Electrical conductivity of Balaghat soils varied from 0.10 to 0.35 dS m^{-1} with a mean value of 0.23 dS m^{-1}, while the same in Chhatarpur soils ranged between 0.10 to 0.30 dS m^{-1} with a mean value of 0.17 dS m^{-1}. $CaCO_3$ contents of Balaghat and Chhatarpur soils ranged from 10 to 80 g kg^{-1} and 10 to 60 g kg^{-1}, respectively and organic carbon contents were from 1.29 to 7.16 g kg^{-1} and 0.79 to 5.20 g kg^{-1}, respectively.

Table 2. Physico-chemical properties of soils of Balaghat and Chhatarpur districts

BALAGHAT DISTRICT								
Tehsil	Soil pH		EC(dSm^{-1})		$CaCO_3$(g kg^{-1})		Organic Carbon(g kg^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Waraseoni	4.3-7.2	5.9	0.10-0.35	0.22	10-65	27.8	1.80-7.16	3.82
Katangi	5.3-6.7	5.9	0.15-0.30	0.22	30-60	41.0	3.70-5.45	4.60
Lalbarra	5.4-7.3	6.4	0.10-0.30	0.21	10-60	32.0	1.29-5.10	2.82
Balaghat	5.0-7.1	6.2	0.10-0.35	0.20	20-70	35.8	2.72-5.05	3.60
Kirnapur	4.7-7.3	6.3	0.10-0.35	0.25	10-80	30.4	2.15-7.16	3.94
Total	4.3-7.3	6.1	0.10-0.35	0.23	10-80	30.4	1.29-7.16	3.79
CHHATARPUR DISTRICT								
Tehsil	Soil pH		EC(dSm^{-1})		$CaCO_3$(g kg^{-1})		Organic Carbon(g kg^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Rajnagar	6.1-7.3	6.7	0.10-0.30	0.19	10-50	26.3	1.99-4.32	3.09
Chhatarpur	5.9-7.6	6.9	0.10-0.25	0.16	10-45	24.4	1.29-4.98	3.13
Bijawar	5.7-7.8	6.5	0.10-0.25	0.16	15-55	29.2	0.79-3.90	2.32
Badamalhera	5.8-7.6	6.9	0.10-0.30	0.18	10-60	25.1	1.63-5.20	3.30
Naugaon	6.8-7.5	7.2	0.10-0.25	0.17	15-45	28.2	1.29-5.10	3.05
Total	5.7-7.8	6.9	0.10-0.30	0.17	10-60	26.0	0.79-5.20	3.08

Distribution of available molybdenum in soil

The data on distribution of available Mo content in soils of various tehsils of Balaghat and Chhatarpur districts are presented in table 3. Available molybdenum content in Balaghat soils ranged from 0.093 to 0.925 mg kg^{-1}, with a mean value of 0.350 mg kg^{-1}. Grigg (1960) have suggested 0.05 mg Mo kg^{-1} as critical limit (low), 0.05 – 0.10 mg Mo kg^{-1} as medium and more than 0.10 mg Mo kg^{-1} as high for ammonium oxalate extractable molybdenum. Considering these, all the soil samples were adequate in available molybdenum. The data of Chhatarpur soils (Table 3) showed the available molybdenum content ranged from 0.090 to 1.381 mg kg^{-1}, with a mean value of 0.496 mg kg^{-1}. Similar work has been carried out by Khilawan (1978) in soils of Morena (M.P.).

Correlation studies between physicochemical properties and available Molybdenum in soil

The correlation coefficient values between soil properties and available Mo of Balaghat district (Table 4) were found to be significant for the soils of Waraseoni (r=0.562**), Kirnapur (r=0.515**) and Lalbarra (r=0.704*) tehsils, while the soils of Katangi and Balaghat tehsils were statistically non-significant. Further, whole Balaghat district, the available Mo exhibited statistically significant and positive correlation with soil pH (r=0.502**). Similarly, correlation coefficients values of Chhatarpur district (Table 3) were significant for the soils (r=0.478*), Bijawar (r = 0.648*) and Badamalhera (r = 0.319*). However, entire Chhatarpur district was indicated statistically significant and positive correlation with soil pH (r=0.240*). Similar relationships have also been reported by Sharma *et.al*. (2003), they have also found a significant positive correlation between available molybdenum and soil pH. As the soil solution becomes more alkaline, the availability of MoO_4^- increases (Lindsay, 1979).

Effect of electrical conductivity on available molybdenum in soils is summarized in table 4. The correlation coefficient between electrical conductivity and available molybdenum was found non-significant in mixed red and black soils of Balaghat and Chhatrapur districts (Table 4). The results indicate that increase or decrease in electrical conductivity of soils did not alter the availability of molybdenum. Similar findings were also reported by Khattak *et al.* (1997) and Sharma *et al.* (2003).

In general, soil organic carbon was found significantly and positively correlated to available Mo in soil. The soils from some tehsils of Balaghat district showed significant correlation i.e. Lalbarra (r=0.640*) and Kirnapur tehsil (r=0.330*) and also for the entire district (r=0.334**). The correlations in case of soils from Waraseoni, Katangi and Balaghat, tehsils were statistically non-significant. However, the soils of Chhatarpur district exclaimed significant correlation with organic carbon. Soils of Chhatarpur and Badamalhera tehsils showed significant correlation with r= 556** and r=0.390*, respectively. While, the soils of Bijawar and Naugaon, tehsils exhibited non-significant correlation and the entire district (r=0.324**). Similar results were also reported by Gupta *et al* (2000). The presence of organic matter may also facilitate the availability of certain element presumably by supplying soluble complexing agents that play a role in fixation of elements. For example soil rich in organic matter contain the readily exchangeable mobile MoO_4^{2-} ion (Kaval'skiy and Yarovaya, 1966). The formation of these complexes may decrease the amount of MoO_4^{2-} bound by metal amides,

Table 3. Acid ammonium oxalate extractable Mo content in soils of Balaghat and Chhatarpur districts

Balaghat district			Chhatarpur district		
Tehsils	Available Mo (mg kg^{-1})		Tehsils	Available Mo (mg kg^{-1})	
	Range	Mean		Range	Mean
Waraseoni	0.093-0.874	0.338(0.206)	Rajnagar	0.090-0.209	0.141(0.037)
Katangi	0.355-0.850	0.526(0.203)	Chhatarpur	0.127-0.874	0.403(0.226)
Lalbarra	0.197-0.803	0.414(0.186)	Bijawar	0.384-1.064	0.661(0.210)
Balaghat	0.127-0.695	0.379(0.214)	Badamalhera	0.127-1.381	0.632(0.294)
Kirnapur	0.093-0.925	0.332(0.192)	Naugaon	0.161-1.126	0.339(0.322)
Total	0.093-0.925	0.350(0.200)	Total	0.090-1.381	0.496(0.302)

Note: Figures given in parentheses indicate standard deviation.

Table 4. Effect of pH, EC, OC and $CaCO_3$ on the availability of Mo in soils of Balaghat and Chhatarpur districts

Tehsil	Soil pH		Electrical Conductivity		Organic Carbon		Calcium carbonate	
	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value
BALAGHAT DISTRICT								
Waraseoni	Y = - 0.757+0.186 X	0.562**	Y = 0.364-0.097 X	(-) 0.002	Y = 0.141+0.026X	0.303	Y = 0.197+0.005X	0.343*
Katangi	Y = - 0.730+0.212 X	0.535	Y = 0.016+2.32 X	0.652	Y = - 0.399+0.101X	0.768	Y = 0.035+0.012X	0.674
Lalbarra	Y = - 0.967+0.215 X	0.704*	Y = - 0.12+2.605X	0.773**	Y = 0.082+0.059 X	0.640*	Y = 0.315+0.003X	0.250
Balaghat	Y = - 0.667+0.169 X	0.549	Y = 0.632-1.263X	(-) 0.528	Y = - 0.199+0.080	0.626	Y = 0.155+0.006X	0.543
Kirnapur	Y = - 0.874+0.191 X	0.515**	Y = 0.29+0.166X	0.055	Y = 0.115+0.028 X	0.330*	Y = 0.25+0.003X	0.266
Total	Y = - 0.653+0.164 X	0.502**	Y = 0.339+0.069X	0.024	Y = 0.139+0.029 X	0.334**	Y = 0.228+0.004X	0.342**
CHHATARPUR DISTRICT								
Tehsil	Soil pH		Electrical Conductivity		Organic Carbon		Calcium carbonate	
	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value	Regression equation	R^2 value
Rajnagar	Y = -0.066 + 0.031 X	0.364	Y = 0.173-0.166X	(-) 0. 297	Y = 0.053+0.014X	0.574	Y = 0.091+0.002X	0.582*
Chhatarpur	Y = -1.158 +0.226X	0.478*	Y = 0.353+0.308X	0.046	Y = 0.059+0.055X	0.556**	Y = 0.31+0.004X	0.160
Bijawar	Y = - 0.721+0.214X	0.648*	Y = 0.732-0.452X	(-) 0.106	Y = 0.532+0.028X	0.253	Y = 0.56+0.003X	0.217
Badamalhera	Y = -0.631 +0.184X	0.319*	Y = 0.394+1.331X	0.261	Y = 0.284+0.053X	0.390*	Y = 0.619+0.00X	0.021
Naugaon	Y = -3.662+0.562X	0.406	Y = 6.916+1.851X	0.435	Y = 15.94+2.006X	0.557	Y = -0.375+0.027X	0.769**
Total	Y = -0.462+0.140X	0.240*	Y = 0.498-0.010X	0.110	Y = 0.219+0.090X	0.324**	Y = 0.402+0.004X	0.135

* Indicates significant at 5% level ** Indicates significant at 1% level

increasing the amount of available MoO_4^{2-} in solution. (Reddy *et al.* 1997). Soil rich in organic matter and with poor drainage traditionally accumulate soluble molybdate, while sandy soils are subject to molybdenum leaching but in a pH dependent manner (Bloomfield and Kelso, 1973).

The correlation coefficient was found to be non-significant for the soils of Katangi, Lalbarra, Balaghat, Kirnapur tehsils however, a significant positive correlation coefficient was found in tehsil Waraseoni (r=0.343*). Calcium carbonate had significant positive correlation with available molybdenum in acidic soils of Balaghat district (r=0.342**). Thus, it may be expressed that the $CaCO_3$ content increased the available molybdenum significantly in acid soils. The correlation coefficient was found to be significant for the soils of Rajnagar (r=0.582*) and Naugaon (r=0.769**) tehsils. The correlation coefficients were observed non-significant in tehsils of Chhatarpur, Bijawar, Badamalhera and the entire district.

Correlation studies between Mo content in soil and plant

The correlation of molybdenum content in soil and plants of Balagaht and Chhatarpur district are presented in table 5 and It is noted that the soil molybdenum of Balaghat district ranged from 0.093-0.803 mg kg^{-1} with a mean value of 0.349 mg kg^{-1} in fields of wheat crop while it was 0.093-0.925 mg kg^{-1} with mean value of 0.359 mg kg^{-1} in the fields of chickpea crop. In grain, molybdenum content ranged from 0.81-5.19 mg kg^{-1}, 0.46-4.35 mg kg^{-1}, with a mean value of 2.19 mg $kg^{-1}$and 1.96 mg kg^{-1} in wheat and chickpea crop, respectively. In case of wheat straw, molybdenum content ranged from 0.34-3.68 mg kg^{-1}, with a mean value of 1.20 mg kg^{-1} while chickpea straw molybdenum varied from 0.46-3.68 mg kg^{-1} with a mean value of 1.70 mg kg^{-1}. Significant correlation between soil and grain molybdenum (r = 0.254) was also recorded.

Soil molybdenum of Chhatarpur district ranged from 0.090-1.381 mg kg^{-1} with a mean value of 0.526 mg kg^{-1} in fields of wheat crop while in the field of chickpea it was 0.104 - 1.064 mg kg^{-1} with a mean value of 0.428 mg kg^{-1}. In grain, the content of molybdenum ranged from 0.81-5.74 mg kg^{-1}, 0.81-5.93 mg kg^{-1}, with a mean value of 2.74 mg kg^{-1} and 2.36 mg kg^{-1} for wheat and chickpea crop, respectively. In case of wheat straw molybdenum content ranged from 0.34-3.68 mg kg^{-1}, with a mean

Table 5. Molybdenum status in soils and plants of Balaghat and Chhatarpur districts

BALAGHAT DISTRICT							
Tehsil	Crop	Soil (mg kg^{-1})		Plant (mg kg^{-1})			
				Grain		Straw	
		Range	Mean	Range	Mean	Range	Mean
Waraseoni	Wheat	0.093-0.737	0.322	0.81-5.19	2.35	0.34-2.92	1.16
	Chickpea	0.127-0.874	0.353	0.57-4.32	2.31	0.69-3.68	1.96
Katangi	Wheat	-	-	-	-	-	-
	Chickpea	0.355-0.850	0.526	0.81-3.22	1.69	2.08-3.37	2.73
Lalbarra	Wheat	0.197-0.803	0.457	0.81-5.19	2.31	0.46-2.22	1.00
	Chickpea	0.222-0.384	0.316	2.22-3.84	3.24	0.81-1.95	1.23
Balaghat	Wheat	0.260-0.695	0.392	0.81-2.31	1.46	0.81-1.30	0.97
	Chickpea	0.127-0.580	0.353	0.93-1.55	1.24	0.57-0.81	0.69
Kirnapur	Wheat	0.150-0.544	0.317	0.81-3.52	2.17	0.57-3.68	1.47
	Chickpea	0.093-0.925	0.338	0.46-4.35	1.67	0.46-3.52	1.45
Total	Wheat	0.093-0.803	0.349	0.81-5.19	2.19	0.34-3.68	1.20
	Chickpea	0.093-0.925	0.359	0.46-4.35	1.96	0.46-3.68	1.70
	Grain Mo V/S Soil Mo r = 0.254*, Y = 0.254 + 0.049 X						
CHHATARPUR DISTRICT							
Tehsil	Crop	Soil(mg kg^{-1})		Plant (mg kg^{-1})			
				Grain		Straw	
		Range	Mean	Range	Mean	Range	Mean
Rajnagar	Wheat	0.104-0.185	0.148	1.05-4.83	3.26	0.34-1.43	0.48
	Chickpea	0.09-0.209	0.135	0.93-2.64	1.77	0.34-2.22	1.13
Chhatarpur	Wheat	0.150-0.874	0.467	0.82-5.74	3.25	0.57-3.22	1.31
	Chickpea	0.127-0.655	0.311	0.81-4.49	3.00	0.81-3.22	2.01
Bijawar	Wheat	0.477-0.978	0.681	0.93-4.16	3.00	0.93-2.64	1.67
	Chickpea	0.477-0.978	0.665	1.05-3.48	2.45	1.02-3.52	2.02
Badamalhera	Wheat	0.127-1.381	0.646	0.81-4.32	2.18	0.46-3.68	1.58
	Chickpea	0.273-0.899	0.590	1.34-5.93	2.76	0.88-5.55	2.44
Naugaon	Wheat	0.185-1.126	0.560	1.95-4.32	3.04	0.46-0.81	0.63
	Chickpea	0.161-0.273	0.205	1.05-2.35	1.72	0.46-1.30	0.81
Total	**Wheat**	**0.090-1.381**	**0.526**	**0.81-5.74**	**2.74**	**0.34-3.68**	**1.37**
	Chickpea	0.104-1.064	0.428	0.81-5.93	2.36	0.34-5.55	2.33
	Grain Mo V/S Soil Mo r = (-) 0.151, Y = 0.590 – 0.036 X						

* Indicates significant at 5% level ** Indicates significant at 1% level

value of 1.37 mg kg^{-1} and for chickpea straw the same was 0.34-5.55 mg kg^{-1} with a mean value of 2.33 mg kg^{-1} soil. The value of correlation coefficient between the soil molybdenum and plant (grain) molybdenum was found to be negative but non-significantly related in the district.

Present study indicated that soil properties influence the availability of molybdenum that it increased significantly with increase in pH, organic carbon and calcium carbonate due to replacement of $MoO4^{2-}$ by OH^- ions. Contrarily, the availability of molybdenum was not statistically affected with EC. The correlation coefficient of soil and plant was found positive and significant in case of soils from Balaghat.

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Resource conservation technologies for improving water productivity

RAJAN BHATT[1], S. S. KUKAL[2] and SANJAY ARORA[3]

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ABSTRACT

Underground water is the world's largest fresh water resource and is critically important for irrigated agriculture. Excessive withdrawal of groundwater leading to the decline in water table and free electricity (in Punjab) further complicated this situation. Different resource conservation technologies (RCTs) viz. laser land leveling, DSR, zero tillage, raised bed planting have the potential to uplift the declining water table. This need determination of complete water balance for each and every RCT. Majority of the RCTs, helps save irrigation water (by cutting of drainage losses) or in other words these can be designated as energy saving practices (which is used to withdraw underground water) as these cut off the drainage loss which is not desirable in the central districts of Punjab where underground water table is declining down at an alarming rate. However, these might be beneficial for the South-Western districts of Punjab which are already suffering from the problems of water logging and salinization.

Keywords: Resource conservation, Water management, Precision agriculture

INTRODUCTION

Water is a must input for agriculture, it's timely and assured availability greatly affects the agricultural production. India -The largest groundwater user in the world (230 km^3 yr^{-1}), more than a quarter of the global total water use (Tyagi *et al.*, 2012). Indian sub-continent groundwater use has soared from 10-20 km^3 before 1950 to 240- 260 km^3 by the turn of the century (Prihar *et al.*, 2010).

The small states of Punjab and Haryana often referred to as the 'Food Bowl' of the country, produce 50% of the national rice production (Dhillon *et al.*, 2010). NASA's gravity mapping satellite "GRACE" tracks the local gravity filed of an area on the assumption that if we remove much of ground water, there is a loss of mass which further resulted in the decrease of the gravity. Recent reports of the satellite showed that in North India about in an area of 440,000 km^2 ground water declined at an alarming rate of 1 ft year^{-1} which further resulted in the loss of 4 cm loss of raw ground water or 18 km^3 year^{-1} (Soni, 2012). The status of water resources in Punjab state are presented in which shows annually we required 43 lakh ha-m of irrigation water and we have 30 lakh ha-m of water annually in our pocket, thus it mean we are already short of 13 lakh ha-m of water which we withdraw from the underground (Table 1) and water level in central parts of the state declining at an alarming rate (Fig.1) where the significance of the different resource conservation technologies (RCTs) increased to manifold but again these RCTs are not universally applicable and are site specific.

Table 1. Status of water resources in Punjab

Annual canal water available at head works	14.54 m ha-m
Annual canal water available at outlets	1.45 m ha-m
Annual groundwater available	1.68 m ha-m
Total annual available water resources	3.13 m ha-m
Annual water demand	4.40 m ha-m
Annual water deficit	1.27 m ha-m

Source: Jain and Kumar (2007)

[1]Assistant Professor (Soil Science), Krishi Vigyan Kendra (PAU), Mansa, Punjab;
[2]Professor, Department of Soils, P.A.U., Ludhiana; [3]Sr. Scientist, CSSRI, RRS, Lucknow

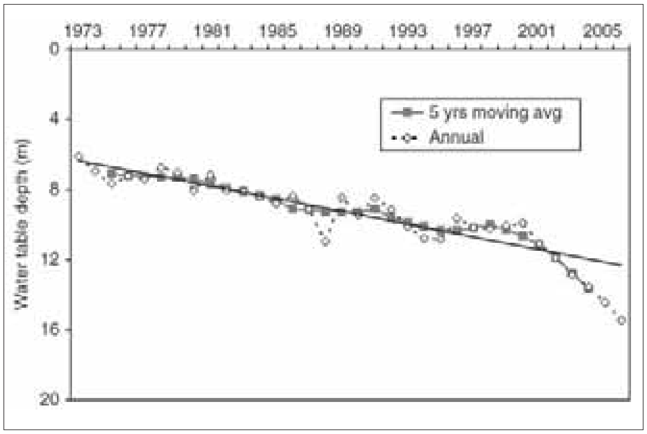

Fig. 1. Depth of water table in central districts of Punjab (Source: Groundwater cell, Govt. of Punjab)

Nationally, the area under groundwater irrigation has increased by 6-times over last six decades (1950-51 / 2005-06) (Fig. 2; Tyagi *et al*., 2012) in contrast to declined share of water in agriculture because of increased demand of non-agricultural sectors has increased from the last few decades. (Fig. 3) (Tyagi *et al.* 2012).

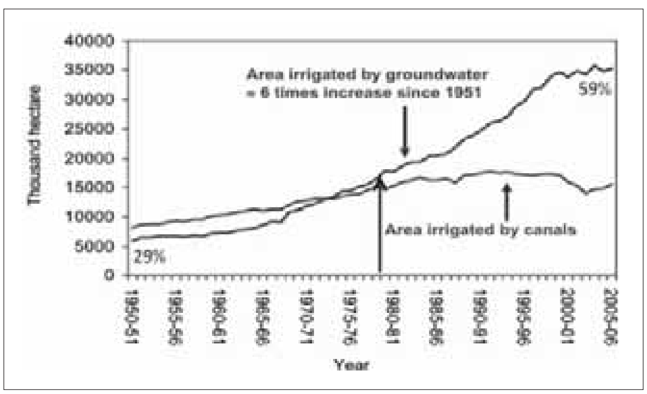

Fig. 2. Irrigation trend by canals and groundwater

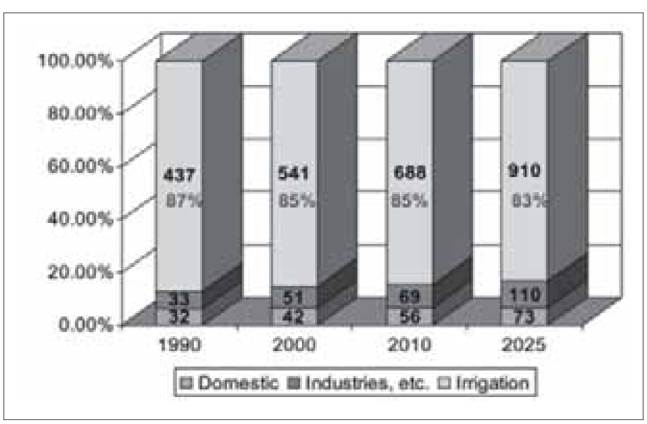

Fig. 3. Annual water utilization pattern of India

Therefore, the comprehensive assessment of innovative resource conservation technologies (RCTs) for efficient water management in crop production should take stock of the costs, benefits and impact on natural resources (Humphreys *et al*., 2010). The laser leveling, direct deeded rice (DSR), bed planting, zero till (ZT) wheat with happy seeder and rice with mechanical transplanter, growing of short duration cultivars and mulching *etc.* are among the common RCTs being advocated in the region that had shown a promising potential for increasing the water productivity of the rice-wheat cropping system. We are going to discuss them as RCTs cutting drainage losses and RCTs cutting evaporation losses.

[A] **RCTs cutting off drainage losses and their effect on water productivity (WP):**

(a) Laser leveller and it's impact on WP: Among various RCTs advocated for the region for improving the water productivity, laser leveling is widely accepted and adopted in the region (Fig 4). It was because of the fact that laser leveler level all the dukes and dikes and cause uniform distribution of the water and caused irrigation on a large area within shorter period of time. In Punjab, laser leveller was introduced on an experimental basis in the Sukhanand village of Moga district on an area of 150 acres and around 300 farmers took part in these demonstrations. It was estimated that around 25-30 per cent of irrigation water could be saved through this technique without having any adverse affect on the crop yield (Bhatt and Sharma, 2009).

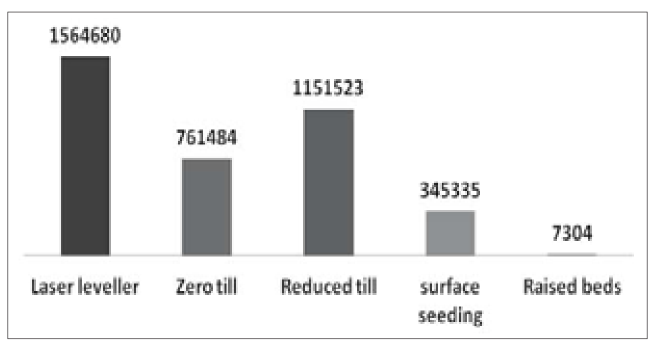

Fig 4. Acreage (ha) of resource conservation technologies in South Asia (Jat *et al*., 2010)

the crop yield augmentation coupled with improved irrigation water productivity with land leveling has been well documented (Kahlown *et al.*, 2006; Jat *et al.*, 2009). Further, Jat *et al.* (2011) showed

Table 2. Effect of laser land leveling and planting techniques on water productivity of wheat (Mean of 2 years)

Treatment	Total number of irrigations applied	Irrigation water use (m^3 ha^{-1})	Irrigation water productivity (kg grain m^{-3} water)
Precision leveling ($N_{126}P_{26}K_{50}$ ha^{-1})	4.5	2847.5	1.80
Traditional leveling ($N_{126}P_{26}K_{50}$ ha^{-1})	4.5	3946.0	1.22
Traditional leveling ($N_0P_0K_0$ ha^{-1})	4.5	4789.5	0.560
SE±	—-	13.88	0.043

Source: Jat *et al*. (2011)

higher irrigation water productivity in laser leveled plots than traditionally leveled plots (Table 2) as compared to the controlled plots when fertilized at the same rate with different fertilizers.

(b) Direct seeded rice and their impact on WP: This RCT avoid irrigation need for puddling operations and sow directly rice seeds into the soil using seed cum fertilizer drill. But yield often is somewhat lower due to severe iron deficiency, much more weed pressure etc.

In the DSR, it was observed that aerobic rice cultivars responded well than the lowland cultivars in terms of grain yield under the water stress conditions viz. water deficient areas however under the submerged conditions the lowland cultivars had an edge over the aerobic cultivars (Bouman *et al.*, 2007; Fig 5). DSR-AWD has resulted in higher irrigation water saving (33-53%) than puddle transplanted rice (PTR) (Fig 6; Sudhir-Yadav *et al.*, 2010), albeit of there was higher reduced seepage and runoff losses under DSR coupled with increased deep drainage (Sudhir-Yadav *et al*., 2011a) under clay-loam soil. They further reported that under the clay loam soils DSR had higher water productivity than the PTR under 20 kPa suction and this might be because of the higher no of micropores of clay loam soil, which retain water at a higher suction however under the sandy loam soil the trend might be different because of higher no of macropores of sandy loam soil which drain out quickly on slightly increasing the suction.

Owing to decreased average crop duration (Akhgari and Kaviani 2011, Table 3), a one-third to one-half saving of irrigation water in DSR than in PTR has been reported while maintaining the crop yield with similar irrigation schedule (Sudhir-Yadav

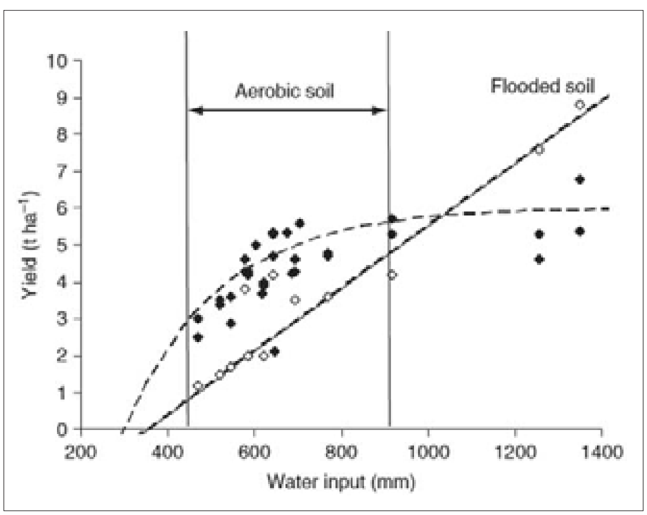

Fig 5. Yield of aerobic rice varieties (black diamonds) and a lowland variety (open diamonds) under flooded and aerobic soil conditions (Bouman *et al.*, 2007)

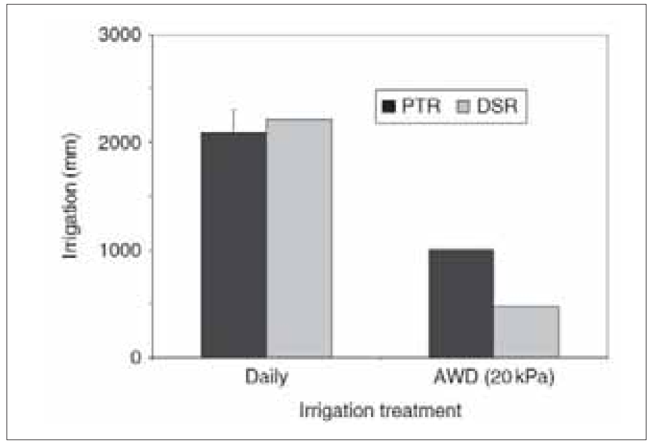

Fig 6. Irrigation water use under PTR and DSR on clay loam soil

Table 3. Effect of planting method on growth duration of rice cultivation

Variety	TPR D1	DSR D2	% decrease in duration
Hassani	137	91	33.5
Ali Kazemi	134	98	26.8
Hashemi	134	98	26.8
Hybrid spring	144	108	25.0

Source: Akhgari and Kaviani (2011)

et al., 2011b). Direct seeded cultivars has a lower yield potential than the flooded cultivars but with 50% less consumption of water. Thus they could be very well cultivated in a region faces scarcity of water, but required rice for food security.

(c) Permanent beds and their impact on water productivity: There were contradictory reports as far as effect of this RCT on water productivity is concerned as Kukal *et al.* (2010) have reported no saving in amount of irrigation water under PTR and transplanted rice on permanent raised beds in a sandy loam soil, because of higher cracking of loam in permanent beds when a full-furrow depth of irrigation was applied but on the contrary, higher water use efficiency (WUE) was observed in bed planted crops (Brar *et al* 2011) although with time, the irrigation water productivity on permanent beds decreased as side slopes of the permanent beds were compacted due to tractor-tyre pressure during repeated re-shaping and sowing of wheat and to natural aging of the beds (Kukal *et al*., 2008). Inquiring about water productivities under no-till, conventional till and permanent beds Jat *et al*. (2006); Singh *et al*. (2010) found higher water productivity under permanent beds as compared to other two methods (Table 4, 5). But Kukal *et al.* (2008) provide evidence that these beds were quite effective initially but year after year due to reshaping operation the side slope of beds got compacted resulting in higher bulk density. Secondly, the surface area of these beds was about 25% higher, resulting in higher absorption of radiant energy which resulted in higher evaporation losses needs more water and finally aged beds had lower water productivity.

(d) Soil matric potential based irrigation and their effect on the water productivity: Tensiometer measuresd the soil matric potential thus a quite effective technique to decide when to irrigate a crop based on the soil suction behavior. (Fig 7). Kukal *et al*. (2005) and Bhatt and Sharma (2010) reported that soil matric tension based irrigation scheduling helps in significant saving of irrigation water with almost similar / higher yields, thus helps in increasing the water productivity in the region as it dictate the farmers as when to irrigate (Table 6, 7).

Fig 7. Soil spec Front view (a), rear view (b) and in action measuring soil water tension (c)

Thus in reality, it is an effective technique to save irrigation water particularly in rice in medium textured soils and KVKs of the PAU, Ludhiana make every effort to make it popularize among the farmers of the state by organizing different camps,

Table 4. Irrigation water productivity (kg grain m^{-3}) of maize genotypes under different establishment methods

Maize genotype	No-till flat	Conventional tillage	Permanent beds
HQPM-1	2.1	2.1	2.9
Shaktiman-4	1.9	1.7	2.6
HM-5	1.5	1.3	1.9
ST-2324	2.1	2.2	3.1
Bio-9681	2.4	2.1	3.0
Mean	2.0	1.9	2.7

Source: Jat *et al.* (2006)

Table 5. Effect of different treatment on root density, soil water content, consumptive water use and water use efficiency

Treatment	Root density (gm^{-3})	Consumptive water use (mm)	Water use efficiency (kg $ha\text{-}mm^{-1}$)
Zero tillage	2358.9	468.0	9.34
Conventional tillage	2400.2	464.8	9.50
Bed planting	2716.9	460.8	*9.91*

Table 6. Water productivity of puddle transplanted rice

Irrigation schedule	Irrigation water productivity (g kg^{-1})
Continuous flooding	0.28
Intermittent irrigation (2 day gap)	0.34
Tensiometer based	0.50

Source: Kukal *et al.* (2005)

Table 7. Soil matric potential-based irrigation scheduling results in farmers fields in Kapurthala district

Year	Per cent Irrigation water savings	Yield differences
2006	29.6-30.7	+0.5 – 1.5%
2007	25.0-27.2	At par
2008	18.0-27.8	At par
2009	16.6-20.8	+0.5 – 1.0%
2010	11.1-21.4	At par

Source: Bhatt and Sharma (2010)

demonstrating in front of the farmers the worth of this technology by conducting on-farm trials and with the result farmers are show their interest in this RCT and Department agriculture and Soil conservation department purchased and gave to the farmers at subsidized rates.

[B] **RCTs cutting off evaporation losses and their effect on water productivity:**

Table 8. Effect of date of transplanting (DOT) and N-levels (Kg ha^{-1}) on the crop water productivities (kg m^{-3})

	N_0	N_{240}	N_{300}	N_{360}	Mean
Transplanting rice on 5 June and wheat on 20 Oct	0.78	1.11	1.13	1.13	1.04
Transplanting rice on 20 June and wheat on 5 Nov	0.78	1.21	1.27	1.30	1.14
Transplanting rice on 5 July and wheat on 20 Nov	0.67	1.13	1.20	1.25	1.06
Mean	0.74	1.15	1.20	1.23	

Source: Jalota *et al.* (2011)

(a) Date of transplanting (DOT) and their influence on the water productivity: DOT is very important for uplifting WP as early transplanted crop has highest evapo-transpiration losses and lower water productivities associated with early transplanted / sown crops (Table 8). Reason being in early transplanted / sowed crop faces dry air, higher vapor pressure gradient and thus finally higher losses, thus we have to give frequent irrigations for having the similar productivity, while transplanting / sowing at appropriate time, rains are there, moist the air, lesser vapor pressure gradient, lesser evapo-transpiration losses and thus finally higher water productivity of the concerned crop. Crop diversification played a pivotal role in decreasing amount of irrigation water required and it was revealed that (Jalota and Arora, 2002; Arora *et al.*, 2008) particularly diversion from rice helped to increase the water productivity for the system as a whole.

Evapo-transpiration losses decreases if system diversified from rice-wheat rotation to cotton-wheat or to the maize-wheat rotation as cotton and maize had lesser water requirements to complete their life cycle as compared to the rice (Table 9).

In wheat, Timsina *et al.* (2008) reported that November 10th was optimum time to increase the crop water and irrigation water productivity because of higher grain yield and lesser use of irrigation water however late and earlier sowing decreases the water productivities because of lesser reported yields with the usage of higher irrigation water (Table 10). Thus upto mid November reported to be the best time to go for wheat sowing for having desired WP_I.

(b) Short duration crop cultivars and their impact on water productivity: Shorter the stay of a crop in the field, lesser evaporation and thus lesser required irrigation water and finally resulted in the higher WP as Jalota *et al.* (2009) reported that in long duration cultivars (PR-118) irrigation water requirements decreased to 110 mm from 25 may to

Table 9. Diversification for improving water productivity

Cropping systems	ET (mm)	E_b (mm)	Component crop yield (t ha^{-1})		Wheat equivalent yield (t ha^{-1})	Water productivities (Kg m^{-3}) based on	
			C_1	C_2		ET	NWL
Rice-wheat	1030	210	6.0	4.5	9.7	0.94	0.78
Cotton-wheat	980	901	2.0	3.5	8.6	0.88	0.80
Maize-wheat	860	220	3.5	4.5	7.2	0.84	0.67

Source: Arora *et al.*, (2008); Jalota and Arora, (2002)

Table 10. Effect of date of sowing of wheat on water productivity (WP_I)

Treatments	Irrigation (mm)	Grain yield (t ha^{-1})	Crop water productivity (g grain kg ET^{-1})	Irrigation water productivity (g grain kg $irrigation^{-1}$)
Oct. 10	257	4.73	1.5	1.9
Oct. 25	284	5.93	1.7	2.2
Nov. 10	279	6.25	1.7	2.4
Nov. 25	289	6.03	1.6	2.2
Dec. 10	277	5.69	1.6	2.1
Dec.25	281	5.25	1.5	1.9
Jan. 25	289	4.96	1.4	1.8

Source: Timsina *et al.* (2008)

10June while to 260 mm if transplanting time delayed to 25th of June. Though they reported some yield loss there but ultimately water productivity increased because of greater saving of irrigation water. But in the short duration cultivars (RH-257) grain yield also increased along with saving of irrigation water which increased the water productivity (Table 11).

(C) Mulching and it's impact on WP: The effect of mulching in improvement of water productivity has been ascribed to restricted evaporative losses because of decrease in radiant energy reaching to soil to cause phase change from liquid water to gaseous phase, decrease of vapor pressure difference within soil and ambient air and finally because of decrease in vapor lifting capacity of the air. (Fig 8) and thereby causing yield augmentation (Bhatt and Khera, 2006, Bhatt *et al*., 2004).

As far dealing with crop residues is concerned, almost every option had a limitation as if we burn the crop residue then it causes the air pollution and secondly allow the fixed carbon to go back in air which is not desired et all. Second option is the incorporation of the residues back into the soil but this option causes N-immobilization and cause a yield loss in the next crop. So finally what should be done? The answer to this very question is Happy

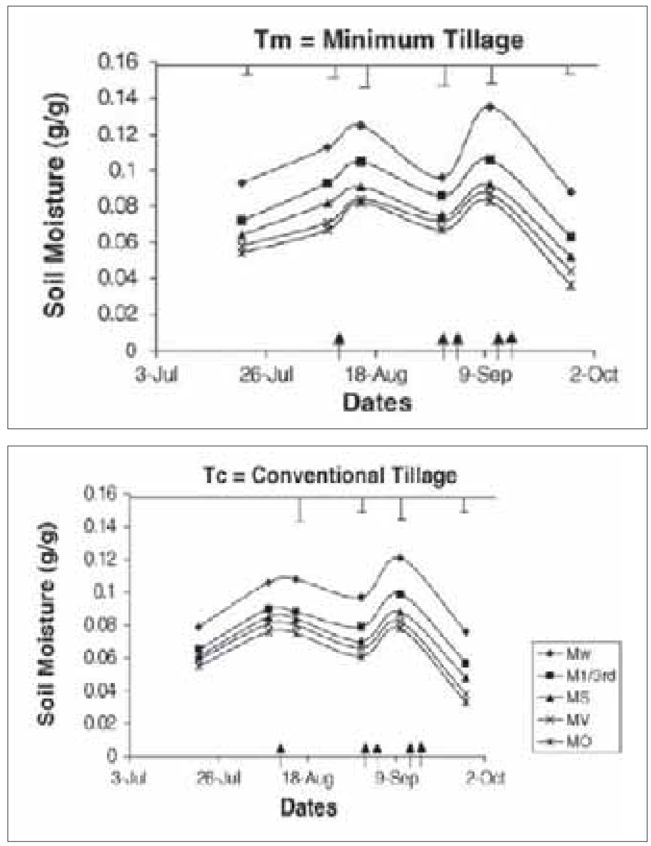

Fig. 8. Soil moisture content of surface soil as affected by tillage and different modes of mulch application

Table 11. Effect of transplanting date and variety on yield and water requirements of rice

Transplanting date	Irrigation water (mm)	Grain yield (t ha^{-1})	Irrigation water (mm)	Grain yield (t ha^{-1})
	PR-118 (155-160 days)		RH-257 (110-120 days)	
25 May	2530	7.5	2350	6.8
10 June	2420	6.6	2310	7.3
25 June	2270	7.1	2120	7.5
Mean	2407	7.1	2260	7.2

Source: Jalota *et al.* (2009

Table 12. Water saving in wheat with ZT (Happy Seeder) over CT in Punjab

Irrigation	CT wheat (cm irrigation^{-1})	ZT wheat (cm irrigation^{-1})	Water saving with ZT over CT method
Pre-sowing irrigation	10	0	100%
First irrigation	7.5	6.38	15%
Second irrigation	7.5	6.75	10%
Third irrigation	7.5	7.5	0
Fourth irrigation	7.5	7.5	0
Total	40.0	28.1	30%

Source: Singh *et al*. (2008)

Seeder as with this technique there is no need for pre-sowing irrigation which finally causes around 30% saving in irrigation water (Singh *et al*., 2008). Happy seeder allowed sowing of wheat crop in the standing paddy stubbles and with this there is no need to remove the rice stubbles outside the field and secondly rice residues act like mulch which decreases the evaporation losses and decrease the amount of water used per irrigation (Table 12).

CONCLUSION

Finally, sustainable use of ground water is an important interdisciplinary challenge and it can

be concluded that most of the RCTs could lead to substantial reduction in irrigation water input by cutting off the drainage losses, which are not desirable in the areas especially where the GW is declining at an alarming rate, as is true for the central districts of Punjab. But, these RCTs have promising role that may be highly useful for the south-western districts of Punjab which are already suffering from the problem of water logging i.e real water saving. Thus for the central Punjab, RCTs viz. growing of short duration varieties and delaying transplanting/sowing of the crops particularly rice (which cuts off the evaporation but not the transpiration) to coincide with the less evaporative demand periods, are the *Real Water Saving Techniques.*

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Ground water quality evaluation of two blocks of Ghaziabad district

MAMTA GAUTAM[1], ANIL KUMAR SINGH[2] and RAJIV MOHAN JOHRI*

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ABSTRACT

The present study was conducted to assess the water quality of ground water in two blocks i.e Mohannagar and Shahibabad of Ghaziabad for its sustainability for public consumption, recreation and other purposes. There are several criteria for assessing the quality of water and Water Quality Index (WQI), a single value integrating several parameters, is one very useful indicator. In this study, thirteen parameters, namely, pH, EC, TDS, TH, alkanity, Ca^{++}, Mg^{++}, HCO_3^-, Cl^-, NO_3^-, SO_4^-, Fe, and Na^+ were used for calculating WQI. Results indicated that 100% of the samples were "unfit" in Mohannagar while it was 84% in Shahibabad block. Of the remaining samples in Shahibabad block, 13% were in the "very poor" while only 3% were in "good" category as far as drinking standards are concerned. Interpretation of the analysis revealed that all the groundwater samples were having WQI much higher than 100, indicating the worst quality of water and totally unsuitable for drinking. It is therefore, essential to chalk out a plan to manage these waters effectively so that their quality is improved and the health of the population is not compromised.

Keywords: Water quality index, ground water quality, Mohannagar, Shahibabad

INTRODUCTION

Groundwater is the major source of water supply for domestic purposes in the urban as well as in rural parts of India. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by most of the agricultural development related activities particularly in relation to excessive application of fertilizer and unsanitary conditions. Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal especially in urban areas (Ramakrishnalah *et al.*, 2009). Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water (Tiwari *et al.*, 1985; Mishra *et al.*, 2001; Naik *et al.*, 2001; Singh, 1992). It is defined as a rating reflecting the composite influence of different water quality parameters. It, thus, becomes an important criterion for assessment and management of groundwater.

In addition to WQIs, decomposition analyses of time series are also useful tools to derive spatio-temporal patterns from a large amount of environmental monitoring data as well as to communicate related information to non-scientific community including decision-makers (Ocampo-Duque *et al.*, 2006; Sanchez *et al.*, 2007; Nasirian 2007; Simoes *et al.*, 2008). Advantages of WQIs include their abilities to integrate a large number of parameters to a single number and provide an easy as well as a simple way to understand spatio-temporal status of water quality for public consumption. Disadvantages of WQIs include the sensitivity of results to the formulation of WQIs, and the loss of information about interactions among variables and impact of single variables (Giljanovic, 1999; Chang *et al.*, 2001; Hallock 2002; Khan *et al.*, 2003).

[1]M.M.H. College Ghaziabad, U.P-201009, India
[2]ICAR, Krishi Anushandhan Bhawan II, New Delhi -110012, India

Since the evaluation of WQI requires many physical and chemical parameters to be measured, the challenge for developing countries is to develop pollution control strategies that are cost effective (Ongley and Booty, 1999) and cost related to analyses is minimal (Ongley, 1998). In such situations, the evaluation of WQI using only a few simple parameters would be a destructive advantage. The WQI approach has many variations in the literature and comparative evaluations have been undertaken (Bordalo *et al.*, 2001). The objective of the present work was assess the sutability of groundwater for human consumption based on water quality index.

MATERIALS AND METHODS

Groundwater Sampling and Analyses

For this study two blocks of Ghaziabad district, *viz.*, Mohannagar and Shahibabad located between 28° 26' to 28°54' North latitude and 77°12' to 78°13' East longitude were selected for the study. Groundwater samples were collected from 30 locations in each block in February-March (pre-monsoon) and October-November (post- monsoon) in 2008 in 500 ml capacity clean plastic bottles from hand pumps, shallow wells and deep wells in the study area. Every bottle was rinsed 2 to 3 times with same water before the actual sample collection. To prevent the microbial infection, four-five drops of toluene were added before the bottle was stoppered. Information related to the date of collection/sampling, as well as latitude and longitude of the sampling point was also recorded by GPS. The physico-chemical pH, electrical conductivity (EC), Na^+, K^+, Ca^{++}, Mg^{++}, CO_3^- and HCO_3^- were determined by standard method as given in APHA (1985).

Water Quality Index

WQI improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends (Boyacioglu, 2007). In the present study, WQI was calculated by using standards of drinking water quality recommended by the Bureau of Indian standards (BIS) and Indian Council for Medical Research (ICMR) and weighted index method developed by Tiwari and Mishra (1985); and Asadi et al. (2007) to determine the suitability of groundwater for drinking purposes. In the present study thirteen water quality parameters, namely, pH, Electrical Conductivity (EC), Alkalinity, TDS, Total hardness, Calcium, Magnesium, Bicarbonate, Carbonate, Chloride, Nitrate, Sulphate, Iron and Sodium were considered for computing WQI by using the following formula:

$$q_n = 100[V_n - V_{io}] / [S_n - V_n] \quad \text{…. (1)}$$

(If there are *n* water quality parameters, the quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the water sample with respect to its standard, maximum permissible value).

Where

q_n = Quality rating for the n^{th} water quality parameter

V_n = Estimated value of the n^{th} parameter at a given sampling point.

S_n = Standard permissible value of the n^{th} parameter.

V_{io} = Ideal value of n^{th} parameter in pure water *(i.e. 0 for all other parameters except pH and Dissolved Oxygen (7.0 and 14.6 mg/L respectively).*

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$$W_n = K/S_n \quad \text{…. (2)}$$

Where

W_n = Unit weight for the n^{th} parameter.

S_n = Standard value for the n^{th} parameter.

K = Constant of proportionality.

The overall WQI was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = Ó\, q_n W_n / \, Ó\, W_n \quad \text{…. (3)}$$

Table 1 gives the critical limits of WQI.

Table 1. Water Quality Index (WQI) and status of water quality

Water Quality Index Level	Water quality status
0-25	Excellent
26-25	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking

WQI maps

The construction of contour maps is one of the standard procedures used in water resources assessment in order to evaluate and predict natural variability and assess the risk regarding groundwater contamination in waste disposal industrial and other sites (Pius et al. 2011; Fekri et al. 2012). This enabled locating the hot spots as far as contaminated ground water was concerned. GIS is a powerful tool to assess the water quality parameter, determining water availability of water, preventing flooding, understanding the natural environment, and managing water resources on a local regional scale (Collet, 1996). GIS techniques facilitate integrate and conjunctive analysis of large volumes of multidisciplinary data both Spatial and non – spatial within the same geo-reference (Saraf and Choudhury, 1998). Spatial analysis extension of GIS allows interpolation of the water quality parameter at unknown location from know values to create a continuous surface which will help us to understand the scenarios of water quality parameter of the study area. There are various Interpolation Techniques such as Inverse Distance weighted (IDW), Spline, Trend surface Analysis and Kriging available in Arc GIS Spatial Analysis

Table 2. Water quality index (WQI) and water quality rating of the ground water samples in the two blocks

Sample ID	Samples location		Water quality Index	Water quality Rating	Sample ID	Samples location		Water quality Index	Water quality Rating
	Latitude	Longitude				Latitude	Longitude		
SM1*	28.788	77.479	472	*UFD*	SS1**	28.837	77.509	77	*Very Poor*
SM2	28.787	77.489	184	*UFD*	SS2	28.836	77.511	100	*UFD*
SM3	28.778	77.503	155	*UFD*	SS3	28.788	77.505	116	*UFD*
SM4	28.784	77.522	188	*UFD*	SS4	28.779	77.506	102	*UFD*
SM5	28.842	77.395	204	*UFD*	SS5	28.787	77.514	145	*UFD*
SM6	28.846	77.515	186	*UFD*	SS6	28.774	77.543	203	*UFD*
SM7	28.933	77.638	157	*UFD*	SS7	28.793	77.542	188	*UFD*
SM8	28.693	77.614	488	*UFD*	SS8	28.794	77.513	29	*Good*
SM9	28.697	77.632	261	*UFD*	SS9	28.815	77.505	148	*UFD*
SM10	28.694	77.396	231	*UFD*	SS10	28.871	77.531	176	*UFD*
SM11	28.696	77.634	172	*UFD*	SS11	28.848	77.455	103	*UFD*
SM12	28.699	77.638	114	*UFD*	SS12	28.824	77.448	147	*UFD*
SM13	28.738	77.603	364	*UFD*	SS13	28.826	77.454	75	*Very Poor*
SM14	28.737	77.616	246	*UFD*	SS14	28.824	77.451	135	*UFD*
SM15	28.752	77.624	157	*UFD*	SS15	28.814	77.442	91	*Very Poor*
SM16	28.748	77.639	291	*UFD*	SS16	28.833	77.426	252	*UFD*
SM17	28.751	77.632	218	*UFD*	SS17	28.834	77.425	135	*UFD*
SM18	28.690	77.505	263	*UFD*	SS18	28.835	77.426	148	*UFD*
SM19	28.752	77.631	160	*UFD*	SS19	28.845	77.429	104	*UFD*
SM20	28.684	77.482	512	*UFD*	SS20	28.809	77.510	137	*UFD*
SM21	28.851	77.493	236	*UFD*	SS21	28.808	77.514	107	*UFD*
SM22	28.833	77.581	311	*UFD*	SS22	28.772	77.528	63	*Very Poor*
SM23	28.924	77.404	444	*UFD*	SS23	28.784	77.491	167	*UFD*
SM24	28.738	77.512	294	*UFD*	SS24	28.787	77.478	123	*UFD*
SM25	28.836	77.524	189	*UFD*	SS25	28.794	77.485	122	*UFD*
SM26	28.832	77.538	530	*UFD*	SS26	28.804	77.492	109	*UFD*
SM27	28.724	77.614	192	*UFD*	SS27	28.798	77.497	124	*UFD*
SM28	28.687	77.604	325	*UFD*	SS28	28.890	77.533	182	*UFD*
SM29	28.782	77.483	163	*UFD*	SS29	28.889	77.541	137	*UFD*
SM30	28.919	77.392	209	*UFD*	SS30	28.79	77.51	153	*UFD*

* Mohannagar Block samples; ** Shahibabad Block samples.

extension. In the present study, Kriging technique was adopted to create the spatial distribution maps of water quality parameters and WQI.

RESULTS AND DISCUSSION

The WQI and water quality rating of the different groundwater samples has been presented in Table 2. According to WQI values, the groundwater in the study block was quite to very hard. The water is non-potable if the index value is more than 100 (Fig. 1). Spatial Distribution of WQI in the study area and it is varying from 114 to 530 with an average WQI value of 264 in Mohannagar block (Fig. 2) but in Shahibabad block (Fig. 3) it varied from 29 to 252 with an average value of 130. It indicated that, 100% of samples were "unfit" in Mohannagar and 84% in Shahibabad block. Of the remaining in Shahibabad block, 13% were "very poor" and 3% "good" as for as drinking standards are concerned. Interpretation of physical analysis revealed that all the groundwater samples were having WQI much higher than 100, indicating the worst quality of water and totally unsuitable for drinking and indicating the "worst" quality of water. Similar results were obtained by Abdullah *et al.* (2008) and Ramakrishnaiah *et al.* (2009) in their area of study.

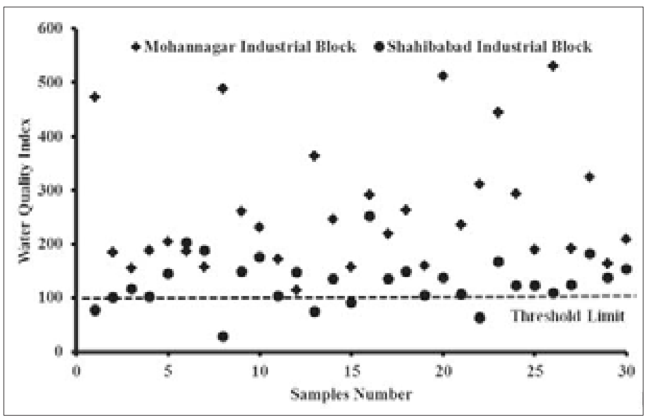

Fig. 1. Distribution of Water Quality Index values in groundwaters of Mohannagar and Shahibabad blocks

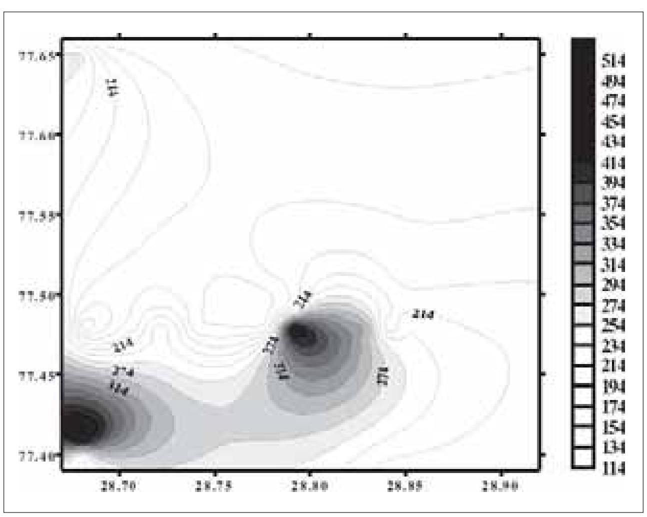

Fig. 2. Spatial distribution of water quality index in groundwater of Mohannagar block

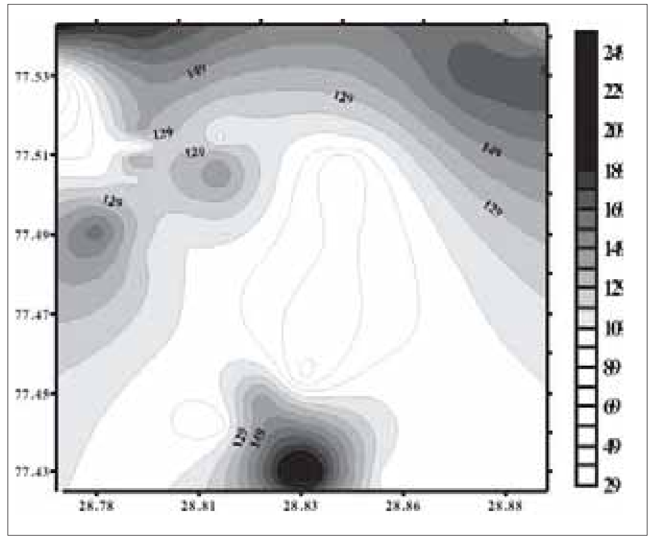

Fig. 3. Spatial distribution of water quality index in groundwater of Shahibabad block

The result of the present study has very clearly brought out that all the samples, based on WQI are in the non-potable category and unfit for human consumption. Most of the organic chemical and synthetic industries, steel mining and coal conversion, textile processing, and pulp and paper milling release these elements into the natural systems (Tabrez and Ahmad, 2009; 2010). However, industries alone are not totally responsible for exposure of the chemicals to the environment and consumers too share a part of the blame. Utilization of gasoline, aerosol sprays, pesticides, and fertilizers lead to the release of pollutants by the consumers directly into the environment (Richards and Shieh, 1986). A number of small- and large-scale industries in India are reported to spill large amount of heavy metals into the sewage in the form of industrial wastes (Tabrez and Ahmad, 2009).

CONCLUSIONS

The result of the present study has very clearly brought out that in both the blocks, the ground waters were of poor quality based on WQI indicating the effective ionic leaching, over exploitation and anthropogenic activities from discharge of effluents from industrial, agricultural and domestic uses. Groundwater is getting contaminated at an alarming rate due to rapid industrialization and becoming unfit for drinking. Proper planning is essential in this venture to preserve the quality of the ecosystem. To meet the basic requirement and ensure potable groundwater quality and reduce contamination, groundwater should be recharged through rainwater harvesting and improper disposal of industrial / domestic effluents must be stopped immediately. An effective monitoring and regulatory mechanism needs to be put in place. The advantage of such a study is that remedial action can be taken by the concerned authorities to prevent further build up and initiate efforts to reduce the toxic levels where ever possible.

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Forecasting dry and wet spell for agricultural planning in South Odisha

B. K. DASH[1], B. PANIGRAHI[2], J.C. PAUL[3], A.P. SAHU[3]

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ABSTRACT

Probability analysis of dry and wet spell along with the onset and withdrawal of monsoon is essential for management of rainfed agriculture and planning for rainwater management. This paper presents the probabilities of dry and wet spell, onset and withdrawal of monsoon and characteristics of rainy season. The rainfall analysis shows that the mean annual rainfall (MAR) of the area is 1756 mm with coefficient of variation 27.42% which indicate less variation of annual rainfall. Higher (86.38%) of rainfall occurred during the monsoon period (June-September) followed by 7.59 % in pre-monsoon period (February- May) and 6.03% in post-monsoon period (October-January). Rainfall analysis revealed that the earliest onset of the rainy season may be expected in week no 23rd and latest by 26th week with mean 24th week (Cv 5.26 %). Similarly, the earliest withdrawal of monsoon may be start by week no 38th with mean withdrawal 43rd week (Cv 10.11%). During rainy season probability of two consecutive wet spell is more than 50% from 24th to 39th week and probability of two consecutive dry weeks is less than 50% from 22nd to 42nd week.

Key words: Onset and withdrawal of rainy season, dry spell, wet spell, south Odisha

INTRODUCTION

Rainfall analysis for any region is essential for planning and design of various soil and water conservation measures, irrigation and drainage systems, water resource development, command area development and overall planning of agricultural operation of the region. In south Odisha, rainfed agriculture primarily depends on the South west monsoon. Start and end of monsoon, weekly rainfall, dry / wet spell and their duration play a vital role in planning of agricultural operation. Location specific characteristics of rainfall is more important for crop planning which is influenced by the variability of the onset and withdrawal of monsoon, dry/wet spells of monsoon. India receives 74% of rainfall by southwest monsoon, 3% by northeast monsoon, 13% pre-monsoon and 10% post monsoon rainfall (Dabral and Jhajharia, 2005). Simple criteria related to sequential phenomena like dry and wet spells could be used for analyzing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations (Srinivasa Reddy *et al*, 2008). Monthly and annual rainfall is helpful for understanding the general picture of the rainfall of the location. However planning of rainfed agriculture as well as water management practices, weekly rainfall data analysis gives more useful application for crop planning (Tiwari *et al*, 1992) and helpful for determining onset, withdrawal and duration of the rainy season, which is perquisite for planning of cropping system (Jat *et al*, 2005). It is an established fact that the crop development will be affected if the dry spells coincides with the sensitive phonological stage of the crop. On the other hand, dry periods at ripening stage of the crop are sometimes beneficial. Hence for the purpose of crop planning and to carry out

[1]Technical Officer, Central Soil and Water Conservation Research and Training Institute, Research Centre, P.B.No-12, Sunabeda, Koraput, Odisha -763002, E mail: benukantha@yahoo.co.in
[2]Professor, Orissa University of Agriculture & Technology, Bhubaneswar
[3]Associate Professor, Orissa University of Agriculture & Technology, Bhubaneswar

the agricultural practices it is important to know the sequence of dry and wet periods (Pandarinath, 1991). In order to stabilise the crop production at certain level, it is essential to plan agriculture on a scientific basis in terms of making best use of rainfall pattern of an area. This necessitates studying the sequence of dry and wet spells of an area so that necessary step can be taken up to prepare contingent crop plan in rainfed regions (Panigrahi and Panda, 2002).

Markov chain Probability Model has been recognized as a suitable model to explain the long term frequency behaviour of wet or dry weather spells. In this model, the conditional probability has been accepted as fully justified in the analysis of weekly rainfall data (Senthilvelan *et al*, 2012). Markov-chain probability has been extensively used to determine the long term behaviour of wet and dry spells (Victor and Sastry, 1979). Pandarinath (1991) and Haripriya *et al* (1996) used the Markov chain probability model to study the probability of dry and wet spells in terms of the short period like week. Many researchers like Singh and Bhandari (1998), Kar (2003), Jat *et al*, (2003) have demonstrated this model for the agricultural planning. Thus the present study is aimed to assess dry and wet spell in monsoon period, onset and withdrawal of monsoon, length of rainy season and rainfall characteristics of south Odisha

MATERIALS AND METHODS

Daily rainfall data of 30 years (1980-2009) were collected from District Agriculture Office, Jeypore, Koraput for analysis of rainfall pattern of south Odisha. Koraput district is situated between 82^0 34' 46" E to 83^0 03' 04" E longitude and 18^0 20' 10" N to 18^0 41' 35" N latitude is a representative district of Eastern ghats. The geographical area of the district is 8.38 lakhs hectare (5.38 % of state) consisting of 14 blocks (Anon., 2001). Soils of the district are red and lateritic group and poor in fertility.

The probability of occurrence of two consecutive dry weeks and wet weeks were computed by Markov chain process (Robertson, 1976). In the present study, it is assumed that the week is wet if it receives 20 mm or more rainfall, otherwise dry (Pandarinath, 1991 and Dash and Senapati, 1992). The different notations used for dry spell and wet spell analysis are given below

$Pd = Fd / N$

Where

Pd= Probability of the period considered being dry

Fd = Number of dry weeks observed

& N= numbers of years of data used

$Pdd = Fdd / Fd$

Pdd= Probability of the dry weeks preceded by another dry weeks (conditional)

Fdd = Number of dry weeks preceded b another dry weeks

Fd = Number of dry weeks observed

$D_2 = Pd_1 \times Pdd_2$

D_2 = Probability of the two consecutive dry weeks

Pd_1 = Probability of the period being dry (1st week)

Pdd_2 = Probability of 2nd week

$D_3 = Pd_1 \times Pdd_2 \times Pdd_3$

Where

D_3 = Probability of three consecutive dry weeks

Pdd_3 = Probability of 3rd consecutive dry week, given preceding week being dry

$Pw = Fw / N$

Pw= Probability of the week considered being wet

Fw = Number of wet weeks observed

& N= numbers of years of data used

Pww, W_2 and W_3 have been calculated in the same method as Pdd, D_2 and D_3 and the notations used have same meaning except the period being wet. Probability of dry spells and wet spells has been estimated by using the above formula.

Start of the rainy season was computed from weekly rainfall data using Morris and Zandstra (1979) method. In this method weekly rainfall was summed by forward accumulation (22+23 +......52 weeks) until a certain amount of rainfall i.e 75 mm is accumulated as it may be sufficient for land preparation and sowing of dry seeded crops. For calculation of forward accumulation, 22nd week has been considered as the starting period for start of monsoon rains. Backward accumulation of rainfall (52+51+.........+30 weeks) was used for end of the rainy season. Accumulation of 10 mm rainfall was chosen for the termination of rainy season, which may be sufficient for ploughing of fields after harvesting of crops (Jat *et al*, 2003). If this process is repeated for a long period, then the probability of occurrence of these values in different weeks are determined to ascertain the start and end of monsoon in the study area. The probability of each rank is calculated by the Weibull's formula:

$P = M / (N+1) \times 100$

Where P is probability, M is rank number and N is number of years of observation.

RESULTS AND DISCUSSION

Rainfall distribution

The mean annual rainfall (MAR) of the area is 1756 mm. The coefficient of variation of was observed to be 27.42 % which indicate less variation of annual rainfall. The year is divided into three distinct season i.e Pre-monsoon (February- May), monsoon (June-September) and Post-monsoon (October-January) (Jat *et al*, 2005). The seasonal rainfall analysis is presented in Fig.1. It is seen from the analysis that the seasonal rainfall is 133.20, 1516.46 and 105.91 mm having Cv 71.58, 27.55 and 89.50 % for pre-monsoon, monsoon and post-monsoon period respectively. Therefore it can be inferred that rainfall was more consistent during monsoon season than other seasons (Dabral *et al*, 2006). Higher (86.38%) rainfall occurred during the monsoon period followed by 7.59 % in pre-monsoon period and 6.03% in post-monsoon period (Fig. 1). The mean rainy days during the pre-monsoon, monsoon and post- monsoon periods were 8.33 (10.65 % of mean rainy days), 63.73 (81.51% of mean rainy days) and 6.12 (7.82 % of mean rainy days) with Cv 56.22, 13.37 and 68.25% respectively. The mean weekly rainfall > 40 mm observed from 24th to 39th weeks have indicates the potential scope for harvesting runoff water for future use (Srinivasa Reddy *et al*, 2008). The weekly average rainfall varies from 0.13mm (50th week) to 131.54 mm (33rd week). The coefficient of variation of weekly rainfall during rainy season varies from 56.32 (34th Week) to 149.38 (26th week) which indicates less variation of weekly rainfall (Jat *et al*, 2005). The weekly average rainfall from 19th to 22nd weeks varies from 13.79 to 21.09 mm. This pre monsoon rainfall may be used for ploughing, seed bed preparation and other pre sowing agricultural operations (Srinivasa Reddy *et al*, 2008, Jat *et al*, 2005)

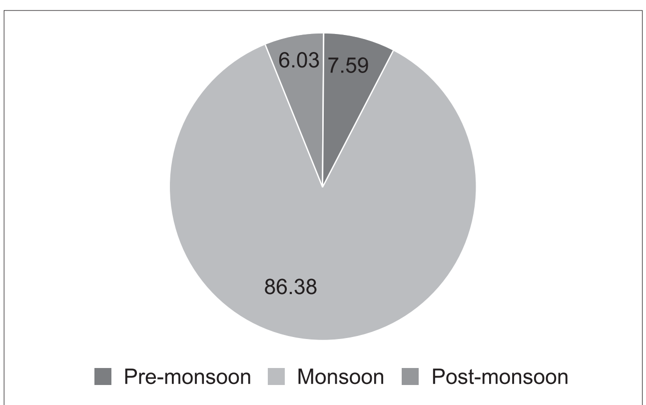

Fig. 1. Distribution (%) of rainfall in different seasons

Monthly rainfall

It is observed that maximum mean monthly rainfall occur in the month of August i.e. 497.46 mm (Cv = 37.09 %) which is 28.34% of total mean annual rainfall and minimum in the month of December i.e. 1.68 mm (Cv=428.77%) which is 0.1 % of total mean annual rainfall followed by January i.e. 5.75 mm (CV 205.67 %) which is 0.33 % of total mean annual rainfall. Fig. 2 represents the percentage mean monthly rainfall in different month of monsoon period. Similarly maximum numbers of rainy days occur in the month of August i.e. 20.8 days (26.61% of total mean rainy days) and minimum in the month of December i.e. 0.17 (0.22 % of annual mean rainy days). Distribution of the mean monthly rainfall and mean monthly rainy days are shown in Figure 3.

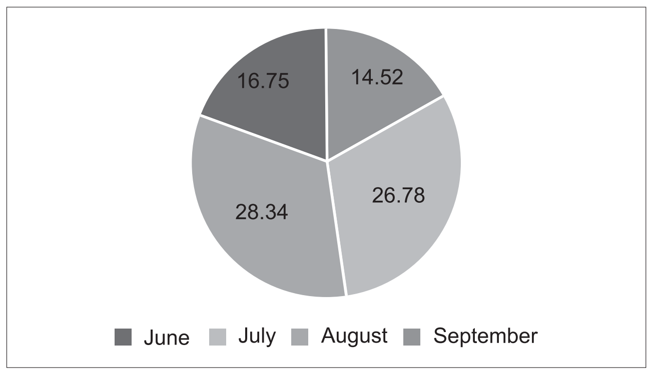

Fig. 2. Distribution (%) of rainfall in different month of monsoon season

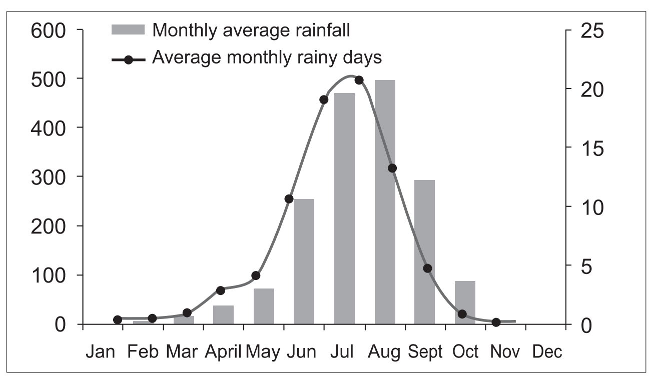

Fig. 3. Distribution of mean monthly rainfall and monthly average rainy days.

Characteristics of rainy season

The rainfall is received mainly from south-west monsoon (June - September) and post monsoon season (October – January). Before the start of monsoon, some rainfall may be expected due to thunder shower. The result of forward and backward accumulation of rainfall (Fig. 4) shows that the onset of rainy season may be expected by 24th week with probability of 51.61% and 90.32% in the 26th week. The earliest start of the rainy season may be expected in week no 23rd and latest by 26th week with mean 24th week (Cv 5.26 %) (Table 3). The earliest withdrawal of south west monsoon in the region is in 38th week with 96.77 % probability and mean withdrawal in 43rd week with coefficient of variation 10.11% (Panigrahi and Panda, 2002). During some of the years post monsoon season rainfall might be extended the rainy season upto 52nd week. The mean monsoon period in this region is 132 days with minimum 105 days.

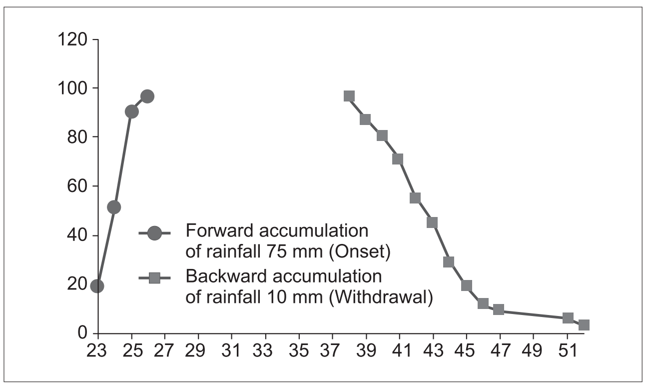

Fig. 4. Probability (%) of onset and withdrawal of rainy season

Analysis of dry and wet spells in monsoon period

The occurrence of dry week is maximum (63.33 %) in the 22nd week and it then inconsistently decreases in the subsequent week (Table 1). The probability of dry week start increasing from 38th week (23.33%) and reaches to the maximum (80 % in 43rd and 44th week). The conditional probability dry week preceded by a dry week is also high upto 24th week (75.0 %) and then falls in the subsequent week. It again starts increasing from 38th week (14.29%) and reaches maximum in 44th week (87.5%). Probability of occurrence of two consecutive dry weeks is high in 23rd week (45.0 %) and decreases in subsequent week and again it starts increasing from 38th week (5.83 %). The study reveals that the

Table 1. Probability of dry spells

Week No.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Pd	63.33	60	26.67	16.67	10.00	10.00	6.67	0	0	6.67	10.00	0	3.33	10.00	6.67	3.33	23.33	26.67	53.33	66.67	66.67	80.00	80.00
Pdd	68.42	66.67	75.00	20.00	33.33	33.33	0	0	0	0	33.33	0	0	0	0	0	14.29	25.00	31.25	55.00	65.00	66.67	87.5
D_2	42.22	45.00	5.33	5.56	3.33	0	0	0	0	2.22	0	0	0	0	0	0.48	5.83	8.33	29.33	43.33	44.44	70.00	62.86
D_3	31.67	9.00	1.78	1.85	0	0	0	0	0	0	0	0	0	0	0	0.12	1.82	4.58	19.07	28.89	38.89	55.00	58.37

Table 2. Probability of wet spells

Week No.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
PW	36.67	40.00	73.33	83.33	90.00	90.00	93.33	100.00	100.00	93.33	90.00	100.00	96.67	90.00	93.33	96.67	76.67	73.33	46.67	33.33	33.33	20.00	20.00
PWW	18.18	41.67	45.45	72.00	85.19	92.59	89.29	93.33	100.00	100.00	96.3	90.00	100.00	96.30	92.86	93.10	100.00	77.27	78.57	50.00	30.00	33.33	50.00
W_2	15.28	18.18	52.8	70.99	83.33	80.36	87.11	100.00	100.00	89.88	81.00	100.00	93.09	83.57	86.90	96.67	59.24	57.62	23.33	10.00	11.11	10.00	0
W_3	6.94	13.09	44.98	65.73	74.4.	75.00	87.11	100.00	96.30	80.89	81.00	96.30	86.44	77.81	86.90	74.7	46.55	28.81	7.00	3.33	5.56	0	0

probability of two consecutive dry weeks < 10% during 24th to 39th weeks. The probability occurrence of three consecutive dry weeks is high from 43rd week onwards (55.0 %) and probability of three consecutive dry weeks is less than 10% between 23rd to 39th weeks. From the above analysis it reveals that during 24th to 42nd week the probability 2 and 3 consecutive dry weeks are within 0 to 44.44 % and 0 to 38.89 % respectively which indicates the probability of irrigation water requirement is less during this period.

Table 3. Characteristics of rainy season

Parameter	Onset	Withdrawal	Duration
Mean week	24.33	43.13	18.8
Earliest week	23.0	38.0	15.0
Latest week	26.0	52.0	26.0
C.V (%)	5.26	10.11	16.55

The probability of occurrence of wet week is low (40.0 %) upto 23rd week but it start increasing upto 39th week (Table 2) and then start decreasing. The probability of wet weeks varies from 73.33 to 100% from 24th to 39th week. The conditional probability of wet week preceded by a another wet weeks is < 50% upto 24th week and then it increases upto 40th week (78.57%). The probability of two consecutive wet weeks is < 20% upto 23rd week and more than 50% till 39th week (57.62%). From 40th week onwards it starts decreasing and reduces to 0 % in 44th week. The probability of three consecutive wet weeks is very low upto 23rd week and it increased as high as upto 100 per cent in 29th week and it start reducing from 38th week. It reduces to 0% by 43rd week.

During 24th to 39th week probability of two and three consecutive wet weeks is varies from 52.8 to 100% and 28.81 to 100% respectively. This indicates that during this period sufficient rain will be available for plant growth (Panigrahi and Panda, 2002). Runoff water generated during this period should harvest for providing irrigation during water deficit period in this area and raising short duration crop in winter season (Singh and Bhandari, 1998).

CONCLUSION

Crop planning and strategy

The major crops in the region are *Oryza sativa, Eleusine coracane, Arachis hypogaea, Lycopersicon esculentum, Zea mays, Phaseolus and Vigna spp,* etc. The weekly average rainfall from 19th to 22nd weeks varies from 13.79 to 21.09 mm. This pre monsoon rainfall may be used for ploughing, seed bed preparation and other pre sowing agricultural operations. Dry spells analysis revealed that from 24th to 40th week, less than 33.33% probability of two consecutive dry weeks is observed. Also the probability of two consecutive wet weeks is more than 50 % from 24th to 39th weeks. The mean onset of rainy season is found to be 24th week with > 50% probability of occurrence. Hence from 23rd week, the sowing of upland crops may be taken up because, the probability of wet week is more than 40 % and average weekly rainfall is more than 20 mm. In the event of delayed rainfall, the sowing operation may be delayed upto 26th week. (Probability for onset of monsoon is > 90 % in the 26th week). During *Kharif* season short duration with low water consumption crops may be grown in the event of delay in onset of monsoon. Other major advantage of growing of short duration cereals, pulses and oil seeds in first week of June and these can be harvested by the mid of September and short duration rabi crops can be sown from 38th week onwards as the average weekly rainfall varies from 11.3 to 70.6 mm from 38th to 43rd weeks with supplemental irrigation by harvested rain water during rainy season. Post monsoon rainfall is highly uncertain and it is risky for growing crops without supplementary irrigation. The contribution of average weekly rainfall more than 40mm from 24th to 39th week (varies from 42.46 to 131.54 mm) and the probability of two consecutive wet weeks is > 50 % from 24th to 39th week. Hence there is a scope of rainwater harvesting which can be used for long duration crops in *kharif* season and for growing vegetables and other low water requirement crops in *rabi* season. As from 43rd week onwards the probability of two and three consecutive dry weeks is more than 50%, it indicates that there may be need of supplementary irrigation for long duration crops of *kharif* season and soil moisture conservation practices may be adopted in upland and medium lands.

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Influence of varieties and integrated nitrogen management on soil nutrient status and nutrient concentration in grain and straw of aerobic rice

S.K. SHARMA[1], SURUCHI TYAGI[2] and Y.V. SINGH[3]

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ABSTRACT

A Field experiments were conducted during the wet (*kharif*) seasons of 2009 and 2010 at New Delhi to study the influence of varieties and integrated nitrogen management on nutrient concentration and soil parameters under aerobic rice cultivation. The treatments included two rice varieties viz. 'PB 1' and 'PB 1121' and 8 integrated nitrogen management (INM) practices viz. N control ($N_0P_{60}K_{40}$); 100 % RDN (120 kg N/ha through urea); 75 % RDN+25%N through Farmyard manure; 75%RDN+ 25%N through green manuring; 75% RDN+ 25% N through biofertilizers; 75%RDN+25% N through vermicompost; 100 % N through FYM +GM+BF+VC and 100 % N through FYM+GM+BF+VC+ $ZnSO_4$. The results showed that soil organic carbon (SOC), available N, available P and available K contents at crop harvest stage were statistically at par in both the rice varieties. SOC, available N, P and K were highest with the application of 100% N by FYM+GM+BF+VC+Zn and lowest with 75% RDN+25% BF. Treatment with 100% N by FYM+GM+BF+VC+Zn showed significantly higher soil EC over control but soil pH was not influenced due to N management practices. Application of 100% N by FYM+GM+BF+VC showed significantly higher microbial biomass carbon (MBC) compared to all other treatments while treatment with 100% RDN showed significantly lower MBC over control. *'PB 1'* variety of rice produced significantly higher grain yield as compared to *'PB 1121'*. Highest grain and straw yield was given by 100% N by FYM+GM+BF+VC+ Zn followed by 100 % N by FYM+GM+BF+VC and 75% RDN+25% VC. N concentration in the grains of *'PB1'* was higher than *'PB 1121'* but in straw, it was higher in *'PB 1121'*. Application of RDN and INM showed significantly enhanced N concentration in grain and straw as compared to control. The highest N concentrations in the grains and straw were recorded with 100% N by FYM+GM+BF+VC+Zn. Concentration of Zn, Fe, Mn, and Cu in grains of rice variety *'PB1'* was higher than *'PB1121'*. Nutrient application with 100% N by FYM+GM+BF+VC+Zn showed highest concentrations of Zn, Fe, Mn and Cu in grains and straw of rice.

Key words: Aerobic rice, integrated nitrogen management, micronutrient concentration, N concentration, soil MBC

INTRODUCTION

Among the production practices, water and nitrogen (N) have special importance in increasing crop yield. Irrigated 'aerobic rice' is a new system being developed for areas with water shortage with access to supplementary irrigation. It entails the cultivation of nutrient responsive cultivars in non saturated soil with sufficient external inputs to reach yields of 70–80% of high input flooded rice. However, dry seeding and subsequent aerobic cultivation of rice create several maladies including the deficiency of micronutrients (Singh *et al.* 2002; Bouman *et al.* 2005). Rice crop is very sensitive to water stress and reduction in water inputs can result in decline of yield (Tuong *et al*. 2004). Nitrogen is the most important nutrient constraint

[1]Seed Production Unit, Indian Agricultural Research Institute, New Delhi-110012; [2]M.M.H. College, Ghaziabad, U.P;
[3]Centre for Conservation and Utilization of Blue Green Algae (E-mail: yvsingh63@yahoo.co.in),
Indian Agricultural Research Institute, New Delhi, 110012

to the productivity of rice. Worldwide N recovery efficiency for cereal production including rice is approximately 35%. The N recovery efficiency for lowland rice is even lower than that reported for other arable crops (De Datta and Crasswell, 1981). Increasing the Zn concentration in food crops is an important global challenge. Among the micronutrients, Zn deficiency is occurring in both crops and humans (White and Zasoski, 1999). Zn deficiency reduces not only the grain yield (McDonald *et al*. 2001), but also the nutritional quality of grain (Cakmak, 2008) and ultimately nutritional quality of human diet. Zn deficiency results in the inability of rice plant to support root respiration during flooded conditions (Slaton *et al*. 2005). In developing countries including India, the need to maximize and sustain food production is very urgent and so increased productivity of the land is essential in the present scenario. Among the production practices water and nitrogen management has special role in increasing rice productivity. Application of organics as a source of nutrient increases the crop growth and yield because of improvement of soil biota and release of nutrients due to their mineralization. The combined use of organics along with inorganic fertilizers also is beneficial for getting sustained crop yields and improving soil biota. Combined use of organic and inorganic sources of N was resulted in better rice yield than inorganic source alone and had residual effect on the productivity of succeeding crop. Besides, it had beneficial influence on physico-chemical properties of the soil in respect of lowering bulk density and pH and improving the organic carbon as well as available nutrient status of soil in general and N in particular apart from improving N use efficiency in rice (Raut and Mahapatra, 2006). With this background an experiment was conducted to evaluate the effect of different sources of nutrients on productivity, soil quality and nutrient concentration in aerobic rice.

MATERIALS AND METHODS

The field experiment was conducted during rainy (*Kharif*) seasons of 2009 and 2010 at the seed production area of Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 meters above the mean sea level (Arabian Sea). The initial soil sample of experimental field had 160.0 kg ha^{-1} alkaline permanganate oxidizable N, 15.0 kg ha^{-1} available P, 262.0 kg 1 *N* ammonium acetate exchangeable K, 0.40% organic carbon and 8.2 pH. The experiment was laid out in split plot design with sixteen treatment combinations comprising of two rice varieties viz. 'PB 1' and 'PB 1121' and eight integrated nitrogen management (INM) practices viz. N control (N_0P_{60} K_{40}); 100 % recommended dose of nitrogen (RDN) i.e. 120 kg N / ha through urea); 75 % RDN + 25% N through Farmyard manure(FYM); 75%RDN+ 25%N through green manuring; 75% RDN+ 25% N through biofertilizers (BF); 75% RDN+ 25% N through vermicompost; 100 % N through FYM +GM+BF+VC and 100 % N through FYM+GM+ BF+ VC+ $ZnSO_4$. A common dose of P (26.2 kg P_2O_5 / ha) and K (33 kg K_2O / ha) was applied in all the plots as basal through single super phosphate (SSP) and muriate of potash (MOP) fertilizers. Nitrogen was applied as per treatments and given through urea, vermicompost, FYM, *Sesbania aculeata* and *Azotobacter* biofertilizer. Doses of FYM, vermicompost and *Sesbania aculeata* were calculated on the basis of their N concentrations and these were applied as basal. Vermicompost contained (on dry weight basis) 1.65 and 1.71 % N, FYM had 0.45 and 0.47% N and *Sesbania aculeata* had 2.47 and 2.65% N in 2009 and 2010, respectively. Biofertilizers (*Azotobacter)* was applied through seed treatment @ 500 g / ha. N through urea was applied in 3 equal splits at basal, active tillering and panicle initiation stage. The experiments were sown in first week of July and before sowing, the field was ploughed, harrowed, leveled and furrowed. Rice seeds were manually drilled in plots with a row spacing of 25 cm. Seed rate of 60 kg / ha was maintained for both the varieties. The field was kept under non-saturated aerobic condition throughout the whole growing season and data on water use was recorded. Supplemental surface irrigations were applied when crop leaves started to roll due to drought stress and drainage was conducted whenever heavy rains resulted in ponding. For weed-management pre-emergence Pendimethalin (Stomp) @ 3.3 liter / ha was sprayed two days after seeding. At maturity, crop was harvested, dried for 3 days, weighed and after threshing grain yield was adjusted to a moisture content of 14%. Straw yield was measured from the total of grain and straw yield. For determination of N concentration plant samples were collected at the time of harvesting and dried in hot air oven at 60±2°C for 6 hours. The oven dried samples were sieved by passing through 40 mesh sieve in a Macro-Wiley Mill. N concentration in grain and straw of basmati rice samples were determined by modified Kjeldahl method. The Fe, Zn, Mn and Cu in of grain and straw of rice crop were determined by DTPA extractable method (Lindsay and Norvell, 1978). Soil samples were collected before beginning of the experiment and after harvest of rice crop from a depth of 0-15 cm and analyzed for organic C, available N, P and K in soil, pH, EC and microbial biomass carbon using standard methods. All the data obtained from the experiment, conducted under split plot design were statistically analyzed using the *F*-test as per the standard procedure and LSD values at P = 0.05 used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Soil organic carbon

Soil organic carbon (SOC) contents at crop harvest stage were statistically at par in both the rice varieties (Table 1). Application of RDN and INM showed significantly enhanced SOC content over the control treatment and 75% RDN+25% BF. Highest soil organic carbon was recorded with the application of 100% N by FYM+GM+BF+VC+Zn followed by 100% N by FYM+GM+BF+VC. SOC content in treatment with 75% RDN+25% VC was higher than 75% RDN+25% GM but the difference between these two treatments was not significant. Treatment with 75% RDN+25% BF recorded lowest SOC content. Increase in soil organic carbon due to addition of organic nutrient sources has been reported(Upadhyay *et al.* 2011; Singh, 2011; Singh and Dhar, 2011; Singh *et al.* 2013) The increase in SOC content due to application of *Azolla*, blue green algae (BGA), FYM and INM has been reported by Singh *et al.* (2011) also.

Available nitrogen (N) in soil

Available N content in soil at crop harvest stage was statistically at par in both the rice varieties (Table 1). Application of RDN and INM significantly enhanced the available N in soil compared to the control treatment during both the years. Significantly higher available N in soil was recorded in 100% N by FYM+GM+BF+VC+Zn followed by 100% N by FYM+GM+BF+VC but the difference in these two treatments was non-significant.

Table 1. Effect of rice varieties and integrated nitrogen management on contents of organic carbon and available N, P and K in soil

Treatment	Organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
Pusa Basmati-1	0.44	0.46	240.63	254.29	16.76	17.43	243.38	250.08
Pusa Basmati-1121	0.43	0.45	237.50	245.88	16.25	16.94	242.00	247.75
S.Em ±	0.006	0.008	1.312	1.243	0.181	0.192	1.185	1.554
LSD (P=0.05)	N.S.	NS	N.S.	3.591	N.S.	N.S.	N.S.	N.S.
Integrated nitrogen management (INM)								
Control	0.35	0.36	194.00	198.31	12.30	12.50	216.50	223.00
100 % RDN (120 kg N / ha)	0.40	0.41	244.00	256.00	16.30	17.02	240.00	246.00
75% RDN+25% FYM	0.43	0.45	234.50	245.33	15.25	15.65	245.50	251.00
75% RDN+25% GM	0.45	0.50	220.00	231.17	14.65	15.18	234.00	239.50
75% RDN+25% BF	0.38	0.39	207.00	213.50	13.70	14.20	228.00	235.50
75% RDN+25% VC	0.47	0.51	260.00	273.33	18.80	19.40	251.50	256.33
100% N by FYM+GM+BF+VC	0.50	0.52	274.00	287.92	20.10	21.25	261.00	265.50
100% N by FYM+GM+BF+VC+$ZnSO_4$	0.51	0.56	279.00	295.10	20.95	22.30	265.00	274.50
SE m ±	0.012	0.016	2.624	2.486	0.362	0.385	2.370	3.107
LSD (P=0.05)	0.036	0.047	7.581	7.181	1.046	1.112	6.846	8.976

RDN: recommended dose of nitrogen, FYM: farm yard manure, GM: green manuring with sesbania, BF: biofertilizer (*Azotobacter*) and VC: vermicompost

Application of 75% RDN+25% VC showed significantly higher available N in soil compared to 100% RDN and 75% RDN+25% FYM or GM or BF. Application of 100% RDN also showed significantly higher available N in soil than 75% RDN+25% FYM, 75% RDN+25% GM and 75% RDN+25% BF. Treatment with 75% RDN+25% BF recorded significantly lower available N in soil than all other nutrient sources. Increased available N due to addition of organic nutrients in soil than the chemical fertilizers has earlier been reported (Yadav and Kumar, 2009; Upadhyay *et al.* 2011; Kumar *et al.* 2012).

Available phosphorus and potassium in soil

Available phosphorus (P) in soil at crop harvest was higher in rice variety *'PB 1'* than *'PB 1121'* but the difference was non-significant during both the years (Table 1). Application of RDN and INM significantly enhanced available P in soil compared to the control treatment. Application of 100% N by FYM+GM+BF+VC+Zn showed significantly higher available P in soil than all the other treatments and it was followed by 100% N by FYM+GM+BF+VC but the differences between these two treatments was non-significant. Application of N with 100% RDN, 75% RDN+25% VC, 75% RDN+25% FYM and 75% RDN+25% GM showed significantly different available P in soil among each other. Available potassium (K) in soil was also higher in rice variety *'PB 1'* compared to *'PB 1121'* but difference was non-significant. Application of RDN and INM significantly enhanced the available K in soil over the control treatment. Nutrient application of 100% N by FYM+GM+BF+VC+Zn showed significantly higher available K in soil than other treatments and it was followed by 100% N by FYM+GM+BF+VC and the difference between these two treatments was non-significant. Application of N through 75% RDN+25% VC showed higher available K in soil than 75% RDN+25% FYM but the difference between these two treatments was non-significant. Treatment with 75% RDN+25% BF showed lowest available K in soil than all other nutrient applications. Upadhyay *et al.* (2011) also reported increased available P and available K due to addition of organic nutrients in soil compared to the chemical fertilizers. Several other workers also found similar results (Yadav and Kumar, 2009; Karmakar *et al.* 2011; Kumar *et al.* 2012). Kumar *et al.* (2011) and Singh (2011) reported enhanced available P and K of soil under rice based cropping system with increasing fertility levels and integrated use of FYM and zinc over the control. Increase in available P and K might be attributed to the direct addition of N, P and K through organic sources.

Soil pH and electrical conductivity

Soil pH and EC were not significantly influenced due to rice varieties (Table 2). Application of RDN and INM also did not show significant variation in soil pH over control in both the years and it varied between 8.20 to 8.30 in 2009 and 8.10 to 8.30 in 2010. Application of RDN and INM significantly enhanced the soil EC over the control treatment. Treatment with 100% N by FYM+GM+BF+VC+Zn showed significantly higher soil EC than other treatments and this treatment was followed by 100% N by FYM+GM+BF+VC but the difference between these two treatments was non-significant. Treatment with 75% RDN+25% FYM also showed higher soil EC than 75% RDN+25% GM but difference was non-significant. Treatment with 75% RDN+25% BF recorded significantly lower soil EC than all the other nutrient applications. Upadhyay *et al.* (2011) and Karmakar *et al.* (2011) also did not find any effect on pH and EC due to addition of organic nutrients in soil over the chemical fertilizers. However, Kumar *et al.* (2012) showed that combination of organic and inorganic fertilizer remained superior for decreasing the soil pH and EC compared to recommended dose of fertilizers alone. Yadav *et al.* (2009) found no much variation in the values of EC after rice whereas, soil pH decrease slightly with the addition of different organic manures.

Microbial biomass carbon (MBC)

Soil microbial biomass carbon (MBC) was significantly declined in rice variety *'PB 1'* as compared to *'PB 1121'* (Table 2). Application of RDN and INM significantly increased the MBC over control treatment during both the years. Application of 100% N by FYM+GM+BF+VC showed increased MBC as compared to all other treatments during both the years. All other nutrient treatment viz. 100% N by FYM+GM+BF+VC+Zn, 75% RDN+25% VC, 75% RDN+25% FYM, 75% RDN+25% GM or 75% RDN+25% BF and 100%

Table 2. Effect of rice varieties and integrated nitrogen management on pH, electrical conductivity (EC) and microbial biomass carbon (MBC) in soil

Treatment	pH		EC (dS/M)		Microbial biomass carbon (mg/kg)	
	2009	2010	2009	2010	2009	2010
Variety						
Pusa Basmati-1	8.23	8.20	0.40	0.42	383.0	387.5
Pusa Basmati-1121	8.26	8.20	0.39	0.41	380.5	384.1
S.Em ±	0.022	0.021	0.004	0.006	0.599	0.878
LSD (P=0.05)	N.S.	N.S.	N.S	N.S.	1.731	2.538
Integrated nitrogen management (INM)						
Control	8.30	8.15	0.32	0.33	292.5	295.0
100 % RDN (120 kg N / ha)	8.25	8.25	0.40	0.42	352.0	355.0
75% RDN+25% FYM	8.30	8.20	0.39	0.41	390.0	392.0
75% RDN+25% GM	8.20	8.10	0.38	0.40	407.5	413.0
75% RDN+25% BF	8.25	8.20	0.35	0.36	368.5	372.0
75% RDN+25% VC	8.20	8.25	0.42	0.46	395.5	399.0
100% N by FYM+GM+BF+VC	8.20	8.15	0.45	0.48	465.0	470.5
100% N by FYM+GM+BF+VC+$ZnSO_4$	8.25	8.30	0.47	0.49	383.0	390.0
SE m ±	0.04	0.04	0.008	0.012	1.198	1.757
LSD (P=0.05)	N.S.	NS	0.022	0.034	3.461	5.075

RDN showed significantly increased soil MBC among each other during both the years. Similar results have been reported by other researchers (Singh, 2010 and Nath *et al.*, 2012).

Grain and Straw yield

Rice variety *'PB 1'* produced significantly higher grain yield (3.80 and 4.04 t/ha) as compared to *'PB 1121'* (Table 3). Application of RDN and INM significantly increased the grain yield of rice compared to control. Maximum grain yield was observed with application of 100% N by FYM+GM+BF+VC+Zn followed by 100 % N by FYM+GM+BF+VC and 75% RDN+25% VC. N application with 75% RDN+25% FYM inclined grain yield than 100% RDN. Application of 100% RDN and 75% RDN+25% GM showed significantly increased grain yield than 75% RDN+25%BF. Rice variety *'PB 1121'* produced higher straw yield as compared to *'PB 1'* but the difference was significant in 2010 only (Table 3). Treatments with INM and RDN significantly increased straw yield of rice as compared to control. Maximum straw yield was observed due to the application of 100% N by FYM+GM+BF+VC+Zn and it was followed by 100 % N by FYM+GM+BF+VC and 75% RDN+25% VC. Treatment with 75% RDN+25% BF showed minimum influence on straw yield as compared to all other treatments having INM with FYM, GM or VC alone or in combination. Similarly enhanced grain and straw yield of rice due to the application of different organic amendments either applied alone or in combinations has been reported by many researchers (Polthanee *et al.* 2008; Yadav *et al.* 2009; Singh *et al.* 2011; Acharya *et al.* 2012; Kadiyala *et al.* 2012). Organic manures increased the fertilizer use efficiency and improved the physical and chemical properties of soil hence making better utilization of nutrients might also be a reason toward increased grain and straw yield.

Concentration of nitrogen in grain and straw

N concentration in the grain and straw of rice variety *'PB 1'* was higher than *'PB 1121'* but the difference was significant in 2009 only (Table 3). Application of RDN and INM significantly increased the N concentration in grain and straw over the control. Highest N concentration was recorded with 100% N by FYM+GM+BF+VC+Zn followed by 100% N by FYM+GM+BF+VC and 75% RDN+25% VC but the differences between these three treatments were non-significant. Application of 75% RDN + 25% FYM also showed higher N concentration than 100% RDN but the difference was non-significant. N application with 75% RDN+25% BF had lower N concentration than all the other treatments. Our findings are in

Table 3. Effect of rice varieties and integrated nitrogen management on yield and nitrogen content in grain **and straw**

Treatment	Yield (t/ha)				N content (%)			
	Grain		Straw		Grain		Straw	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
Pusa Basmati-1	3.80	4.04	6.43	7.57	1.40	1.38	0.58	0.57
Pusa Basmati-1121	3.60	3.87	6.65	8.35	1.37	1.36	0.57	0.55
S.Em ±	0.063	0.05	0.13	0.17	0.004	0.012	0.004	0.008
LSD (P=0.05)	0.18	0.15	N.S.	0.50	0.012	N.S.	0.012	N.S.
Integrated nitrogen management (INM)								
Control	2.52	2.80	4.95	6.28	1.28	1.26	0.46	0.42
100 % RDN (120 kg N / ha)	3.67	4.00	6.47	8.00	1.39	1.36	0.57	0.55
75% RDN+25% FYM	3.92	4.21	6.83	8.22	1.41	1.39	0.59	0.57
75% RDN+25% GM	3.45	3.89	6.17	7.89	1.36	1.33	0.54	0.52
75% RDN+25% BF	3.27	3.50	5.78	7.67	1.32	1.29	0.51	0.48
75% RDN+25% VC	4.13	4.35	7.07	8.33	1.44	1.42	0.63	0.61
100% N by FYM+GM+BF+VC	4.23	4.39	7.23	8.50	1.45	1.44	0.65	0.64
100% N by FYM+GM+BF+VC+$ZnSO_4$	4.40	4.50	7.80	8.78	1.46	1.46	0.67	0.69
SE m ±	0.126	0.106	0.260	0.347	0.008	0.024	0.008	0.017
LSD (P=0.05)	0.37	0.31	0.75	1.00	0.02	0.07	0.02	0.05

conformity with Yadav *et al.* (2005) and Mankotia *et al.* (2008). Kadiyala *et al.* (2012) reported increased N uptake in grain of aerobic rice due to increasing doses of N. The increased N concentration might be due to the sufficient and continued availability of N from inorganic and organic source that eventually led to higher N uptake (Dixit and Gupta, 2000). Mehdi *et al.* (2011) also reported increased N concentration in grain and straw of rice due to the integrated use of organic manures and inorganic fertilizers. This might be due to improvement of the soil environment which encouraged proliferation of roots resulting in more absorption of water and nutrients from larger area and depth. Moreover, organic manures after decomposition released nutrients which became available to the plants and thus increased N concentration. Singh *et al*.(2013) observed that application of the recommended dose of chemical fertilizers and INM significantly increased the concentrations of N in grains and straws of rice compared to control.

Concentration of Zn, Fe, Mn and Cu in grain and straw

Concentrations of zinc (Zn), iron (Fe) and copper (Cu) in grain and straw of *'PB 1'* were significantly higher than *'PB 1121'* but manganese (Mn) concentrations in grain and straw of both the rice varieties were non- significantly different (Table 4 and 5). Application of RDN and INM significantly enhanced the Zn content over the control treatment. Nutrient application through 100% N by FYM+GM+BF+VC+Zn showed significant higher Zn concentration than all other treatments. Treatment with 100% N by FYM+GM+BF+VC also showed significantly higher Zn content than 75% RDN+25% VC and 75% RDN+25% FYM during 2009. However in 2010, Zn concentration was significantly higher in 100% N by FYM+GM+BF+VC and 75% RDN+25% VC only. N application through 100% RDN also showed significantly higher Zn concentration than 75% RDN+ 25% GM and 75% RDN+ 25% BF during both the years. Application of RDN and INM significantly increased the Fe concentration in grain and straw over the control treatment during both the years except the treatment with 75% RDN+25% BF which showed non-significant difference to the control treatment in 2009. Application of nutrient through 100% N by FYM+GM+BF+VC+Zn had significant higher Fe concentration than all the other treatments. Application of N through 100% by FYM+GM+BF+VC showed significantly higher Fe concentration compared to 75% RDN+25% VC and 75% RDN+25% FYM. Mn concentration significantly enhanced due to the application of RDN and INM over the control treatment. Treatment with 75%

Table 4. Effect of rice varieties and integrated nitrogen management on concentration of Zn, Fe, Mn and Cu in grain of rice

Treatment	Zn content (mg/kg)		Mn content (mg/kg)		Fe content (mg/kg)		Cu content (mg/kg)	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
Pusa Basmati-1	22.13	21.36	36.41	35.36	23.23	22.90	11.50	10.68
Pusa Basmati-1121	21.34	19.85	35.29	34.25	22.73	22.30	11.09	10.45
S.Em ±	0.108	0.175	0.320	0.195	0.240	0.169	0.122	0.068
LSD (P=0.05)	0.313	0.507	0.923	0.564	N.S.	0.487	0.354	0.197
Integrated nitrogen management (INM)								
Control	15.80	15.15	28.70	26.60	18.85	18.35	9.80	8.90
100 % RDN (120 kg N /ha)	21.65	20.75	34.70	33.95	21.75	21.45	10.75	9.80
75% RDN+25% FYM	22.95	21.85	36.05	35.40	22.53	22.23	11.15	10.15
75% RDN+25% GM	20.00	19.55	31.40	30.50	21.25	20.80	10.30	9.50
75% RDN+25% BF	17.40	16.50	29.90	28.45	20.00	19.35	10.25	9.15
75% RDN+25% VC	23.95	21.90	39.75	38.80	24.95	24.60	11.85	11.35
100% N by FYM+GM+BF+VC	24.70	23.00	42.00	41.38	26.70	26.15	12.70	12.15
100% N by FYM+GM+BF+VC+$ZnSO_4$	27.40	26.13	44.30	43.35	27.80	27.83	13.53	13.50
SE m ±	0.217	0.351	0.639	0.391	0.479	0.337	0.245	0.136
LSD (P=0.05)	0.626	1.013	1.846	1.129	1.384	0.974	0.707	0.394

Table 5. Effect of rice varieties and integrated nitrogen management on concentration of Zn, Fe, Mn and Cu in straw of rice

Treatment	Zn content (mg/kg)		Mn content (mg/kg)		Fe content (mg/kg)		Cu content (mg/kg)	
	2009	2010	2009	2010	2009	2010	2009	2010
Variety								
Pusa Basmati-1	38.69	38.05	52.63	52.20	64.30	64.03	33.11	32.90
Pusa Basmati-1121	37.44	36.44	51.89	51.58	63.58	63.34	32.82	32.39
S.Em ±	0.222	0.302	0.296	0.254	0.292	0.236	0.223	0.180
LSD (P=0.05)	0.64	0.87	N.S.	N.S.	N.S.	0.68	N.S.	N.S.
Integrated nitrogen management (INM)								
Control	28.35	27.70	40.15	39.70	52.15	51.65	26.77	26.70
100 % RDN (120 kg N /ha)	37.00	36.10	51.30	50.30	64.50	64.25	31.15	30.80
75% RDN+25% FYM	39.15	37.93	53.30	52.60	66.00	65.60	32.82	31.97
75% RDN+25% GM	34.60	34.55	49.27	48.88	60.65	60.25	30.00	29.30
75% RDN+25% BF	30.75	30.02	44.05	43.35	56.45	55.70	28.45	27.45
75% RDN+25% VC	41.90	41.10	55.65	55.00	68.77	68.20	36.30	35.45
100% N by FYM+GM+BF+VC	44.75	43.55	60.85	60.30	70.10	69.67	38.25	38.50
100% N by FYM+GM+BF+VC+$ZnSO_4$	48.00	47.00	63.50	65.00	72.90	74.15	39.98	41.00
SE m ±	0.444	0.603	0.592	0.508	0.584	0.472	0.446	0.360
LSD (P=0.05)	1.28	1.74	1.71	1.47	1.69	1.36	1.29	1.04

RDN+25% VC showed significant higher Mn concentration than 75% RDN+25% FYM. Lowest Mn concentration was recorded with 75% RDN+25% BF except than the control treatment. Application of RDN and INM increased the concentration of Cu in all treatments compared to control but differences were significant in few treatments only. Nutrient application with 100% N by FYM+GM+BF+VC+Zn showed significantly higher Cu concentration over all other treatments. Treatment with 100% N by FYM+GM+BF+VC recorded significantly higher Cu content than 75% RDN+25% VC and 75% RDN+25% FYM. Increased concentration and uptake of Zn, Fe, Mn and Cu in rice grain due to the application of different combination of organic materials and biofertilizers has been reported (Gogoi *et al.* 2010). They argued that this might be due to chelating action of organic compounds released during decomposition of manures and prevention of these cations from fixation, precipitation, oxidation and leaching. This showed that organic sources of nutrients not only increased the grain yield but also increased the micronutrient concentrations and uptake in grain and straw. Similar results were reported by Pandey *et al*. 2007.

CONCLUSION

Under aerobic rice management 100% N application through organic sources like by FYM +GM + BF + VC+ Zn was found to be the best since it was superior than other treatment in respect of grain and straw yield, physico-chemical properties of the soil and enhanced the concentrations of N, Zn, Fe, Mn and Cu in grain and straw. This treatment was followed by 100% N by FYM+GM+BF+VC and 75% RDN+ 25% VC. Rice variety *'PB 1'* was superior than *'PB 1121'* under aerobic rice management.

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Artificial Neural Network approach to evaporation modelling

JITENDRA SINHA[1], B. L. SINHA[1], M. K. VERMA[2], D. K. CHOUBEY[3], KARNIKA DWIVEDI[3], ASHULATA NETAM[3], REKHA BAI[3] and PRINCY SAHU[3]

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ABSTRACT

Artificial Neural Network (ANN) based evaporation models have been developed for Raipur region in Chhattisgarh. Observation of maximum temperature (T_{max}), minimum temperature (T_{min}), relative humidity (RH), wind speed (WS), sunshine hour (SSH) & evaporation (E) for the past 23 years have been used for training and testing of the ANN models. Several input combination were tried and seven different models have been developed so as to find out the importance of different input parameters in modelling the evaporation. Performance evaluation of the models have been carried out by calculating statistical evaluation criteria viz. mean absolute deviation (MAD), root mean square error (RMSE), coefficient of correlation (CC) and Nash - Sutcliffe coefficient efficiency (CE). The encouraging results were supported by high values of CC - CE & low RMSE - MAD. Scatter plots between observed and simulated values of evaporation showed that most of the values lie near 45^0 lines. The model with combination of all input parameters provided better estimate of evaporation than individual parameters.

Key words: Artificial Neural Networks; Back propagation ANN, Hidden Layers; Evaporation Models; Training; Testing; Performance Evaluation Criterion.

INTRODUCTION

Evaporation is conversion of water from liquid to gaseous state through the absorption of heat energy. Evaporation is a very important phenomenon in the hydrologic cycle. Therefore, accurate estimation of evaporation loss from the water body is of primary importance for monitoring and allocation of water resources for agriculture and municipal water supply. Although evaporation is an important component of water balance, the data required for its accurate estimation are commonly available only at widely spaced measurement stations. In order to estimate the evaporation, direct measurement methods or physical and empirical models can be used. Using direct methods require installing meteorological stations and instruments for measuring evaporation. Installing such instruments requires specific facilities and cost which is very difficult to be specified.

According to Linsley *et al*. (1982) radiation is by far the most important single factor affecting evaporation and Chow *et al.* (1988) reported that in addition to solar radiation, the mechanism of transporting the vapour from the water surface has also a great effect. Vapour pressure deficit, temperature, barometric pressure, humidity and wind speed were emphasized by Singh (1992) as the controlling factors.

In the hydrological practice, evaporation can be estimated by conventional approaches like direct or indirect methods involving use of the empirical equations. The predominant pan evaporation measurement method utilizes a 48 inch diameter pan that sits above ground, known as the Class-A

[1] Assistant Professor, Soil & Water Engineering, FAE, IGKV, Raipur
[2] Head, Department of Civil Engineering, National Institute of Technology, Raipur,
[3] Students, BRSM College of Agricultural Engineering & Technology, Mungeli, Chhattisgarh

evaporation pan. The indirect methods use meteorological data to estimate evaporation by empirical based methods or statistical and stochastic approaches. The indirect methods are namely Temperature based formulae, Radiation method, Humidity based relation, Penman formulae, Energy balance approach etc. These methods of evaporation estimation have been applied by Abtew (2003), Terzi, *et al.* (2006), Rosenberry (2007) etc. Although all these approaches are based on Penman formula, they are sensitive to site-specific evaporation parameters, which can vary from one place to other. The literature review showed that these equations vary greatly in their ability to define the magnitude and variability of the evaporation from the reservoirs. It is therefore necessary to develop alternate approaches to estimate the evaporation rates based on meteorology variables, which are comparatively easier to measurements and estimation.

Evaporation process is complex and needs non-linear modeling and hence, can be modeled through Artificial Neural Networks (ANN). ANN is a flexible mathematical structure, which is capable of identifying complex nonlinear relationships between input and output data sets. The ANN models have been found useful and efficient, particularly in problems for which the characteristics of the processes are difficult to describe using physical equations.

Many researchers have investigated the applicability of ANN in hydrology to rainfall-runoff modelling (Zealand, 1999, Sinha, J. 2012), short-term stream flow (Luk, *et al.* 2000), rainfall (Tokar, *et al.* 1999), reservoir inflow (Mohammadi, *et al.* 2005) etc. The ANN models are also applied to estimate the Pan evaporation by Terzi, *et al.* (2006), Kokya, *et al*. 2008, Eslamian, *et al*. 2008 and recently Moghaddamnia, *et al.* 2009.

MATERIALS AND METHODS

The meteorological observatory located in Raipur (21^0 14' 9" N latitude and 81^0 42' 10" E longitude), is at a distance of about 1.7 km from Indira Gandhi Krishi Viswavidyalaya Raipur towards east on right side of National Highway-6. The study area generally has a dry tropical weather which is moderate except in summer when the peak temperatures usually reach as high as 46^o C in May and January is the coldest month with daily minimum temperature drops to about 9^o C. The onset of monsoon is usually from 15th June and the monsoon season extends up to September. The long term rainfall data of study area reveals that about 90% rainfall occurs in the five successive months from June to October. The relative humidity is very low in summer (38-49%) and reaches above 76 percent during monsoon. The sun shine hours during monsoon month i.e. July and August are very less (3-5 hours / day). Average sunshine hours are about 7.6 hr / day. The wind is moderate and blow with average speed of 1.8 km / hr. Hot winds are experienced from April to first week of June. Frequency of moderate to severe drought in the study area is around 6 to 7 years and the recurrence of drought on a lower scale is in every 3 to 4 years. The study area is a part of Chhattisgarh - popularly known as rice bowl of central India where large number of indigenous rice varieties is grown.

Data on maximum temperature, minimum temperature, relative humidity, vapour pressure, wind speed, sunshine hour & evaporation from 1981 to 1983, 1985 to 1989, 1992 to 1998, 2001 to 2008 (23 years) were collected from Department of Agro-meteorology, College of Agriculture, IGKV, Raipur (C.G.).

In this study seven different combination of inputs have been tried and named M-1, M-2, M-3, M-4, M-5, M-6 and M-7. Details of these combinations are shown in Table 1.

Table 1. Combinations of input variables considered in developing ANN models

Model	Input Vectors
M 1	Temperature (max & min), Relative Humidity (RH), Wind Speed (WS) and Sunshine hour (SS)
M 2	Temperature(max), Relative Humidity, Wind Speed and Sunshine hour
M 3	Temperature (avg), Relative Humidity, Wind Speed and Sunshine hour
M 4	Temperature (max), Wind Speed and Sunshine hour
M 5	Temperature (max) and Sunshine hour
M 6	Temperature (max) and Wind Speed
M 7	Temperature (max)

Development of Artificial Neural Network models

In this study back propagation algorithm (Rumelhart and McClelland, 1986) is used to develop ANN models. It involves computation of the ANN errors and the propagation of the errors back through the network in order to update weights accordingly. It is used in layered feed-forward ANNs. The artificial neurons are arranged in layers, and send their signals "forward", and then the errors are propagated backwards. The network receives inputs by neurons in the input layer, and the output of the network is given by the neurons on an output layer. There may be one or more intermediate hidden layers. The back propagation algorithm uses supervised learning. The idea of the back propagation algorithm is to reduce the error (difference between actual and expected results), until the ANN learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal.

An optimal architecture is the one yielding the best performance in terms of error minimization while retaining a simple and compact structure. The back propagation becomes computationally cumbersome with increase in the number of hidden layers. There are no fixed rules as to how many nodes should be included in a hidden layer. If there are less number of nodes in the hidden layer the network may have difficulty in generalization. On the other hand, the network may take a longer time to learn if there are too many nodes in the hidden layer and it may tend the network to memorize instead of learning and generalization (Vemuri, 1992). Most of the past research work suggest that one hidden layer is sufficient in explaining evaporation. Hence, in this study, one hidden layer was adopted. For deciding the number of nodes in hidden layer, network growing technique (Gallant, 1986; Kwok and Yeung, 1995) was used. It started with one hidden nodes and the number of nodes were increased at an increment of one node. After each such trial the performance evaluation criteria were observed to see satisfactory results.

In the present study the BPANN was designed by using MATLAB codes. A programme was written, edited, debugged and run in MATLAB. The programme was suitably modified to accommodate different input combinations. The activation function chosen is 'logsig' while performance function chosen is sum squared error (sse).

Performance evaluation of models

The statistical model evaluation criteria considered in this study are as follows:

Mean Absolute Deviation (MAD)

It is a measure of mean absolute deviation of the observed values from the estimated values. It has a unit and is not a normalized criterion. It is expressed as,

$$\text{MAD} = \frac{\sum_{j=1}^{n} \left| O_j - S_j \right|}{n}$$

where, O_j = Observed runoff (m^3/s), S_j = Simulated runoff (m^3/s), n = Total number of observations.

Root Mean Square Error (RMSE)

It is an alternative to the criterion of residual error (Yu, 1994) and is expressed as the measure of mean of the residual variance summed over the period, that is,

$$\text{RMSE} = \sqrt{\frac{\text{residual variance}}{\text{n}}} = \left(\frac{\sum_{j=1}^{n} \left(O_j - S_j\right)^2}{n} \right)^{1/2}$$

Correlation Coefficient (CC)

The correlation between the observed and simulated values is described by the correlation statistic, called the correlation coefficient. It is estimated by the equation:

$$CC = \frac{\sum_{j=1}^{n} \left\{ \left(O_j - \bar{O}\right)\left(S_j - \bar{S}\right) \right\}}{\left\{ \sum_{j=1}^{n} \left(O_j - \bar{O}\right)^2 \sum_{j=1}^{n} \left(S_j - \bar{S}\right)^2 \right\}^{\frac{1}{2}}} x100$$

where, $\bar{O}$ and $\bar{S}$ are mean of observed and simulated runoff values.

Coefficient of Efficiency (CE)

Nash and Sutcliffe (1970) proposed the criterion on the basis of standardization of the residual variance with initial variance and named it as the coefficient of efficiency.

$$CE = \left\{1 - \frac{residual\ variance}{initial\ variance}\right\} x\ 100 = \left\{1 - \frac{\sum_{j=1}^{n}(O_j - S_j)^2}{\sum_{j=1}^{n}(O_j - \overline{O})^2}\right\} x\ 100$$

RESULTS AND DISCUSSION

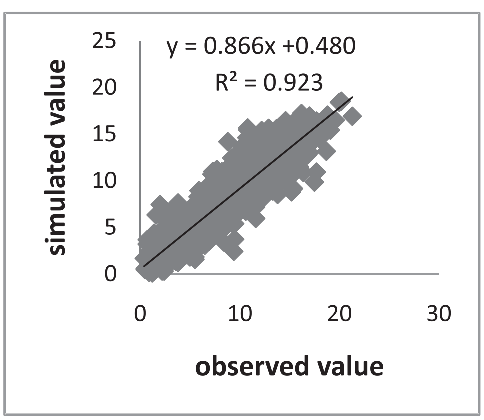
A standard back propagation algorithm was employed to estimate the network parameters (weights and biases). The data were scaled to fall between 0 and 1, as the activation function used in the hidden and output node is a sigmoid function. This scaling was achieved by using the maximum and minimum of each variable of interest. In the present study only one hidden layer was used as it was found to be working well. Optimum network was obtained after a large number of trials by using different combination of these parameters carried out on data set.

In this study 7 models have been developed based on different input combination and output being evaporation. All the models have been trained with 70% of the patterns (5880) and tested with 30% (2520) of the patterns. Values of different performance evaluation criteria viz. MAD, RMSE, CC and CE are analyzed both during training and testing. The network was selected based on maximized CC & CE values and minimized MAD & RMSE values both in training and testing. After detailed numerical experiment the best performance in each model has been selected. Performance of the different models along with the network architecture is given in table 2. Relationship between observed and simulated evaporation during training and testing for models M-1 through M-7 is explained in figure 1 through figure 6.

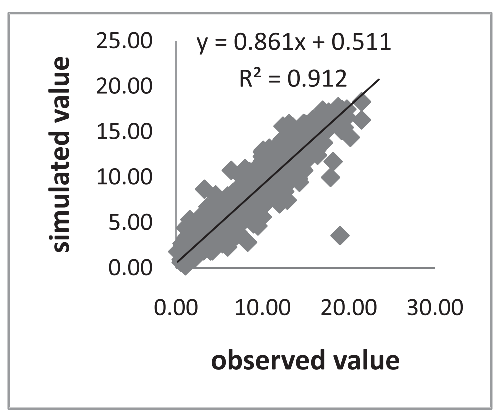
Table 2. Performance of the different models along with the network architecture

ModelName / Network Architecture (NOIN-NOHN-NOON)	Input combination	Training				Testing			
		MAD	RMSE	CC %	CE %	MAD	RMSE	CC %	CE %
M-1/5-4-1	**Tmax+Tmin+ RH+WS+SS**	0.9841	**2.0346**	**85.24**	**72.66**	**0.7501**	**1.1029**	95.5	**90.4**
M-2 / 4-4-1	Tmax+RH+WS+SS	**0.9671**	2.0405	85.14	72.5	0.755	1.1161	**95.61**	90.17
M-3 / 4-3-1	Tavg+RH+WS+ SS	0.9967	2.0547	84.92	72.11	0.764	1.1153	95.23	90.18
M-4 / 3-4-1	Tmax+WS+SS	1.0209	2.0789	84.53	71.45	0.7988	1.1635	95.01	89.32
M-5 / 2-4-1	Tmax+SS	1.1218	2.154	83.28	69.35	0.9366	1.35	92.59	85.62
M-6 / 2-4-1	Tmax+WS	1.0725	2.0974	84.23	70.94	0.8511	1.2116	94.44	88.42
M-7 / 1-4-1	Tmax	1.142	2.1673	83.05	68.97	0.9508	1.356	92.6	85.49

NOIN- Number of input nodes, NOHN- Number of hidden nodes, NOON- Number of output nodes

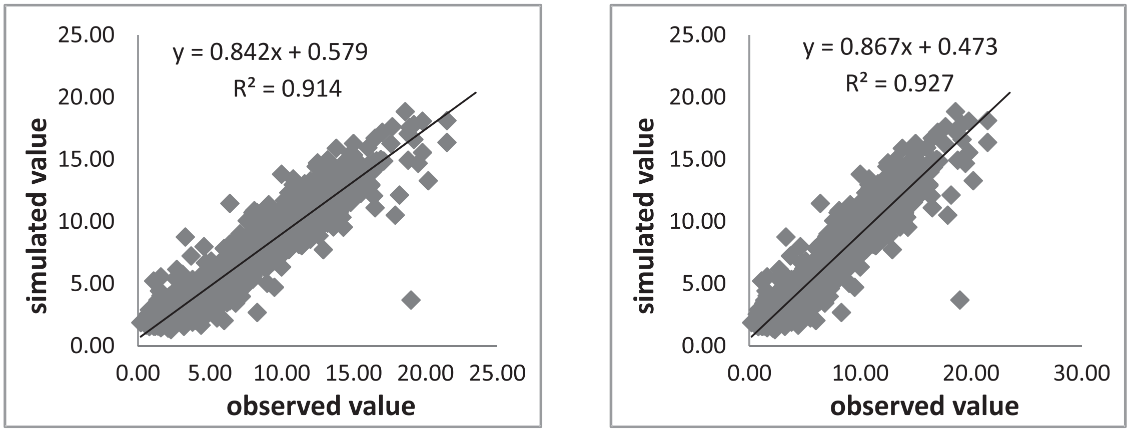


Training



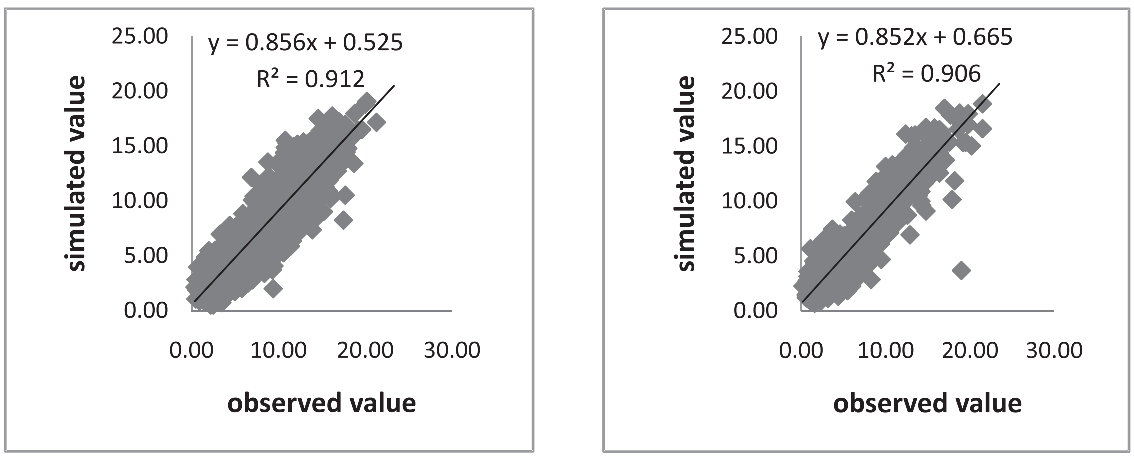
Testing

Fig. 1-2: Relationship between observed and simulated evaporation for **model M-1** during training and testing



Training **Testing**

Fig. 3-4: Relationship between observed and simulated evaporation for **model M-2** during training and testing



Training **Testing**

Fig. 5-6: Relationship between observed and simulated evaporation for **model M-3** during training and testing.

Comparison of developed models

Performance of the developed ANN models has been assessed by comparing the simulated evaporation with observed pan evaporation values. The relationship is demonstrated through scatter plots. As seen from table 2, the most suitable model (M-1) according to input is the ANN (5-4-1) model, in which we have taken 5 inputs i.e. T_{max}, T_{min}, RH, WS and SSH with 4 hidden nodes in single hidden layer. The model showed higher CC value i.e. 85.24% during training and 95.5% during testing, highest CE value i.e. 72.66% during training and 90.4% during testing, smallest value of RMSE i.e. 2.0346 during training and 1.1029 during testing and smallest MAD values i.e. 0.9841 during training and 0.7501 during testing. The performance of model M-2, (ANN 4-4-1) is at par with the model M-1. The added advantage of model M-2 is that it is developed with 4 inputs only (leaving the T_{min}), hence, simpler in comparison to the model 5-4-1.

CONCLUSION

The process of evaporation is very much complex and non-linear in nature. Using direct methods of measurements require installing meteorological stations and instruments, which is difficult to execute. ANN models have been found to estimate daily evaporation with acceptable accuracy. Most of the simulated values with ANN are lying near the 45Ú line. The performance clearly suggests the utility of ANN models. The study also concludes that combination of all input parameters provides better estimate of evaporation than individual parameters.

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Land use based characterization of soils in relation to geology and slope in micro-watershed of Shiwalik foothills

KULDEEP K. THAKUR, SANJAY ARORA[1], S.K. PANDITA and V.C. GOYAL[2]

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ABSTRACT

The soil samples of the watershed were collected to characterize the soils under different land uses and having different slopes. The mechanical analysis of the soils from the study area have dominant sand fraction ranging from 50.60 to 80.22%, with an average of 65.8%, followed by silt fraction ranging from 10.63 to 34.92% with an average of 22.6% and the average clay content was 11.59%. The sediments have been classified as sandy loam, loamy sand, sandy clay loam and loam. The higher fraction of sand in study area accounts for less cohesion and subsequently increases the rate of infiltration in the soils which help in groundwater recharge. The average water holding capacity in the area is 32.88% and average infiltration rate is 0.54 cm / min. The low water holding capacity, high porosity and coarse texture of the soil indicates moderately high infiltration rate in the area. The average good porosity and permeability help in groundwater recharging through infiltration ultimately leading to groundwater recharging.

Key words: geology, foothill, soil properties, Shiwaliks, land use

INTRODUCTION

The Jammu region is divided into two physiographic units i.e., northern hilly terrain and outer plain area. The hilly terrain comprises of Siwalik Group of rocks that has developed badland topography due to repeated cycles of erosion and dissection resulting into a network of ravines (Ram, 1982). The terrain is mostly rugged with gigantic dip slopes and escarpments. The outer plain area is comprised of Kandi and Sirowal belts. The submontane region of Himalayas fringing the Siwalik Hills termed as Kandi belt (Bhabhar Zone), is a steeply sloping belt of less than 10 to 30km width extending discontinuously from Jammu and Kashmir to Assam (Arora et al., 2006). The Kandi is steeply sloping and flattens downstream, imperceptibly merging with the Sirowal (Terai) in the south.

Kandi are fan deposits, which are highly porous and capable of allowing insitu percolation of large quantities of rainwater / surface water, but are deprived of the water because of substantial runoff due to steep topographic gradient (Bhan *et al.*, 1994). The deposit shows reworking everywhere by sheet flooding and severe gullying by hill torrents. Infiltration capacity is generally high in the area, varying from 12cm / h in bare land to about 19cm / h in forest and agricultural lands, and about 26 cm / h in grassland (Goyal and Rai, 1999-2000). A high soil loss rate (about 10 to 45 tonnes / ha / yr) is estimated in the Kandi belt (Srinivasulu *et al.*, 2001). The water holding capacity of the soils is very low (Arora et al., 2006). Due to excessive permeability, losses of nutrients by leaching are high.

This study has been carried out in the Balawal watershed area in Jammu District of Jammu and

Department of Geology, University of Jammu, Jammu 180 001, J&K
[1]Division of Soil Science and Agricultural Chemistry, S.K. University of Agricultural Sciences and Technology, Faculty of Agriculture, Chatha 180 009, Jammu, J&K
[2]National Institute of Hydrology, Roorkee, Uttrakhand

Kashmir State. The area under investigation forms part of the Upper Siwalik in addition to the Kandi belt. Most of the area comprises of the clasts (pebble, gravel and boulder) bounded by coarse sand and clay. The area has a good potential for the groundwater storage, however still faces acute shortage during the summer season. This is because most of the rainfall is lost due to the sheet flooding resulting into loss of the soil cover. This precarious situation can be related to non-adoption of watershed management techniques in the area. This study focuses on characterization of the water and soil resources in the Balawal watershed.

The study area receives fairly high rainfall (1200mm approx.) but also has high level of runoff and deep water table conditions. Streams are ephemeral and dry stream beds present a very dry look to this area. Majority of the area is fast urbanizing, causing concern on water quality and landscape. Agriculture continues to be an important vocation of the people of the Kandi belt, providing livelihood to about 70% of the population. Due to the absence of any perennial source of surface water coupled with deep groundwater conditions, there has always been acute shortage of water for the sustenance of life and agriculture in the watershed area. Most of the area in the Balawal watershed is still under active erosion. The area has undulating topography with numerous gullies and dissected drainage. Existing water scarcity and water quality problems experienced in the area make water harvesting and soil conservation a critical issue for sustainable development.

MATERIALS AND METHODS

Based on the reconnaissance survey 29 soil samples were collected randomly and representatively from the sub-watersheds of the study area at two depths (0-15cm and 15-30cm) preferably from the agricultural fields (Fig. 1). The data were obtained on the grain size analysis by wet sieving method, bulk density by mass and weight method, permeability by variable head method and porosity by using specific gravity method. The pH, electrical conductivity, organic carbon content, soluble sodium percentage (SSP), Ca, Mg, Na, K were determined by using standard procedures.

The electric conductivity was determined using a 1:2.5 (w:v) soil: water ratio and soil pH was also determined in 1:2.5(w:v) soil:water ratio (Jackson, 1973). Organic carbon was determined by wet digestion method outlined by Walkley and Black (1934). Water holding capacity of soil was determined by Keen Raczkowski box method. Pore space was found out as outlined by Chopra and Kanwar (1991). Exchangeable Ca, Mg, Na and K in soil samples were determined after extraction in neutral normal ammonium acetate and Ca and Mg in the extract was estimated through versenate titration and Na and K through flame photometer (Richards, 1954). Infiltration rate was determined in-situ using double ring infiltrometer.

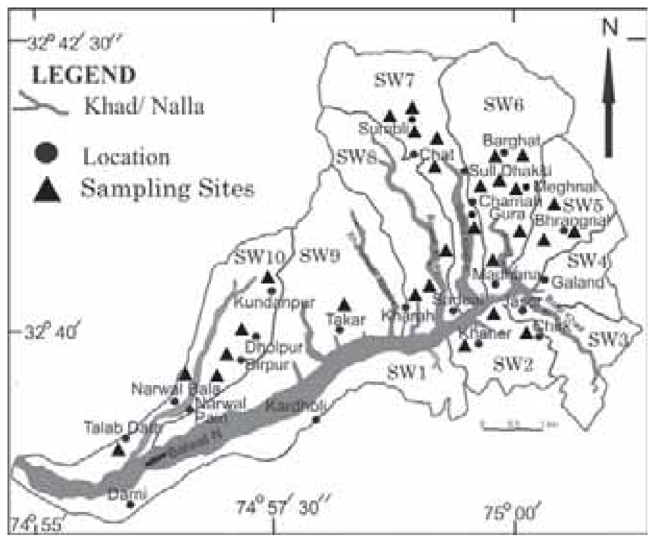

Fig. 1. Soil sampling site map of the study area

The soil samples have been sieved and analysed in the laboratory to determine texture classes, according to USDA system. The soils of the study area are predominated by textural class sandy loam (loamy soil) comprising about 72%, followed by 17% of loamy sand (sandy soil), 7% of sandy clay loam (loamy soil) and 3% of loam (loamy soil) (Table 1). Important physical characteristics of soil are its texture and structure which affect capacity of absorption and retention of water and hence alter the growth rate of natural vegetation. The texture of the soil depends upon the proportion of sand, silt and clay particles. The combination of sand, silt and clay define soil textural class, bulk density and the water holding capacity. The physical parameters of the soil samples are given in (Table 1).

The major cultural features (forests, open scrub, river and settlements) from Survey of India

Table 1. Geological settings in Shiwalik foothills

Sirowal belt	Fine sediments (sand, silt, clay)	Recent to Sub-recent
Kandi belt	Coarse sediments (boulders, cobbles, pebbles, sand, silt, clay)	Recent to Sub-recent
Upper Siwalik	Boulder beds, sandstone, mudstone	Pleistocene

toposheets were delineated on the base map using Corel-Draw Version-12 environment in the PC. Tie points of the toposheets were marked. During the fieldwork, ground truth data were collected for different landuses of the study area. In addition to the GPS readings, the observation sites were marked on the toposheets. For the ground truth sites at various locations, information with reference to forest type and crop type was noted in the performa of ground truth data collection. The surrounding landuses were also sketched for each ground truth site.

RESULTS AND DISCUSSION

Geological setting

The Siwalik group of rocks is divided into lower, middle- and upper subgroups. The upper Siwalik subgroup in Jammu has been classified into Purmandal Sandstone, Nagrota formation and boulder conglomerate by Ranga Rao *et al.* (1988) (Fig. 2). The boulder conglomerate formation, the uppermost unit of the upper Siwalik subgroup is the unconsolidated deposit comprising of discontinuous beds of conglomerates intercalated with friable, grey / buff sandstones and orange / brown mudstones and clays. The local geological setting in chronological order given by Pitale (1967) is presented in Table 1.

The Boulder Conglomerate of Upper Siwalik and recent gravels are similar in composition. The piedmont plain formed by the coalescence of alluvial fans, gently slopes towards south and subsequently merges imperceptibly into flat terrain. Soil erosion has adversely affected the landscape patterns because of semi-arid to arid climate and non-uniform rainfall.

Soil texture

The average sand fraction in the soils of the study area is 65.8%. The minimum sand fraction is 50.60% in the SW6 with moderately fine texture and falls in the sandy clay loam textural class. The common name for this type of soil as per USDA system is loamy soil. The maximum sand fraction (80.22%) showing coarse texture in SW10 is referred to loamy sand textural class and the common name of such soils is sandy soil (Gupta et al., 2010). The dominance of coarse sand fraction may be due to deposition in the watershed by the khad located adjacent to the sample site.

The average silt fraction in the study area is 22.6%. The minimum silt fraction is 10.63% in the SW10, which falls in the loamy sand textural class. This soil type shows coarse texture and the common name for it as per USDA system is sandy soil. The maximum silt fraction showing medium texture is 34.92% in SW7 with loam textural class with the common name as loamy soil.

The average clay in the soils of study area is 11.59%. The minimum clay fraction with moderately coarse texture is 1.98% in the SW9, which falls in the sandy loam textural class. The common name given to this type of soil as per USDA system is loamy soil. The maximum clay fraction with moderately fine texture is 23.05% in SW7 which is categorized as sandy clay loam textural class and the common name given to the soil is loamy soil.

The present study reveals that the samples collected for mechanical analysis (Table 2) have dominant sand fraction ranging from 50.60% to 80.22%, with an average of 65.8%. The silt fraction ranges between 10.63% and 34.92% with an average of 22.6%. These sediments are classified as sandy loam, loamy sand, sandy clay loam and loam. The higher fraction of sand in the area accounts for less cohesion and subsequently increases the rate of infiltration in the soils which help in groundwater recharge.

The mechanical analysis of the soils supports the field examination with regard the texture. The area mostly comprises of loose sandy loam type of soil comprising boulders and gravel with sand and ferruginous clay matrix. On the whole, the soils of the study area are dominated by the sandy loam to loamy sand texture. It has been observed that texture determines the pore size and influences the tendency of soil to form aggregates. Sand contains relatively large size pores favourable to high rates of infiltration, but sand grains largely remain separated without the tendency to cohere. Medium and fine textured soils have much smaller size pores, but tend to aggregate into bigger sized lumps with micropores between the soil aggregates. The soils in this study generally show low clay content and higher amount of coarse and fine sand. The higher percentage of sand leads to higher infiltration rate, contributing moderate rapid permeability in the area. The presence of clay in the lower part of the soil clearly indicate that these have been formed due to weathering of sandstone *in-situ* followed by production of large coarse fraction.

Bulk Density

The values of bulk density and dry density were obtained with the help of density apparatus. The bulk density ranges from 1.41 g cm^{-3} in SW7 to 1.68 g cm^{-3} in SW6 with an average value of 1.52 g cm^{-3} (Table 2). The high values of the BD indicate that the infiltration rate in the SW6 (Madana village) is moderately high (0.65cm / min) due to low water holding capacity (27.11%) and high porosity (42.42%).

Water holding capacity

The soil texture greatly influences the water holding capacity, porosity, permeability and their by affecting the rate of infiltration. The minimum water holding capacity in the area is 17.20% with infiltration rate 1.18cm / min in the SW10 (Table 1). The soil of SW10 is composed of 80.22% of sand with coarse texture. The maximum water holding capacity is 45.14% with infiltration rate of 0.12cm / min in SW5. The SW5 has moderately coarse texture with sand 53.65% and high content of organic

Table 2. Properties of the soils in the micro-watershed

Sub-watershed	No.	Code	pH (1:2:5)	EC (dS / m)	OC (%)	Ca (meq / 100g soil)	Mg (meq / 100g soil)	Na(meq / 100g soil)	K (meq / 100g soil)
SW2	1	Khaner	6.13	0.36	0.18	2.69	1.05	0.10	0.09
	2	Chirk O.head tank	6.02	0.38	1.81	1.95	2.32	0.09	0.16
	3	Chirk	5.25	0.53	0.77	3.12	2.87	0.08	0.11
SW5	4	Bhrangnal Pond	7.04	0.35	0.84	6.54	3.19	0.08	0.17
	5	Bhrangnal well	6.34	0.50	0.85	3.19	1.76	0.10	0.10
	6	Bhrangnal	6.72	0.40	0.86	3.06	1.88	0.08	0.16
SW6	7	Meghnal well	6.12	0.47	0.69	2.79	2.04	0.06	0.13
	8	Meghnal khad	6.85	0.33	0.71	4.91	4.12	0.08	0.26
	9	Barghat Pond	6.22	0.43	0.72	3.49	3.21	0.09	0.12
	10	Barghat well	6.05	0.43	1.17	2.18	2.60	0.10	0.18
	11	Sull Dhakki	5.94	0.33	0.82	3.01	1.18	0.11	0.10
	12	Charnah well	6.36	0.33	0.64	2.80	2.78	0.07	0.13
	13	Madana	6.00	0.38	0.40	3.64	1.72	0.09	0.12
SW7	14	Sumbali well / Pond	6.24	0.33	0.57	2.73	1.78	0.07	0.14
	15	Sumbali	6.65	0.48	0.86	2.63	2.83	0.11	0.09
	16	Sumbali well	5.66	0.37	0.74	2.18	2.60	0.10	0.18
	17	Chat	5.78	0.40	0.96	2.79	2.04	0.06	0.13
	18	GuraSumbali	6.18	0.55	0.58	4.08	1.93	0.10	0.13
	19	Gura Pond	6.14	0.40	0.62	2.43	3.11	0.10	0.10
SW8	20	Kharahwali khad	6.36	0.43	0.60	2.80	2.78	0.07	0.13
	21	Kharah dugwell	6.62	0.45	1.08	4.38	3.68	0.07	0.23
	22	Bawli kharah	6.84	0.43	0.62	2.95	3.17	0.12	0.10
SW9	23	Takkar crusher	7.12	0.48	0.55	4.91	4.12	0.08	0.26
SW10	24	Narwal Birpur	7.32	0.35	0.58	3.06	2.15	0.08	0.16
	25	Dholpur	6.55	0.33	0.36	3.19	1.76	0.10	0.10
	26	Kundanpur pirbaba	5.45	0.33	1.24	6.54	3.19	0.08	0.17
	27	Narwal bala	6.10	0.41	0.99	2.49	1.82	0.05	0.12
	28	Narwal pain	7.28	0.33	0.44	2.18	2.60	0.10	0.18
	29	Datatalab orchard	6.35	0.31	0.69	5.84	2.85	0.07	0.15

carbon (0.85%). The average water holding capacity is 32.52% and average infiltration rate is 0.54cm / min. The observations in this study clearly indicate that as the water holding capacity increases, the rate of infiltration decreases and vice-versa.

Water-holding capacity is controlled primarily by soil texture and organic matter. The soil structure is important for the movement of water through the soil and to surface erosion. The larger pores allow the soil to take up large amounts of rainwater over a short period of time, and thus the possibility of runoff and surface erosion is reduced and the rate of infiltration is enhanced. On the whole, the average low values of water holding capacity (32.52%) and low average values for organic carbon (0.75%) indicate high rate of infiltration (0.54cm / min). The dominant sandy loam texture and structure of the soil suggest moderately high rates of infiltration in the watershed.

Water holding capacity of the soils studied is dependent on clay content of the soil as is evident from the bivariate Pearsons correlation analysis (r= 0.76*) (Table 2). Water holding capacity is negatively correlated with bulk density and sand content with coefficient values of -0.31 and -0.58, respectively. Infiltration rate of the water in the soil was positively and significantly correlated with the sand content (r=0.87*) and negatively with silt and clay content (r=-0.84* and r=-0.45).

Table 3. Correlations matrix for soil properties

	BD	PS	WHC	CLAY	SILT	SAND	IR
BD	1.000	-0.339	-0.308	-0.298	-0.009	0.159	0.063
PS		1.000	0.505	0.259	0.190	-0.279	-0.257
WHC			1.000	0.760	0.244	-0.576	-0.470
CLAY				1.000	0.177	-0.645	-0.445
SILT					1.000	-0.866	-0.835
SAND						1.000	0.874
IR							1.000

Soil pH

The water present in the soil is a significant determinant of soil aeration and its fertility. Various forms of water are present in soils that exhibit a complex interrelationship. The proportion of exchangeable bases in a soil is obtained by the process of measuring concentration of hydrogen ions. It is assumed that the proportion of other ions which can be held by the clay humus complex depends on the space left by hydrogen ions.

The proportion of free hydrogen ion in the soil solution is measured and stated as pH. Soils possess a pH ranging from 4 to 10, where the former value is for strongly acid soils and the latter value is for alkaline soils that contain free sodium carbonate. The pH value in this study ranges from 5.25 in SW2 to 7.32 in SW10 with an average of 6.33 indicating that these soils are slightly acidic to neutral in nature.

Organic carbon

Organic matter is found in varying amounts in soils and is almost confined near the surface. A wide spectrum of materials makes up the soil organic matter, which ranges from undecomposed plant and animal tissue to humus. Carbon makes up over one-half of the organic matter and carbon content is commonly used to characterize the amount of the organic matter in soils.

The organic carbon in this study ranges from 0.4% in SW6 to 1.81% in SW2 with an average of 0.76%, indicating the moderate organic carbon content. The high carbon content is important for the formation of soil structures which control the particle size and pores of the soil. Higher amount of carbon content in the soil increase its water holding capacity.

Potassium

Potassium is an essential nutrient of soil to attain a better yield. In the study area the potassium content varies considerably from sub-watershed to sub-watershed. The potassium content ranges from 0.09 meq / 100g soil in SW2 and SW7 to 0.26 meq / 100g soil in SW9 and SW6 with an average of 0.15meq / 100g soil indicating moderate potassium content. Most of the soil samples have been collected from the cultivated fields. Overall the region is deficient in potassium content, because unirrigated crops prefer light textured and alkaline soils with low potassium content.

Electrical conductivity

Electrical conductivity (EC) is the ability of a material to transmit (conduct) an electrical current and is expressed in milli Siemens per meter (mS / m) or dS / m. The electrical conductivity of the soil depends on the salinity present in the soil. The electrical conductivity ranges from 0.31dS / m in SW10 to 0.55dS / m in SW7 with an average electrical conductivity of 0.4 dS / m. Soils with water-filled pore spaces that are connected directly with neighbouring soil pores tend to conduct electricity more readily. Soils with high clay content have numerous, small water-filled pores that are quite continuous and usually conduct electricity better than sandier soils. Dry soils are much lower in conductivity than moist soils. The low clay content and the dominant sands in the soils of the area also suggest low electrical conductivity. Higher the EC of the soil lower will be the wheat production. The average moderately low Na (0.85meq / 100g soil) indicates low EC of the soils hence does not affect the wheat production.

Ionic contents

The sodium content ranges from 0.05 meq / 100g soil in SW10 to 0.12 meq / 100g soil in SW8 with an average of 0.085 meq / 100g of soil, which indicates low sodium content in the area. The less salinity in the study area suggested the better soils for the wheat production as higher salinity reduces wheat production and vice-versa. The calcium content ranges from 1.92 meq / 100g soil in SW2 to 6.54 meq / 100g soil in SW5 and SW10 with an average sodium content of 3.39 meq / 100g of soil in the study area. Every plant needs calcium to grow. Calcium plays a very important role in plant growth and nutrition, as well as in cell wall deposition. Calcium helps to maintain chemical balance in the soil, reduces soil salinity, and improves water penetration. Calcium neutralizes cell acids. Calcium is found in many minerals in soil, but is relatively insoluble in this state. Magnesium is abundant in the earth's crust. It is found in a wide variety of minerals. Magnesium becomes available to plants as these minerals weather or break down. The majority of the soils in study area have low levels of Mg. The magnesium content ranges from 1.05 meq / 100g soil in SW2 to 4.12 meq / 100g soil in SW6 and SW9 with an average magnesium content of 2.52 meq / 100g of soil. Magnesium is held on the surface of clay and organic matter particles. Although this exchangeable form of Mg is available to plants, this nutrient will not readily leach from soils. The low potassium and sodium content in the soil is because of the mineralogy of the parent rock which is dominated by the silicate minerals and absence of feldspar minerals.

Landuse/landcover

The landuse / landcover of the area is shown in (Table 4 and Fig. 2). Out of the total area of the

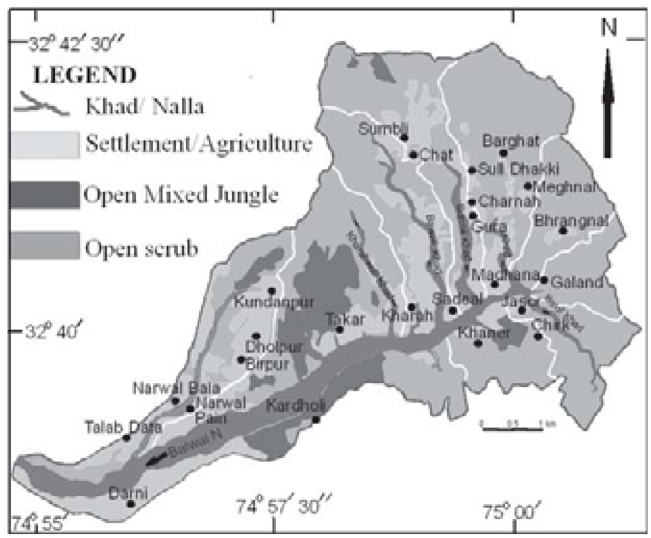

Fig. 2. Landuse / landcover map of the study area

Table 4. Quantitative landuse and land cover of the study area

Sub-watershed	Total area (km^2)	Settlement & Agriculture(km^2)	Open mixed Jungle(km^2)	Open scrub (km^2)	Khads (km^2)
SW1	2.95	0.89 (30%)	0.29 (10%)	0.44 (15%)	1.33 (45%)
SW2	1.85	0.06 (3%)	0.09 (5%)	1.3 (70%)	0.4 (22%)
SW3	1.95	0	0	1.85 (95%)	0.1 (5%)
SW4	1.43	0	0	1.33 (93%)	0.1 (7%)
SW5	2.2	0.02 (1%)	0	1.95 (89%)	0.23 (10%)
SW6	4.67	1.02 (22%)	0	2.56 (55%)	1.09 (23%)
SW7	4.2	1.47 (35%)	0	0.84 (20%)	1.89 (45%)
SW8	3.98	2.4 (60%)	0	1.19 (30%)	0.39 (10%)
SW9	5.87	1.46 (25%)	2.64 (45%)	1.29 (22%)	0.48 (8%)
SW10	4.34	3.25 (75%)	0.34 (8%)	0.43 (10%)	0.32 (7%)
Total	33.44	10.57 (32%)	3.36 (10%)	13.18 (39%)	6.33 (19%)

watershed 39% is covered by open scrub, followed by settlement and agriculture of about 32%. The settlement and agriculture are so mixed that it is difficult to separate these cultural features because of the rural conditions of the study area that is why both these cultural features have not been separated so far. The area covered by khads (stream lets) is about 19% of the total area of the watershed, indicating the intensity of the surface runoff and soil erosion due to sheet flooding in the area is very high particularly during the monsoon season. Only 13% of the study area is covered by open mixed jungle (dense forests) indicating that the forests are degrading rapidly due to the daily requirements for timber, firewood and fodder for cattle to the growing population in the study area.

CONCLUSION

As the study area shows undulating topography and steep slopes, construction of rainwater harvesting structures are needed for effective water management. The average pH (6.33) indicates that the soils in the study area are slightly acidic in nature. The moderate organic carbon (average 0.76%) help in formation of soil structures which controls the porosity and also help the rainwater to percolate in the soil, for groundwater recharging.

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Status of tribal agriculture in Odisha perspective

BHUPENDRA SINGH NAIK[1], PRAVEEN JAKHAR and M. MADHU

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ABSTRACT

Shifting cultivation is most prevalent in Eastern and North Eastern Regions of India. Odisha alone accounts for the largest area of 1.6 m ha (36.6%) under shifting cultivation in India. However, there are wide variations in the areas reported under shifting cultivation in Odisha by the different agencies. This system of agriculture is extensively practiced by tribals in Odisha and about 2 lakh tribal families from more than 20 tribal communities are engaged in this practice. Shifting cultivation is locally known as the *podu chasa* but tribals in different parts of Odisha have their own names for this practice. The tribals consider it as a means of livelihood and a way of life mixed with celebration of many festivals. Though the evil effects of shifting cultivation are devastating and responsible for the degradation of the environment and ecology, it is still practiced by the tribals of Odisha. Due to growing tribal population, the earlier practice of 15-20 years *Podu* cycle has been reduced now to 2-3 years, thereby resulting in large scale soil erosion and land degradation. The characteristics, distribution and extent of area under shifting cultivation, and tribal perception and impact of shifting cultivation practice in Odisha are discussed. Promising initiatives to curb shifting cultivation are indicated.

Key words: Shifting cultivation; *Podu*; Tribes; Eastern Ghats; Soil erosion

INTRODUCTION

The Shifting cultivation is considered to be the most ancient system of tribal agriculture dating back to the lower Neolithic period. Its origin has been traced back as old as between 13000 and 30000 BC (Goswami *et al*., 2009). It is also known as "Field Forest Rotation" or slash and burn agriculture It is not only prevalent in Asia and Africa, but also practiced by people of Latin American and European countries. In England it is called "Swidden" and in Africa it is called "Zande" system(Goswami *et al*.,2009).In India, the practice of shifting cultivation is prevalent in Eastern and North Eastern Regions. About 85% of the total cultivation in northeast India is by shifting cultivation(Singh & Singh,1992). About 5.0 million tribal families in India are practicing this system of agriculture on 4.37 million hectares of land covering 11 states (Sahu *et al*., 2005).

In the present paper an effort has been made to assess the characteristics, distribution, extent of shifting cultivation in Odisha. In addition, the deteriorating effects due to shifting cultivation and promising initiatives for controlling it have also been discussed.

Shifting cultivation in Odisha

Odisha is situated in the eastern part of India having geographical area of 15.57 m ha comprising 4.75 % geographical area of India. It lies in the tropical zone between lat 17º 472 and 22º342 N and long 81º 222 and 87º 292 E and is blessed with varied bio-diversities and rich natural resources. The total population of the state is 36.7 million of which 22.12 % is tribal population (Census 2001) constituting 62 tribal communities. Agriculture is the major source of livelihood in Odisha. Shifting cultivation is prevalent among tribals.

The common term used for shifting cultivation in Odisha is called 'Podu' derived from Oriya term 'Poda' means burning. It is also called *Podu chasa* means doing cultivation by burning.

[1] Scientist-SS (SWC Engg), email: naikbsn74@rediffmail.com
Central Soil and Water Conservation Research and Training Institute, Research Centre, Sunabeda, Koraput Dist (Odisha)

Characteristics of shifting cultivation and its distribution

The characteristics of shifting cultivation in Odisha can be broadly divided according to the local topography, climate, population density, land use and cropping pattern, community involved in shifting cultivation and ownership of the land. The topography and climatic conditions largely influence the land uses and cropping pattern. Besides these the social structures of the community and population density also largely govern the method of shifting cultivation. Based on topography, climate and population density of shifting cultivation area, Odisha is divided in to three zones namely North Zone, South Zone and Central Zone (Table 1).

Central Zone consisting of 36 Blocks under shifting cultivation is largely mountainous with

Table 1. Distribution and characteristics of shifting cultivation in Odisha

Zone	Sl No	Name of the Blocks	Population per km^2	Relief in meter	Rainfall (mm)	Slope %	Accessibility
Central Zone	1	G.Udayagiri	251-450	600-900	1250-1500	60	Accessible
	2	Rayagada(G)	251-450	100-300	1500-1700	30-60	Accessible
	3	Bandhugao	101-250	300-600	1000	2-8	Inaccessible
	4	Bisum Cuttack	101-250	300-600	1000-1250	30-60	Accessible
	5	Dasmantapur	101-250	600-900	1250-1500	2-8	Less accessible
	6	Kolnara	101-250	100-300	1250-1500	2-8	Accessible
	7	Laxmipur	101-250	900-1200	1250-1500	15-30	Accessible
	8	Rayagada(Koraput)	101-250	100-300	1000-1250	30-60	Accessible
	9	Th Rampur	101-250	600-900	1750-2000	15-30	Accessible
	10	Tikabali	101-250	600-900	1000-1250	15-30	Accessible
	11	Baliguda	51-100	300-600	1000-1250	15-30	Accessible
	12	Chakapada	51-100	300-600	1000-1250	30-60	Accessible
	13	Chandrapur	51-100	100-300	1000-1250	8-15	Accessible
	14	Gudari	51-100	100-300	1000	2-8	Accessible
	15	Gumma	51-100	300-600	1250-1500	30-60	Accessible
	16	Gunupur	51-100	100-300	1000-1250	2-8	Accessible
	17	K.singpur	51-100	300-600	1000-1250	2-8	Accessible
	18	Kasipur	51-100	600-900	1250-1500	30-60	Accessible
	19	Khajudipada	51-100	300-600	1000	2-8	Accessible
	20	Langigadh	51-100	300-600	1000-1250	30-60	Accessible
	21	Muniguda	51-100	300-600	1000-1250	2-8	Accessible
	22	Nuagaon	51-100	300-600	1000-1250	15-30	Accessible
	23	Pottangi	51-100	900-1200	1250-1500	15.-30	Accessible
	24	Ramnaguda	51-100	100-300	1000-1250	15-30	Accessible
	25	Raikia	51-100	600-900	1000-1250	2-8	Less accessible
	26	Semiliguda	51-100	600-900	1250-1500	8-15	Accessible
	27	Daringbadi	26-50	600-900	1000-1250	15-30	Accessible
	28	Mohana	26-50	300-600	1000-1250	15-30	Accessible
	29	Nuaguda	26-50	300-600	1000-1250	30-60	Accessible
	30	Phiringia	26-50	600-900	1000-1250	15-30	Accessible
	31	Phulbani	26-50	300-600	1000	15-30	Accessible
	32	Narayanpatna	26-50	300-600	1000	30-60	Inaccessible
	33	R.Udaygiri	26-50	600-900	1250-1500	30-60	Accessible
	34	Kothgarh	11-25	300-600	1000-1250	30-60	Accessible
	35	Tumudi bandh	11-25	300-600	1000-1250	30-60	Accessible
	36	Padampur	51-100	100-300	1000	2-8	Accessible

Zone	Sl No	Name of the Blocks	Population per km^2	Relief in meter	Rainfall (mm)	Slope %	Accessibility
South Zone	1	Khair put	26-50	300-600	1500-1750	15-30	Accessible
	2	Korkunda	26-50	100-300	1500-1750	2-8	Accessible
	3	Kalimela	11-25	100-300	1000-1250	2-8	Accessible
	4	Kudumulguma	11-25	300-600	1250-1500	15-30	Inaccessible
	5	Malkanigiri	11-25	100-300	1500-1750	2-8	Accessible
	6	Podia	11-25	100	1000-1250	2-8	Accessible
North Zone	1	Harichandanpur	101-250	300-600	1000-1250	2-8	Accessible
	2	Barkote	51-100	100-300	1250-1500	1-2	Accessible
	3	Lahunipada	51-100	100-300	1250-1500	1-2	Accessible
	4	Palalahara	51-100	100-300	1250-1500	1-2	Accessible
	5	Telkoi	51-100	100-300	1000-1250	2-8	Less accessible
	6	Bansapal	26-50	600-900	1250-1500	15-30	Less accessible
	7	Koida	26-50	300-600	1250-1500	1-2	Accessible

Source: District statistical hand books of respective districts of Odisha (1995)

Eastern Ghats. Eastern Ghats continues in some parts of Southern Zone followed by large area of plateau. In Central Zone, the topographic condition varies from place to place and in most cases altitude varies within the range of 300-900 meters. North Zone consists of 7 Blocks with less topographic diversity and the areas lie between 300- 900 meters of altitude. The southern zone consists of 6 Blocks and it has two separate areas; mountainous near the boarder of Andhra Pradesh and the larger area of plateau near the boarder of Chhattisgarh, where the altitude ranges from 100-300 meters.

In the Central Zone, the slope variation is between 2 and 60 %, but large areas fall within the range of 30-60 %. In both the Northern and the Southern Zones, the average slope varies between 1 and 8%.

The Block wise detailed information about relief, rainfall, slope, accessibility and population density is shown in table 1.

Ragi, jowar, small millets and pulses i.e. pigeon pea (*Kandul*) are the dominant crops grown in shifting cultivated areas. It is observed from the land use study at community level that the whole area under shifting cultivation in Odisha can be divided in to two regions namely paddy - oilseed zone of the north and millet - pulses zone of the central and southern parts. It seems that distribution of rainfall largely determines the cropping pattern. Beside rainfall, the condition of slope of the land is also responsible for selection of the crop. By and large, it is observed that the area receiving more than 1400mm rainfall is suitable for hilly paddy. On gently sloping area, due to more retention of rain water, paddy can be cultivated with less rainfall. This seems to be the single most reason for preferring millet crops in the central and southern zones of shifting cultivation area.

Ownership right of shifting cultivated fields among tribes

The type of ownership for shifting cultivated field varies among the tribes from individual ownership to communal ownership which is governed by tribal customary rules. Among the Juang and Paudi Bhuiyan of Keonjhar district, the land under shifting cultivation is the communal property owned by all the villagers in common. Every year in the month of *Magha* (January-February) the village headman and the priest select the land for cultivation. Generally the patch which has completed its rotation cycle and is sufficiently covered with trees and bushes is considered suitable to be cleared for shifting cultivation. After the patch is selected, the headman demarcates the boundary lines by putting mark on trees by axe and the land is sub-divided into several plots which are allotted to the households (Mohapatra & Devi, 1973). The ownership of land after allotment is transferred to the head of the household for a period of 2 to 3 years till he cultivates it actively. In Koraput and Ganjam areas the communal ownership of the village over *Podu* land is completely absent. Each household owns a number of sites on hill slopes and uses these in rotation. In course of time, Podu land has become private property which can be owned and inherited by customary right. There is no legal sanction behind it. A Bonda tribal man even sells his plots under shifting cultivation to another and mortgages it whenever he is in need (Mohapatra and Devi, 1973). Among the Koya, the unreserved forest land is treated as private property and is also inherited by the legal heirs.

Extent of shifting cultivation in Odisha

The problem of shifting cultivation is most acute in Odisha than any other state in the country. Odisha alone accounts for the largest area of 1.6 m ha (36.6%) under shifting cultivation in India and about 2 lakh tribal families are engaged in such practice. It has been estimated that about 5298 sq km area annually is under this primitive agriculture practice. The areas affected by *Podu chasa* was about 776 sq km approximately prior to 1936. It became nearly 31079 sq km in 1948 after annexation of princely states. In the pre-plan periods, attempts were made to make an estimate of the area under shifting cultivation in the State. Mooney (1951) had made estimation about the area under shifting cultivation as 32681.2 sq.kms or about one-fifth of the total land surface in the state. About one million tribal people in Odisha depend upon this type of cultivation for their living (Mohapatra and Devi, 1973). The areas under shifting cultivation in Odisha available from different sources are given in Table 2.

Lenka (2001) stated that 184018.46 ha (1.18%) is under shifting cultivation in Odisha. Shifting cultivation is prevalent in Sambalpur, Keonjhar,Koraput, Phulbani, Ganjam, Kalahandi and other southern and western districts of Odisha, covering 119 blocks. The district wise details of area under shifting cultivation is given below in table 5.

Table 2. Area under shifting cultivation in Odisha from various sources

Source	Year	Population	Area affected	
		Size	Sq.km	Hectares
H.F. Mooney	1951	9,35,700	32681.2	32,68,120
Forest enquiry committee report	1959	9,27,900	33074	3307400
ICAR	1958	10,00,000	8000.0	8,00,000
Dhebor Comm	1960-61	9,35,700	8333.35	8,33,335
French Inst. Pondichery & ICAR	1967	7,06,412	30233.0	30,23,358
FAO/UNFPA	1980	7,06,400	26490.0	26,49,000
Task Force	1983	-	26490.0	26,49,000
ERTS.-IImagery	1984	-	9200.92	920092.30

Source : Odisha Review (2006)

According to National Remote Sensing Agency (2004), the total area under shifting cultivation in Odisha is 1177.28 sq km. The district wise details are given in Table 3.

Table 3. District wise area under shifting cultivation (abdonded jhum and current Jhum)

District	Shifting cultivation area (sq km)		Total area under shifting cultivation (sq km)
	Abdoned Jhum	Current Jhum	
Debgarh	3.93	0	3.93
Gajapati	27.01	180.31	207.32
Ganjam	19.91	0	19.91
Jharsuguda	0.05	0	0.05
Kalahandi	94.82	50.70	145.52
Keonjhar	18.75	1.59	20.34
Koraput	16.81	26.22	43.03
Malkangiri	26.88	25.62	52.5
Nayagarh	21.33	12.20	33.53
Phulbani	306.03	304	610.03
Rayagada	2.40	35.24	37.64
Sambalpur	3.10	0	3.1
Sundargarh	0	0.38	0.38
Total	541.02	636.26	1177.28

Source: Waste Land Atlas of India (2003)

The tribes of Odisha involved in shifting cultivation

This practice is followed by more than 20 tribal communities in Odisha. The major tribal communities are *Paudi Bhuiyan*, *Buniya,Jatapa*, *Kamar*, *Juanga*, *Kondha*, *Kutia Kondha*, *Dongaria Kondha*, *Saura,Lanjia Saura*, *Paraja*, *Godaba*, *Koya*, *Didayi*, *Bonda*, *Peranga* and *Erenga Kolha* (Dash,2006).Many festivals and other such rituals revolve around the *Podu* fields, because the tribal view *Podu* cultivation not just as a means of their livelihood, but as a way of life. Different tribes involved in shifting cultivation in the different areas of the state are given in table 4.

Table 4. Tribes practicing shifting cultivation in different areas of the state

Tribe	District (undivided)	Area
Bonda	Koraput	Khairput area of Malkangiri Sub-Division
Didayi	-do-	Kudumulgumma area of Malkangiri Sub-division
Koya	do-	Malkangiri sub-Division
Gadaba	-do-	Similiguda & Pottangi area of Koraput Sub-Division
Paroja	-do-	Dasamantapur area of Koraput Sub-division
Lanjia Soura	-do-	Puttasingi area of Gunupur Sub-Division
	Ganjam	Parlakhemundi Sub-division
(a) Kondh	Koraput	Koraput Sub- Division, Rayagada Sub-division
	Phulbani	Kandhamal Subdivision
	Kalahandi	Th. Rampur and Lanjigarh of Kalahandi Sub-division
	Sambalpur	Bamara area of Deogarh Sub-Division, Rairakhol Sub-Division
(b)Kutia Kondh	Koraput	Gudari, Ramanguda Muniguda, Chandrapurarea of Gunupur Sub-Division.
	Phulbani	Balliguda Sub-Division
(c)Dongria Kondh	Koraput	Bisamcuttack area of Gunupur Sub-Division.
Juang	Keonjhar	Telkoi, Harichandrapur area of Keonjhar Subdivision
Paudi Bhuiyan	Keonjhar	Telkoi, Banspal area of Keonjhar Sub-division
	Sundargarh	Bonai Sub-division
	Dhenkanal	Pallahara Sub- Division
	Sambalpur	Bamara area of Deogarh sub- Division
Erenga Kolha	Sundargarh	Bonai Sub- division
Parenga	Koraput	Pottangi area of Koraput Sub-Division

Source: Odisha Review (2006)

Local tribal terms for shifting cultivation

Different tribes of Odisha practicing *Podu chasa* (shifting cultivation) have different names for this kind of subsistence activity. These are usually expressed by the names given to their swiddens among different categories of land under cultivation. The Juang of Keonjhar call it Toila chasa and their brother tribe, the Paudi Bhuiyan identify it by Biringa or Kaman, Bagada or Baru is the term used by the Saora of Ganjam to distinguish their swiddens. The Dongria Kondh of Rayagada district calls it as "Haru" and the Desia Kondh of Rairakhol and Bamra sub-division call it as 'Rama'. The Kondh of Kalahandi district use different term, '*Dongar Chasa'* and livang or Kunda Chasa is the term prevalent among the Bonda of Malkangiri district. Shifting cultivation practiced by the Koya of Malkangiri district in the foot hills is called Lanka podesanad.

*Practice of shifting cultivation (*Podu chasa*) by tribal*

Podu cultivation is generally done on the hills. In the first year of *Podu* cultivation, tribals sow *Kandul* (variety of pigeon pea) in the field. Sowing is done by broadcasting the seeds at pre-monsoon time. The tribals ensure adequate protection of their shifting cultivated field. The yield differs from area to area depending on local climatic factors. After harvest, the land is left fallow. During the pre-monsoon, *Suan* (a variety of rice), *Kangu* (a variety of maize) and ginger are sown. Generally, *Haldi* is sown with *Kangu* and *Suan*: *Haldi* forms the underground crop having economic value, and *Kangu* and *suan* form the overland crops for consumption. At many places ginger is raised as the pure crop. At maturity, harvesting of overland crops is followed by harvesting of underground crop. Generally, after the third year, the tribals abandon this land and shift to new land. On the abandoned land, natural regeneration starts from the available root stocks and seed bank. Bamboo comes up naturally; and *Kendu*, *Mahua*, *Terminalia* along with certain other climbers also regenerate. Generally, this land is not cultivated for the next 20-30 years. This period is called Podu cycle. During this period, tribals use this land to collect root suckers which are used as eatables. *Mahua* and *Eleocarpus* (Salpa) trees are used for the preparation of liquor for their consumption. Due to demographic pressure, this podu cycle has now drastically reduced to 2-3 years in Odisha.

Deteriorating effects shifting cultivation

Shifting cultivation causes loss of flora and fauna which includes precious species of tree plants, shrubs, medicinal plants and minor forest products. With reduction in its cycle from 20–30 years to 2–3 years, the land under shifting cultivation looses its nutrients and the top soil. Frequent shifting from one land to the other also affects the ecology of the region. During the last fifty years, the forest cover of Odisha has been drastically reduced. For instance, the forest area of Odisha in 1962 was about 65868.9 sq. km. which was reduced to 57184 sq.km in 1997. In the tribal districts of Odisha, forest area of 25760 sq. km. in 1993 was reduced to 25424 sq. km. in 1997(Forest Survey of India, 1997). The districts found badly affected are Koraput, Keonjhar, Phulbani and Ganjam. Due to this unscientific practice, the soil quality becomes poor and infertile with low water holding capacity. The land & soil characteristics and change in soil properties under this practice are given in tables 5 & 6.

The problem of soil erosion due to shifting cultivation is very serious in Odisha. The quantum of soil loss varies from 84 to 170 t/ha/ year in bare fallow. It is estimated that, on an average 7-10 t/ ha/ year surface soil is lost along with plant nutrients due to such practice (Table 7).

Table 7. Loss of soil and nutrients due to erosion

Particulars	Loss (q/ha)	Loss in Rs.(approx)
Top Surface soil	70-100	-
O.C.	1.0	1000
N	0.12	300
P	0.05	125
K	0.32	320
Other nutrient	0.45	500

Apart from soil and nutrient losses, major adverse effects due to shifting cultivation can be summarized as follows:

- Loss of productivity of land, reduction in family income and increase in poverty.
- Denudation of existing forest and its degradation.
- Wild animals become shelterless and enter in to human habitations.

Table 5. Land and soil characteristics observed under shifting cultivation in Odisha

Land	Soil
Climate: Tropical	Depth class: Shallow
Slope : Steep	Parent material : Colluviums of laterites, Khondalite, Granite, Kniss
Drainage: Excessive	Mineralogy: Ferratic Silicaceous
Surface stoniness:Moderate to strong	Particle size : Sandy skeletal
Relief : Undulating	Temp-regime : Isohyperthermic
	Soil reaction (pH): Acidic Ground water : >5 m
	Surface texture: Sandy Erosion : Very severe
	Water holding capacity: Low
	Class of soil : Typical Haphustalfs, Rhodustalfs, Kandic and Rhodic paleustalfs, Aeric Haphustalfs.

Source: "Soils of Odisha for optimizing land use" by NBSS & LUP (ICAR), Nagpur

Table 6. Change of soil properties due to shifting cultivation

Soil properties	Before burning	After burning	End of crop cycle
pH	5.1	5.5	4.2
OC (5%)	0.13	0.25	0.05
Available P	3.3	5.5	1.2
Available K	210	570	40
Exchangeable ca(mc/100g)	7.15	9.46	2.82

Source : Waste land management by V.V. Dhrubanarayan(1992)

- Drying up springs and small water sources below the hills.
- Causes heavy flood in the rivers.
- Severe soil erosion and loss of top fertile soil.
- Heavy siltation in the nallas, river and reservoirs.
- Loss of reservoir capacity as well as production potential of hydroelectric project.
- Causes water/moisture scarcity for plants, animals and human being.
- Ecology is disturbed permanently and can not be restored.

Initiatives to curb shifting cultivation

It is important to restore ecological balance in the hill areas and to improve socio-economic conditions of tribal families practicing shifting cultivation. The following initiatives and efforts can be made for controlling shifting cultivation and keeping the tribal people away from such unscientific practice.

1. Providing better employment opportunities and income generation on a regular basis through proper utilization of the land resources, i.e. by equitable distribution of waste land among the tribals. But, the various schemes of the Government, under the tribal plan, will have to pump in sufficient resources for proper reclamation and development of the wasteland through agro-forestry and silvi-pasture practices.
2. By encouraging cooperative efforts for carrying out forest-based activities, i.e. basket making, rope making, cane furniture processing of minor forest produce, honey collection, etc. have to be made commercially viable by providing proper marketing facilities. This will not only discourage tribals from practicing shifting cultivation but will also help them monetarily.
3. Village Forest Committees can be formed and it can work for the protection and development of the degraded forests. These committees by providing suitable incentives to the tribals, after the time of harvest can divert some of the tribals away from the shifting cultivation. Generating employment opportunities during the lean season of forestry operations will also prevent tribals from shifting to other areas. Employing the tribals for collection of *kendu* leaves and *sal* seeds and also involving the tribals in the various rural employment schemes is also the need of the hour.
4. By conducting mass awareness programme and educating tribal men, women and children about the menace of shifting cultivation. The services of various non-Governmental organizations and voluntary agencies, besides the regular Government machinery, are required for undertaking such work on sustainable basis.
5. Implementation of various land development programmes for tribals i.e land/jhola land development, development of irrigation, agriculture development, raising of orchards and horticulture plantations, raising of plantation crops, forest plantation, pasture development, animal husbandry, development of pisiculture and soil conservation measures.
6. Creation of subsidiary occupation like fishery, sericulture, poultry, piggery etc. to generate additional income and employment.
7. Creation of food surplus will reduce the area under shifting cultivation.

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ICT intervention and application in technology-led agricultural development

V.K. BHARTI[1], HANS RAJ[2], MEETALI[3], DEEPSHIKHA[4] and SURAJ BHAN[5]

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ABSTRACT

Learning is the cognitive process of acquiring knowledge or skill through study, experience or teaching while Information Communication Technologies (ICT) mediated learning is a process used to acquire data, information, skill or knowledge that enables learning in a virtual world where technology merges with human creativity to accelerate and leverage the rapid development and application of deep knowledge. ICT based learning covers a wide set of applications and process such as web-based learning, computer mediated learning, virtual classrooms and digital collaboration. This includes the delivery of content via internet/intranet (LAN/WAN), audio and videotapes, satellite broadcast, interactive TV, PDA, mobile phone, CD-ROM and other available technologies. ICT mediated learning provides utilities for achieving goal of education for all, and in turn acts as an enabler in reducing the digital divide, plummeting poverty and promoting socio-economic empowerment. But, the integration of ICT in education needs considerable investment in time and resources. The usefulness of ICT in extension management has also been felt in the recent past to speed up the process of technology dissemination in agriculture to harness the full potential of latest technologies being developed by National Agricultural Research System. Krishi Vigyan Kendras (KVKs) in particular could play a vital role in this sector owing to their network in every corner of the country. The experiences of Digital Green in documentation of best practices through community participatory video clips provide scope for interactive and horizontal learning. Strategic collaboration of partners is to be encouraged for ICT based knowledge modeling in view of local knowledge base, local needs and research-based outputs as well as socio-economic and cultural factors, besides content and capacity building of the partners. The mKrishi stressed upon the potential of mobile phones for information dissemination in the rural areas which has remained largely unexplored despite the penetration of mobiles phones in these areas mainly due to diversity in language, inability to localize and personalize services in order to address individual needs. IFFCO explored the possibility of tying up with telecom services providers to provide such infrastructure facilities in the villages making co-operative societies a vehicle for economic development of the rural areas. Telecommunications is a fast growing arena to transform Indian rural landscape. In the recent years, it has demonstrated its potential to play a vital role in contributing the empowerment of people living in Indian villages.

Keywords: Digital Green, ICT, mKrishi, KVKs, PDA

INTRODUCTION

Communication is the ability to ensure that an idea, thought, memory, historical facts or other forms of information is conveyed between any two entities. In the agriculture sector, the need for communication is to convey the knowledge and information that will contribute to alleviating poverty, changing livelihoods and having a positive effect on national economics. The lack of awareness of its existence often leads to duplication of efforts and wastage of resources.

[1] Chief Production Officer, [2] Information System Officer, Directorate of Knowledge Management in Agriculture, ICAR, KAB-I, New Delhi-110012; [3,4] Scholars, Electronics & Communication Engineering
[5] President, Soil Conservation Society of India, New Delhi-110012

Technology is a powerful tool that can narrow the gap between those countries that are benefiting from globalisation and those in which globalisation has led to heightened marginalisation. The use, application and transfer of modern technologies are central to sustainable development. The global revolution caused by the advancement and deployment of Information communication technology demands the full involvement of the entire agricultural community if the technology is to be effective. Information communication technology, which continues to revolutionise all facets of life in the world, has opportunities for fostering technological capabilities, and thus enhancing the prospect of economic development.

The Information and Communication Technology (ICT) is playing a key role in agricultural growth and development in the country by providing timely and useful information in a demand-driven mode. As a commitment to deliver cost-effective and production-oriented technologies for the welfare of farming community, the Indian Council of Agricultural Research (ICAR) has adopted innovative approach towards developing ICT based information dissemination system. There are considerable resources of knowledge and information in the ICAR system that can be harnessed for realizing full potential of technological interventions developed so far. Several ICT-driven information delivery mechanisms have been developed for quick, effectual and cost-effective delivery of messages. The e-connectivity of ICAR institutes has been strengthened and around 200 Farm Research Centers have been provided e-linkage for establishing an interactive interface between farmers and scientists. The research journals have been made available in open -access mode for the benefit of students, researchers, farmers and various stakeholders belonging to national and global communities.

Best practices of digital green

The Digital Green was incubated in Microsoft Research India's Technology for Emerging Markets Team in 2006 and has been functioning as independent nonprofit organization. It uses information and communication technology to improve the social-economic and environmental sustainability of small farmer livelihoods. The Digital Green aim to raise the quality of life of people through targeted production and dissemination of agricultural information through a cost-realistic medium of participatory video and mediated dissemination in partnership with local, existing people-based extension systems of civil society organizations and governments. The system comprised of participatory process for content production, locally generated digital video database, human-mediated facilitation for dissemination and training, and structured sequencing to sustainably engage communities. Digital Green has primarily scaled by building on its partnerships with seven non-governmental organizations- PRADAN, BAIF, Samaj Pragati Sahayog, ACCESS, Action for Social Advancement, PRAGATI, and VARRAT - and recently began a partnership with the Government of India's National Rural Livelihood Mission. Digital Green currently reaches over 900 villages and 60000 farmers in the country and is extending to parts of Sub Saharan Africa and South Asia.

The video based approach which has several important advantages to traditional forms of agricultural content. Video creation tends to be faster and less expensive than other types of media, as advanced preparation in "lesson"-planning can minimize post-production editing. Video can compress the time needed to reveal the changes and provides a means of bringing relevant demonstrations into the homes of farmers. Video recordings encourage the coalesce of scattered information into a systematic and comprehensive format with a localized context. The Digital Green database are made by the experts at the grassroots level and expert reviewers ensure the accuracy, clarity, and completeness of the content, and guide the construction of a time- and location-sensitive video-based curriculum.

The principal means of disseminating content from the Digital Green database is shipping DVDs to a village. Villages are provided minimum of a TV and DVD player operated by NGO field staff and managed by local farmers. The night showings usually involve small groups of 10 to 20 farmers willing to come together at a common place within short distance of their homes. These groups serve as informal farmer training schools in the evenings and are complemented by field programs in daylight hours.

The screening of content should follow a sequence that prompts interest and leads to adoption of village. The approaches which worked well when entering a new village include entertaining clippings, such as a women group singing folk songs, to attract an audience; testimonials and interviews with progressive farmers that disclose the concepts and experiences associated with the practices; 3-5 minute highlights of a broad spectrum of the proposed practices; comparative demonstrations with progressive farmers that visibly (perhaps, to a humorous extent) show the benefits of the practices; familiar farmers from the local vicinity (preferably, the same village) attempting the practices; and experts detailing concepts and step-by-step instructions for the practices.

Communities may be approached by organizing a village gathering in a central location to showcase highlights of the services that will be provided. Identify interested farmers through extension staff introducing a particular practice to these farmers on the field. Now, informally screen content of peer farmers and experts demonstrating practices to various areas of a village and introduce small groups of interested farmers with a regular schedule of content screenings and motivate community participation by generating a local competition to learn, adopt and innovate better agricultural processes.

Extension workers use the programming as a tool to disseminate content to a larger audience while maintaining personalized support and encourage farmers to attempt processes on their own and announce their availability to individually visit farmer plots as required.

The emphasis was focused to motivate farmers to adopt relevant new techniques with clarity and completeness, particularly when they observe their peers benefiting from them. The Digital Green database is not intended to be a physically centralized system. Instead, it is designed to work as a decentralized network of hubs and spokes. Each hub is a demonstration village, which is transformed into a center of excellence through the concerted efforts of NGOs and experts and the hubs themselves are "networked" together. The spokes are typically neighboring villages that also need help but which are difficult to reach because of lack in expert resources. Each hub is responsible for expert content production for the local region, content distribution in its local neighborhood, teacher training and interactions with other hubs. Recording hubs in which field extension activities are concentrated provide a sequential stream of new content that can be screened to surrounding hubs and spokes. He said that the hubs-and-spokes model has effectively scaled up the Digital Green system.

The network of partner extension systems and communities has produced over 2,200 short, 8-10 minutes videos which have been found to be 10 times as effective, per dollar spent, converting farmers to better farming practices than traditional approaches to agricultural extension has left a greater impact of technology during the last three years.

Role of ICT in knowledge empowerment of farmers

The Virtual Academy for th Semi-Arid Tropics (VASAT) was initiated in 2002 with a view to leveraging Information and Communication Technologies (ICT) mediated Open and Distance Learning (ODL) methods to reach drought information to a large section of communities in a short period of time. Its objective is to create demand-driven content that can be localized to suit the rural communities and their intermediaries, to convert the scientific know-how to field-level do-how. ICRISAT has started KSI Connect – A Virtual Knowledge Series (http://ksiconnect.icrisat.org) from ICRISAT for the faster and effective technology dissemination. ICRISAT has focused on affordable and light weight technologies while commissioning the platform. ICRISAT has also started e-learning courses on agriculture that includes general information on the crops, cultural management practices, production constraints such as biotic and abiotic stresses, relevant reference material and video clippings on the relevant topics.

RLOs (approach adopted by ICRISAT i.e. RLO technology which is a new paradigm in lifelong learning) are the e-learning resources available freely and openly to anyone who can use, reuse, remix, recycle and redistribute it in restricted or unrestricted manner.

The important characteristics of RLOs include 1) Digitally available online 24/7; 2) Self contained-each learning object can be taken independently; 3) Reusable – a single RLO may be used in multiple contexts for multiple purposes; 4) Searchable easy to found learning material; 5) RLO is tagged with meta data; 6) RLO are small units of learning (5-15 minutes) that do not overload a learner with content; 7) Flexible- easy to update and change; 8) Standardized-adopt the same organizational structure; 9) Can be aggregated learning objects can be grouped into a large collection of content, including traditional course structures; 10) Provide interoperability-blend into Learning Management Systems (WevCT Vista, Moodle); 11) Suited to address a new type of learner- "Net generation learner" adapted to multi tasking and digital technologies; and 12) Enhance student centered learning.

A platform called AgriLORE (www.agrilore.org) was developed to create the learning material in the form of RLOs. AgriLORE portal has also been designed and implemented to have provision for creating profiles for courses, this is anticipated to support open and distance learning. He also presented the way forward for KVKs which include electronic KVK governance platform, knowledge sharing platform for KVKs (KVK Connect - a virtual knowledge series platform; KVK Net - Social Networking Platform and both farmer and KVK personnel profile), Open Access Repositories, KVK Open Courseware Platform and location specific ICT4D models etc.

The Aadarsh Welfare Society (AWS) located in Addakal and functional in 37 villages was associated as a key partner in the use of information to enhance drought preparedness. Hub-and-spokes model has been applied to facilitate the information flow into the study area. The hub is generally a set up with reasonable computing facility and Internet access. This is where the value addition to generic information derived from the networks is carried out and location-specific information is generated. Rural access points are linked to this hub by telephone. Volunteers at the rural access points receive location-specific information from the hub and deliver it to rural families in a variety of ways (blackboards, public speakers etc). The bottom-up approach involved local volunteers collecting information from different sources, such as the nearby markets, government departments and traders.

Most of the information needs of typical rural residents are met by approaching family members, neighbours or friends (who themselves are not well informed in most cases). At a secondary level, the farm input suppliers; local shops and markets act as important and credible sources of information. Technical information on agriculture, available with a range of agencies is not easy to access by most rural families. This compounds the problem of information poverty in particular. As a first step, it is decided to strengthen the access to crop-related information, which is the core of a drought information system.

ICT and remote sensing applications in disaster management in agriculture

With changing climatic conditions, the rural community is facing uncertainty in their livelihoods. People need timely information to combat such situations. Geo-ICT (location based services, spatial decision making and geo computations) and Sensor Network (distributed sensing units pertaining to weather, crop and soil parameters under micro-climatic conditions) are promising real-time information gathering and dissemination technologies towards developing solutions for majority of the agricultural processes on a real-time basis.

'Geo-informatics' has emanated in the form of satellite remote sensing, Geographical Information System (GIS) and Global Positioning System (GPS). These technologies could play a vital role in providing comprehensive information on various natural resources management, monitoring and sustainable development in the new millennium. The science of remote sensing could play a vital role in strengthening the National Extension System to reach out the farmers across the locations in addition to effective planning and execution of the programmes.

Various satellites and sensors on-board provide with numerous possibilities of analyzing the data for disaster prediction and mitigation purposes. Integration of remote sensing with GIS and web technology makes it an extremely powerful tool to identify indicators of potential disasters. Information sharing through Internet reduces data acquisition time and thus providing efficient way to carry out real time disaster predictions (floods, forest fire, tsunami and hurricane etc.). Changing land use and assessment of its impact on the system in general within reasonable time frame and with greater degree of accuracy becomes possible with new technology.

mKRISHI

The potential of mobile phones for information dissemination in the rural areas which has remained largely unexplored despite the penetration of mobiles phones in these areas mainly due to diversity in language, inability to localize and personalize services in order to address individual needs. mKRISHI® platform uses mobile technology to cater the absolute needs of the rural sector. mKRISHI® serves to achieve farmer specific solutions in local language by reaching farmers individually to understand their needs. It is an innovative platform that delivers services to rural communities and connects farmers with a variety of stakeholders, packaging multiple services through communication devices like mobile phones. It can also integrate wireless sensors and script technology with communication devices to provide an enhanced solution. Mobile-to-web console, Automatic Weather Station (AWS) and sensors integration, complex parametric device integration, research content integrations & linkages, enterprise back-end integration, Geographical Information System (GIS) and local language renderers Technology convergence is to be given more emphasize.

Apart from the technological innovation, mKRISHI® has enabled the possibility for information exchange between various stakeholders of the rural economy. Many agri-input companies, rural banks, insurance companies, governments and agricultural universities find it convenient/ economical to reach a group or individual farmers using TCS' mKRISHI® platform and can be customized according to the needs of each customer. Various other services of mKRISHI portals viz. mKRISHI® Lite, mKRISHI® Regular, mKRISHI® Plus which can serve as a vital link for the overall benefit of various stakeholders. mKRISHI for KVKs can serve for personalized service dissemination, customized fertilizer advice, market linkage to improve income, introduce GAP certification and transfer "latest techniques" from lab to land. Overall, TCS' mKRISHI® platform integrates multiple technologies to empower farmers with vital information based on specific needs like weather, fertilizer usage and pest control. It allows them to check for information in their local languages with image and voice through mobile phones and provides the relevant information. The convergence of these critical technologies with specific personalization and scalability benefits both customers and farmers.

Technological empowerment of farmers: Best practice of IFFCO Kisan Sanchar Ltd.

All telecom companies today are exploring expansion plans in the rural market. IFFCO explored the possibility of tying up with telecom services providers to provide such infrastructure facilities in the villages making co-operative societies a vehicle for economic development of the rural areas. Amongst the various means of communications available, IFFCO narrowed down on mobile telephony given the ease with which communication through mobile phones could be made available in far flung areas of the country. Telecommunications is a fast growing arena to transform Indian rural landscape. In the recent years, it has demonstrated its potential to play a vital role in contributing the empowerment of people living in Indian villages. Indian Farmers Fertilizer Cooperative Limited (IFFCO) together with telecom giant Bharti Airtel and Star Global Resources Ltd., has promoted IFFCO KISAN SANCHAR Ltd. (IKSL) as a joint venture.

Airtel is extending its network backbone to IKSL and also provide a sustainable income generating business opportunities to cooperative societies. In this model, the telecom products of Airtel are made available to farmers. The same sim card which is used for communication is turned into power house of knowledge for empowering people living in villages through relevant and pertinent information which is being provided by IKSL through Value Added Services (VAS).

In addition to large number of programmes like field demonstrations, campaigns, soil testing critical input package, medical campaigns, village adoption, farmers trainings etc., IFFCO has distinction of floating several institutions of focused programmes targeting rural India like CORDET, IFFCO foundation, Kisan Sewa Trust and IFFDC. Unique initiatives have also been launched through subsidiaries like free insurance coverage under "Sankat Haran Bima Yojna" and commodity trading. IFFCO was amongst the first in India to have realized the importance and benefits of information and communication technologies (ICT) for the overall development of rural India and has implemented special project under "ICT initiatives for farmers and cooperatives". Lack of communication infrastructure is a major challenge and is a serious impediment in taking the fruits of ICT to rural parts of the country. Majority of the villages which form bulk of India, fall abysmally short to basic source of quality communication. IFFCO has realized that absence of reliable medium as well as appropriate services of relevance to ride over it have been acting as a major bottleneck. The need of the hour is to take valuable information inputs to farmers directly to their ears and eyes. IKSL has been formed with an exclusive mandate to design, develop, source and supply state of the art, economical and rural communications with value addition of content and services. The various services for subscribers of IKSL include free voice messages; helpline; call back facility; and phone-in program on specific subjects of interest to farmers, mobile based quizzes etc. To further improve the effectiveness of its services, IKSL promotes focused communities or groups with common interest such as sheep and goat rearing, dairy, fisheries etc.

ICAR support for developing ICT

State of the art of IT in agriculture and food in India

A number of efforts have been made to use IT to improve the performance of agricultural research, education, and extension. Major projects are:

(i) The ICAR developed software systems under National Agricultural Technology Project (NATP) are:

- Database Management Systems: For Genebank Management, Identification and Management of Nematodes in India, Poultry Disease Diagnostics and Remedies, Animal Genetic Resources of India, Agricultural Pest Information, Pulse Informationfor Uttar Pradesh, and Potato Pests.
- Application Software Systems: For Implementing HACCP by Seafood Processing Plants and Identification of Eggs and Larvae of Parasites.
- Expert Systems: For Grape, Cabbage and Mushroom Cultivation, Cotton Insect Pest Management, and Statistical Quality Control of Dairy Plants.
- Simulation Systems: A model, RAINSIM, for Rain Water Simulation.

(ii) Research projects initiated by ICAR under National Agriculture Innovation Project (NAIP) are:

- Krishi Prabha-Indian Agricultural Dissertations Repository (Proponent: Chaudhary Charan Singh Haryana Agricultural University (CCSFIAU), Hisar)
- Consortium for e-Resources in Agriculture (CeRA) (Proponent: Indian Agriculture Research Institute, New Delhi).
- Development of e-Courses for B.Sc. (Agriculture) degree program (Proponent: Tamilnadu Agriculture University (TNAU), Coimbatore, Tamilnadu).
- Development of e-Courses for Bachelor of Veterinary Science and Animal Husbandry (V.Sc. & A.H). degree program (Proponent: Tamil Nadu Veterinary and Animal Sciences University (TANUVAE, Chennai).
- Re-designing the Farmer-Extension-Agricultural Research/Education Continuum in India with ICT-mediated Knowledge Management (Proponent: ICRISAT, Hyderabad).
- AGROWEB - A Digital Dissemination System for Indian Agricultural Research (ADDSIAR) (Proponent: National Bureau of Plant Genetic Resources (//BPGR) NewDelhi).
- Development of e-courses for Bachelor of Fisheries Science (B.F.Sc) degree programme (Proponent: Karnataka Veterinary Animal & Fisheries Sciences University (KI/A FS U) Mangalore, Karnataka).
- Development of e-courses for B.Sc.(Horti.) degree programme (Proponent: University of Agricultural Sciences (UAS), Bangalore).
- An E-Publishing and Knowledge System in Agricultural Research (Proponent: Directorate of Information & Publication of Agriculture (DIPA), ICAR).
- E-Home Science Courseware Consortium (Proponent: Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad).
- A Decision Support System for Agricultural Commodity Market Outlook (Proponent: National Centre for Agricultural Economics & Policy Research (NCAP), New Delhi).

- Development and maintenance of a Rice Knowledge Management Portal (Proponent: Directorate of Rice Research (DRR), Hyderabad).
- Establishing and Networking of Agricultural Market Intelligence Centres in India (Proponent: TNAU, Coimbatore).
- Strengthening Statistical Computing for National Agricultural Research System (NARS) ((Proponent: IASRI, New Delhi).
- A DSS for Enhancing Productivity in Irrigated Saline Environment using Remote Sensing, Modeling and GIS (Proponent: CSSRI, Karnal).
- Strengthening of digital library and information Management under National Agricultural Research System (NARS) (e-GRANTH) (Proponent: Indian Agricultural Research Institute, New Delhi).
- Mobilizing mass media support for sharing agro-information (Proponent: DIPA, New Delhi).
- Integrated Information Dissemination System (IIDS)for dissemination of farm and farmer specific advisories/information at user preferred mode (voice, text, image) and time, (Proponent: Medialab Asia, Acharya N G Ranga Agricultural University, National Institute of Rural Development, Mudra Institute of Communications)

iii) As part of MLAsia activities, DeitY has initiated the research projects outlined below:

- eSagu-An IT-based personalized agricultural advisory system based on the crop images and farm history. Digital photos of crops sent to agricultural scientists & customised advice sent back to coordinator / farmer (Internet and Mobile). De-livered 100,000+ expert advices to 13000+ farmers on 32 different crops covering 200+villages in 7 districts of Andhra Pradesh.
- aAqua-Web based discussion and advisory forum for farmers. It allows users to create, view and manage content in their native language. Technology is transferred on non exclusive basis for large scale deployment.
- AgroSense-A cost effective Wireless Sensor Network device, which helps in real-time monitoring of the Agro-Metrological parameters like temperature, humidity, rainfall and wetness of soil, electrical conductivity, soil pH.
- DEAL-A Multimedia platform for creation, sharing and dissemination of agricultural information among farmers and experts. Created an ontology based agricultural vocabulary database in Hindi with more than 28,000 agricultural items
- Community Radio: Community Radio Stations at five SAU were commissioned, namely in Faizabad (UP), Ranchi (Jharkhand), Coimbatore (TN), Hisar (Haryana) and Raipur (CG).
- GraminGyan Kendra - Models for use of ICT to improve social infrastructure and public interaction for the emerging knowledge based society. Nine Gyan Kendras in Vindhya region of U.P is established under the project.
- Integrated Agri Services Program (IASP) - Model for delivery of a portfolio of-agricultural advisory, financial services, input services, output procurement and information services on a single platform, in a commercially sustainable manner
- Integrated Information Dissemination System (IIDS) - The consortium led by MediaLab Asia has studied major ICT initiatives in Agriculture in India *vis-a-vis* information need of the Indian farmers. Based on the field study (1381 farmers from 57 villages across 12 states) and analysis of 26 ICT initiatives, an Interactive Information Dissemination System (IIDS) for farmers has been developed. The IIDS is an integrated system with a combination of IVRS, Mobile Application and Interactive Portal for dissemination of farm and farmer specific advisories / information at user preferred mode (voice, text, image) and time.
- Mobile Based Agricultural Extension System in North-East India (M4Agri NEI) –To empower the farmers by providing right information at the right time. (Proponent: Central Agricultural University (CAU), Imphal & Medialab Asia).

iv) As a part of C-DAC activities, DeitY has initiated the research projects outlined below:

- Ubiquitous Agriculture (u-Agri) Application of Wireless Sensor Networks (WSN) in the Agricultural Domain, for micro climate monitoring. (Proponent: C-DAC Hyderabad and Central Research Institute for Dryland Agriculture (CRIDA),
- Ask an Expert: The Ask an Expert application seeks to connect the experts and users in an

authentic, efficient and coordinated manner. (Proponent: C-DAC Hyderabad)

- Dynamic Market Information -Dynamic Market Information (DMI) seeks to provide accurate market related information to farmers and related stakeholders on daily basis,(Proponent: C-DAC Hyderabad)
- e-Vyapar-e-Vyapar is a buyer-seller platform which facilitates information exchange between buyers and sellers. (Proponent: C-DAC Hyderabad).
- Real Time Weather forecast -The service aims at providing 72 hour weather forecast information at mandal / block level. On a pilot basis, the forecasts were made available for over 3 1,000 stations spread across six states (Proponent: C-DAC Hyderabad).
- Climate Controlled Research Greenhouse - Climate control system for research greenhouse suitable for climate resilient agriculture / transgenic research. (Proponent: C-DAC Mohali)
- Wireless sensors for field application -Low power wireless sensor motes for easy deployment both in greenhouses as well as in the held. (Proponent: C-DAC Mohali)
- Low Cost Programmable Irrigation Scheduler: Low cost time based irrigation scheduler as an import substitute which performs user defined functions and controls appropriate actuators (i.e., solenoid valves, and motor) to irrigate the fields. (Proponent: C-DAC Mohali).
- Tele-veterinary -Telemedicine has now been considered as a parallel health care delivery system, so much so that apart from humans, this technology is now being extended to animals. (Proponent: C-DAC Mohali).
- Hydroponics -It plans to design and develop an automatic hydroponics feeding system to increase agricultural production in the areas of infertile soil as because it does not involve the use of soil. (Proponent: Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya Palampur (CSK HPKV) and C-DAC Mohali).
- Development of electronic nose for monitoring industrial obnoxious odorous constituents generated from pulp and paper industries under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: NEERI Nagpur& C-DAC Kolkata)
- Web Enabled Access of Agricultural Information under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: Birsa Agriculture University, Ranchi& C-DAC Kolkata)
- Application of Digital Image Processing Technologies in Tasar Sericulture. (Proponent: PRADAN, Jharkhand & C-DAC Kolkata)
- Exploratory study / scientific investigation / Experimentation to monitor thickness of silk yarn online during spinning / reeling operations under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: PRADAN Jharkhand & CDACKolkata)
- Investigation of possible technologies for estimation of silk content in a cocoon in noninvasive manner under Application of Electronics for Agriculture & Environment (eAgriEn) (Proponent: PRADAN Jharkhand & C-DAC Kolkata)
- Development of Handheld E-Nose employing Embedded systems and indigenoussensors made by Sensor Hub under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: C-DAC Kolkata)
- Development of Membrane Electrode Array Based Novel Sensing System for Rapid Taste Characterization of Food and Agro Produces under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: IIT Kharagpur & C-DAC Kolkata)
- Developing tools for a Decision Support System Framework for Tea Production System using a Wireless Sensors Network (WSN) under Application of Electronics for Agriculture & Environment (eAgriEn). (Proponent: Tea Research Association, Jorhat & C-DAC Kolkata)
- Olfaction for Biotechnology with specific Application of (Proponent: C-DAC Kolkata):

  i. Soil quality testing for fertility

  ii. Waste water quality monitoring

  iii. Quality estimation of Cardamom

  iv. Cheese ripening process
- e-safeT "Temperature Data Logger-The e-SafeT is a compact, ultra-low power data logger consisting of a High resolution temperature sensor, Memory, Visual indicators and Wireless link. (Proponent: C-DAC Noida)

- Intelligent Advisory System for Farmers (IASF) -To develop an advisory system for farmers of north eastern states which will provide them automatic answers to their farming related queries. (Proponent: C-DAC Mumbai). Project aims to develop an Intelligent Advisory System (expert system) for automatic answering queries related to farming activities carried out in North-eastern states of India.

V) As a part of DeitY, TDIL has initiated the research projects outlined below:

- Voice based Information Access for Agricultural Commodity Prices (Automatic Speech Recognition in Indian Languages) - Automatic Speech Recognition (ASR)engines for Agricultural Commodity Prices for six Indian Languages namely Hindi, Marathi, Bengali, Assamese, Tamil and Telugu languages have been developed.(Proponent: TDIL)
- Text to Speech (TTS) in Indian Languages -Text to Speech systems integrated with screen reader for 6 Indian Languages namely Hindi, Bengali, Marathi Tamil, Telugu and Malayalam languages have been developed. (Proponent: TDIL)
- Other Multilingual Technologies-Various Multilingual technologies and Software Tools such as Machine Translation systems, Transliteration, Open Office, Localized Web Browsers and Fonts have been developed. (Proponent: TDIL).

Other Efforts

- Efforts have been made to connect all ICAR labs, KVKs and agricultural universities, and to strengthen e-connectivity within agricultural universities,
- A National Agricultural Research Database was developed and bibliographic inputs were provided for inclusion in AGRIS database.
- The government of India has decided to launch a central scheme called AGRISNET. The objective of AGRISNET is to provide improved services to the farming community through use of ICT.
- A system called Agricultural Knowledge Management Unit (AKMU) is being implemented to bring information management culture to NARS so that agricultural scientists can carry out research more effectively by having systematic access to information available in India as well as in other countries, better project management of agricultural research, and modernization of office tools.
- To resolve the crop husbandry related problems, the Ministry of Agriculture, Departments of Agriculture, Ministry of Information and Communications Technology, and Agricultural and Horticultural Universities are making efforts to facilitate the advances in agricultural / horticultural technologies to reach farmers through Web Portals; Kisan Call Centers, etc.
- Some other important efforts to disseminate information to farmers are eSagu, agropedia, aaqua, and digitalgreen.
- For planning / forecasting purposes, GIS / GPS based systems are being used (National Remote Sensing Center, Hyderabad).
- Agricultural Marketing Information System (AGMARKNET) has been developed and operated by Directorate of Marketing and Inspection, Department of Agriculture and Cooperation, Ministry of Agriculture. It is a Mission Mode Project, started under National-Governance Action Plan (NeGAP) 2005.

CONCLUSION

ICT-based education and training leads to improved learning environment. However, as with most research on education and technology, the effectiveness of ICT-based mass learning is still fragmented. Learning with ICT leads to more reflective, insight learning with more empowered and democratic diffusion amongst learners.

The experiences of “Digital Green” in documentation of best practices through community participatory video clips provide scope for interactive and horizontal learning. Such ICT mediated approach can be further tested and refined by KVKs in public-private partnership mode to establish its relevance in field extension. Research on ICT application in terms of cost effective information acquisition, improving efficiency of KVKs, impact of ICT interventions and linkages with organizations need to be strengthened. Strategic collaboration of partners is to be encouraged for ICT based knowledge modeling in view of local knowledge base, local needs and research-based outputs as well as socio-economic and cultural factors, besides content and capacity building of the partners. Innovations in Mobile-based information system have tremendous scope of more coverage of farmers, last mile connectivity and interactivity. The experiences of mKRISHI and IKSL are encouraging and can be further improved based on feedback and public private partnership. Capacity building of KVK staff through ICT mediated tools may be encouraged for data acquisition, processing, analysis, and sharing from remote sensing for effective functioning of KVKs.

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Proceedings of 6th National Conference on Krishi Vigyan Kendra, Enabling farmers for Secondary Agriculture held on 3-5 Dec 2011 at Jabalpur, India

Proceedings of 6th National Conference on Krishi Vigyan Kendra, Integrated Technologies and Best Practices, held on 20-22 Nov. 2012 at Ludhiana, India

SOIL CONSERVATION SOCIETY OF INDIA

G-4/A, NATIONAL SOCIETIES BLOCK, NASC COMPEX, DEV PRAKASH SHASTRI MARG, New Delhi-110012

INCOME AND EXPENDITURE STATEMENT FOR THE YEAR ENDING 31ST MARCH, 2013

Previous Yr. Rs. P.	EXPENDITURE	Current Year Rs. P.	Previous Yr. Rs. P.	INCOME	Current Year Rs. P.
7,677.00	Entertainment/Hospitality Expenses	20,956.00	1,450.00	Admission Fee	1,330.00
61,371.50	Stationary & Printings Expenses	47,451.00	12,190.00	Annual Membership Subscription	13,642.00
2,34,724.00	Publication of Journals of SCSI Expenses	2,97,724.00	34,500.00	Library Membership Subscription	31,900.00
72,659.00	Postage Expenses	1,12,588.00	5,02,001.50	Interest on Deposit/Bank Interest	3,52,473.58
91,800.00	Salary, Wages Remuneration etc. Paid	95,100.00	1,790.00	Student Annual Membership Subscription	2,000.00
1,320.00	Miscellaneous Expenses	11,416.00	470.00	Sale of Old Journals	-
65,283.00	Depreciation to Stock & Assets of SCSI	76,411.00	15,012.00	Miscellaneous Receipts	19,000.00
11,236.00	Audit Fee Paid	11,236.00	1,51,600.00	Overheads/Institutional Exp. Received for Trainings	1,07,300.00
32,576.00	Telephone Rent/Calls Charges	21,711.00	2,29,340.00	Sale of Society's Publications	11,48,500.00
6,780.00	Conveyance Hiring Expenses	16,992.00		**Financial Assistance for Printing of Journals by ICAR**	
65,000.00	Annual Rent Paid to ICAR	65,000.00	2,06,250.00	- For the year 2012-13	1,07,638.00
1,07,638.00					
22,060.00	Web-Site of SCSI Renewal Charges	4,494.40	-	Registration Fee of National Conference	26,500.00
13,597.00	Publication of Newsletters of SCSI Expenses	67,693.00	-	TA Cost of Prof. J.S. Bali Received	7,682.00
1,000.00	Subscription for Newsletters, Journals etc. Expenses	-			
14,136.00	Travelling (Outstation) Expenses	87,652.00			
-	Printing of Bulletin of National Conference	52,503.00			
-	Bank Charges/Commission Paid	502.00			
-	Repairs/Annual Maintenance Contract Expenses	2,360.00			
-	National Conference on BIOWD, 2009 Expenses	32,778.00			
4,53,384.00	**Excess of income over expenditures**	**7,93,398.18**			
11,54,603.50	**T O T A L**	**18,17,965.58**	**11,54,603.50**	**T O T A L**	**18,17,965.58**

Place : New Delhi
Dated : 05.07.2013

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Chartered Accountant, Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

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(SURAJBHAN)
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Sd/-
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Secretary General

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(R.A.S. PATEL)
Treasurer

SOIL CONSISERVATION SOCIETY OF INDIA
G-4 / A, NATIONAL SOCIETIES BLOCK, NASC COMPLEX
DEV PRAKASH SHASTRI MARG, NEW DELHI – 110012

BALANCE SHEET AS ON 31ST MARCH, 2013

Previous Year 2011-12 Rs. P.	LIABILITIES			Current Year 2012-13 Rs. P.
	Funds & Liability			
6,02,003.27	(a) General Reserve Funds as on 31.03.2012	-	Rs. 6,02,003-27	
	Added Excess of Income over Expenditure	-	(+) Rs. 7,93,398-18	13,95,401.45
37,00,000.00	(b) Corpus Fund of Society (SCSI)	-		37,00,000.00
19,36,908.00	(c) Share Towards Life Membership as Liability	-	Rs. 19,36,908-00	
	Added contribution towards liability since 01-04-12	-	(+) Rs. 34,400.00	19,71,308.00
1,582.00	(d) Suspense Account		…..	1,00,000.00
11,236.00	(e) Provision for Outstanding Audit Fee For 2012-13		…..	11,236.00
520.00	(f) Provision for Late (Dr.) K.G. Tejwani Charitable Trust Award		…..	-
50,000.00	(g) Provision for Prof. J.S. Bali's Gold Medal Award		…..	50,000.00
42,961.00	(h) Provision for Late Y.P. Bali Memorial Fund		…..	42,961.00
1,300.00	(i) Friends of Tree Memberships Subscription		…..	1,300.00
-	(j) Outstanding Financial Assistance of ICAR for National Conference, Lucknow (Carried forward for the year 2013-14)		…..	2,25,000.00
4,881.00	(k) Outstanding Payment to Dr. S. Subramaniyan's Account		…..	-
63,51,391.27			**TOTAL**	**74,97,206.45**

Contd.....

Previous Year 2011-12 Rs. P.	ASSETS		Current Year 2012-13 Rs. P.
	Property and Stocks:		
22,456.00	(a) Almirahs (11 Nos.) of Steel Made	Rs. 22,456-00	
	Less Depreciation @ 15%	(-) Rs. 3,368 -00	19,088.00
6,390.00	(b) Personal Computer (2 Nos.) with other Accessories	Rs. 6,390-00	
	Added New PC purchased from the dealer	(+) Rs. 48,720-00	
	Less Buyback value of the one old PC by the dealer	(-) Rs. 5,000-00	
	Less Depreciation @ 60%	(-) Rs. 30,066-00	20,044.00
7,576.00	(c) Fax Machine HP-4355	Rs. 7,576-00	
	Less Depreciation @ 15%	(-) Rs. 1,136-00	6,440.00
3,659.00	(d) Printers (2 Nos.) of HP-Laser / HP-2060	Rs. 3,659-00	
	Less Depreciation @ 60%	(-) Rs. 2,195-00	1,464.00
1,057.000	(e) C.V.T. Voltage Regulator	Rs. 1,057-00	
	Less Depreciation @ 15%	(-) Rs. 159-00	898.00
2,65,348.00	(f) Furniture & Fixture for Office Premises of SCSI	Rs. 2,65,348-00	
	Less Depreciation @ 10%	(-) Rs. 26,535-00	2,38,813.00
53,989.00	(g) Automatic Duplexing Unit	Rs. 53,989.00	
	Less Depreciation @ 15%	(-) Rs. 8,098-00	45,891.00
28,513	(h) Split Air Conditioners (2 Nos.)	Rs. 28,513-00	
	Less Depreciation @ 15%	(-) Rs. 4,277-00	24,236.00
3,845.00	(i) Refrigerator (180 ltrs. - Kelvinator)	Rs. 3,845-00	
	Less Depreciation @ 15%	(-) Rs. 577-00	3,268.00
	Outstanding Advance/Payments from:		
32,778.00	Advances to SCSI, KSC for National Conference on BIOWD, 2009	Rs. -	
-	NRAA, Planning Commission, New Delhi for Gujarat Consultancy	Rs. 1,10,850-00	
-	Library Membership Subscription Account	Rs. 1,000-00	
-	Advance to RCS-SCSI from SCSI (Seed Money) Account	Rs. 1,000-00	1,12,850.00
	Investment/Fixed Deposit:		
51,53,058.15	Fixed Deposits of Society at Syndicate Bank at Pusa Campus, New Delhi	---	61,53,058.15
	Current Assets		
7,66,490.12	(a) Balance in Syndicate Bank Branch at Pusa Campus, New Delhi	---	8,67,617-30
4,184.00	(b) Cash-In-Hand	---	2,538.00
2,048.00	(c) Balance Unused Postal Stamp-tickets	---	1,001.00
63,51,391.27		**TOTAL**	**74,97,206.45**

Place : New Delhi
Dated : 05.07.2013

Verified and found correct

Sd/-
for Rajesh Kumar Sachdeva & Associates
Chartered Accountants, Flat No. 1013, Naurang House
21, Kasturba Gandhi Marg, New Delhi – 110001

Sd/-	Sd/-	Sd/-
(SURAJ BHAN)	(JAGATVEER SINGH)	(R.A.S. PATEL)
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Certificate of Registration of Societies.

ACT XXI OF 1860.

No. 14 of 1952-1953.

I hereby certify that Soil Conservation Society of India

has this day been registered under the Societies Registration Act, XXI of 1860.

Given under my hand at Patna

this Twentieth day of September

One thousand nine hundred and fifty-two.

Asst. Registrar of Joint Stock Companies. Bihar

13.9.52.

J. S. C. 36.

MFP--12 JSC--12436--(M-143)--21-5-64--5,000.

21/x/13

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Types of contribution

Papers should mainly be based on original works/experience or ideology on any aspect of soil and water conservation including the generation and interpretation of basic data for these programmes.

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Manuscripts are required neat and clean in Laser Print or Letter Quality in font size 10/12 point on Bond Paper in English with one Photocopy double spaced, with wide margins and along with one soft copy should be sent to the Cheif Editor, Soil Conservation Society of India, National Societies Block A/G-4, National Agricultural Science Centre Complex, Pusa Campus, New Delhi 110 012. Only two copies of illustrations and plates need to be sent.
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The text should suitably be subdivided; the main heading has to be in capital letters, secondary heading also in capitals but in side position and tertiary heading should be normal typescript in side position. Underline only those words that should be in italics. Use the metric system. The abstract should not be exceed 200 words; it should highlight only techniques ans significant finding and thus be more concise than a regular 'Summary'. References should be written in the form as given below:

Ahuja R L, Garalapuri V N, Manchanda M L and Khanna S S. 1978. Physiography and Soil Association of Haryana, J. Ind. Soc. Soil Sc. 26:261.

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These should be kept to the absolute minimum in view of the high cost of reproduction.

Line diagrams and maps should neatly be drawn in Black ink on tracing paper of drawing paper. The original drawings should ordinarily be not more than 35 x 25 cm in size with letter size and spacing so arranged as to permit easy 2/3 reduction.

All photographs should be of good quality, original or printed on glossy paper and should not exceed page (21 x 13 cm.) They should preferably by in squares or rectangles.

If annotated air photos of India are sent, the author(s) should send a certificate tot the effect that Defence Clearance has been obtained for printing.

Length

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Natural Resource Management for Food Security and Rural Livelihoods

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New Delhi, INDIA

In Collaboration with

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ADDRESSES FOR CORRESPONDENCE

Dr. Suraj Bhan
President
Soil Conservation Society of India
G-4/A, National Societies Block
National Agricultural Science Centre
(NASC) Complex, DPS Marg (Pusa),
New Delhi – 110012
Phone / Fax: +91-11-25848244,
(M): +91-9868808980
Email: icscsi2015@gmail.com

Shri Jagatveer Singh
Secretary General
Soil Conservation Society of India
G-4/A, National Societies Block
National Agricultural Science Centre
(NASC) Complex DPS Marg (Pusa),
New Delhi – 110012
Phone: +91-11-25848244
(M): +91-9868822627
E-mail: jagat53@yahoo.co.in

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E-mail: soilsci@gmail.com, bhan_suraj1945@yahoo.com; Website: http//www.soilcsi.in

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