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Wasteland mapping for their prioritization and management using high resolution satellite data and GIS - A case study

INDAL RAMTEKE, PRASHANT RAJANKAR, VIVEK KALE AND VINOD BOTHALE

Maharashtra Remote sensing Applications Centre, VNIT Campus, Nagpur 440 011, India

Abstract: The present study was carried out in Phaltan tehsil, Satara district of Maharashtra to study the village-wise spatial distribution of wastelands using high-resolution satellite data of IRS P6, LISS-IV combined with ancillary information. The results indicated that 17 villages fall in high priority (10.19 per cent area), 32 villages in medium and 70 villages in low priority classes, respectively and these villages needs immediate attention to arrest further degradation.

Additional key words: *High resolution, prioritization, wasteland management, GIS*

Introduction

The information on kind and distribution of wastelands is needed for a variety of purposes like planning reclamation programmes, rational land use planning, bringing additional areas into cultivation and also to improve productivity. To bring all the wastelands under productive use through afforestation, plantations, agro-forestry, horticulture and other productive use, it is necessary to have an accurate and reliable database on the type, extent and ownership of wastelands so that the same can be integrated with cadastral maps.

Remote Sensing and Geographic Information System (GIS) techniques are widely accepted as most reliable, rapid and cost effective for collection of data on status of natural resources over large areas (Saxena *et al.* 2000). The availability of high spatial resolution (<6.0 m) satellite data has made it possible to map the information on 1: 10000 scale or larger. Remote Sensing satellite data amenability for further processing in GIS environment, results in valuable database over large areas, in time effective manner (Kasturirangan *et al.* 1996; Rao *et al.* 1996). The present paper discusses the mapping and categorization of wastelands in Phaltan tehsil, Satara district of Maharashtra using IRS-LISS-IV data for their management.

Materials and Methods

Study area

Phaltan tehsil, located in the north eastern part of Satara district, Maharashtra lies between 17°48'21" to18°05'51" N latitude and 74°09'02" to 74°43'01" E longitude covering an area of 1177.69 sq km (Fig. 1). Geologically, area is covered with Deccan trap and alluvium along major rivers. The tehsil receives annual rainfall of about 462 mm and is classified as drought prone area in the district. The northern part of tehsil is intensively cultivated, whereas, southern part is under cultivation or vegetation (in patches). The wastelands is mostly concentrated in this part.

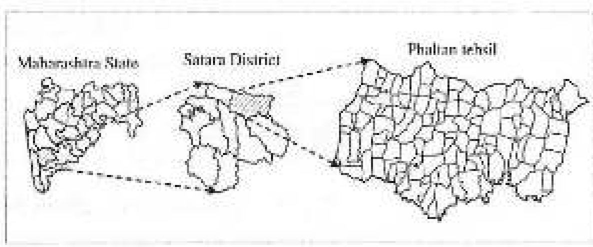

Fig.1. Location map of the study area

On-screen visual interpretation approach using standard image interpretation keys like tone, texture, size, pattern, association *etc.* for delineation of different wastelands categories from multi seasons satellite images (Table 2) were adopted. Geo-referenced mosaic of village maps are used to extract the village-wise area statistics under each wasteland categories, using Arc-GIS software. Many factors like, rainfall, severity of degradation, population, poverty of area, funds for implementation the remedies *etc.* have been considered while rating the priority for wastelands treatment. In present study, the spatial distribution and area of wasteland coverage in the particular village is considered, it is assumed that, higher the area under wastelands there is poor or no natural resources availability so that it calls immediate attention (NRAA 2012).

Table 2. Keys of interpretation for different categories of wastelands

Wasteland Categories	Colour / tone	Shape	Size	Texture	Pattern	Association
Mining / Industrial area-Industrial	Greenish, bluish black, whitish shades ,with dark red tone	Regular with boundary	medium to large	Coarse	Contiguous with boundary	Associated with built-up area generally away from city, plantation, well-established infrastructure
Mine / Quarry	Smooth bluish tone, blackish tone around coal mine area	Irregular	Small to medium	Coarse	--	Associated with hilly terrain along roadside, good infrastructure like road/railway
Scrub Forest (Canopy cover less than 10%)	Light red to dark brown, grey to bluish white	Irregular & discontinuous	Varying-small to big	Smooth texture	Contiguous to non- contiguous in appearance	Associated with medium relief mountain/hill slopes at the fringes of dense forest cover and settlements
Land with scrub	Red to brown to greenish blue	Irregular and discontinuous	Varying-small to large	Coarse texture	Contiguous to dispersed	Associated with moderate slopes in plains and foot hills and are generally surrounded by agriculture land
Land without scrub	Light yellow to brown to greenish blue, grey depending upon surface moisture	Irregular and discontinuous	Varying-small to large	Coarse texture	Contiguous to dispersed	Associated with moderate slopes in plains and foot hills and are generally surrounded by agriculture land
Barren Rocky / Stony waste	Greenish blue to yellow to brownish	Irregular and discontinuous	Varying-small to large	Medium	Linear to contiguous to dispersed	Associated with steep isolated hillocks/hill slopes , crests, plateau and eroded plains, lateritic out-crops, mining and quarrying sites

Villages in Phaltan tehsils are grouped into three priority classes *viz.* High (> 50% area), Medium (25-50% area) and Low (< 25% area) based on the % area under wasteland in individual village (Binay Kumar and Uday Kumar 2011).

Dominant wasteland categories such as land with scrub, land without scrub, stony waste / barren area, grazing lands, mining area *etc.* identified in the study area.

Result and Discussion

Major wasteland categories mapped in Phaltan tehsil are scrublands (with scrub and without scrub), stony waste / barren rocky areas, grazing lands, degraded forest and mining / industrial wastelands (Table 3, Fig.3).

Table 3. Wasteland categories and their aerial extent

Wasteland categories	Slope %	Soil depth	Area (sq km)	% TGA
Land with scrub	Gently slopping	Moderately deep	35.24	2.99
Land without scrub	Moderately slopping	Shallow	260.57	22.13
Mining / Industrial wastelands	Gently slopping	Shallow	0.49	0.04
Stony waste	Moderately steep to steep	Very shallow	11.62	0.99
Grazing land	Gently slopping	Shallow	1.39	0.12
Degraded forest	Moderately slopping to steep slopping	Very shallow	36.61	3.11
Settlements			4.8	0.41
Waterbodies (river, tank, canal)			18.4	1.56
Normal/Miscellaneous	Very gently slopping	Deep to very deep	808.57	68.66
		Total	**1177.69**	**100**

The normal/miscellaneous category includes area under dense forest, agriculture and settlements which occupy northern part of tehsil. The area appeared in dark red tone with smooth texture and irregular pattern in plains. Data showed that out of 1177.69 km^2, about 345.92 sq km of area (29.37 %) of the tehsil are under different types of wastelands. (Table 3). The salient characteristics of the different wasteland categories are discussed below.

Scrubland - land with scrub

These are the areas where scrubs, less than 5 meters in height, dominate the landscape (>10 %) associated with shallow and skeletal soils, extremes of slopes, severe erosion and excessive aridity. This category of wasteland occupies about 35.24 sq km of area (3% of TGA). These appear in light yellow to brown or greenish blue depending on the surface moisture and vary in size from small to large having either contiguous or dispersed pattern.

Scrubland - land without scrub

These lands are associated with moderate slopes (8-15%) in plains and near foot hills and are surrounded by agricultural lands. These lands have sparse vegetation (< 5 %) or devoid of vegetation with thin soil cover and spread over 260.57 sq km area (22.13% of TGA).

Degraded forest

These lands are under the forest boundaries, in which vegetative cover is less than 10 per cent. These lands are confined in the fringe areas of notified forest, appearing dark grey to light red tone during maximum green period. The tonal variations are subject to change with the foliage cover and the season of data acquisition. Scrub forest occupies about 36.61 sq km area (3.11% of TGA).

Other categories

Stony waste/barren rocky area, grazing lands and mining/industrial area occupies nearly 0.99, 0.12 and 0.04 % of the area, respectively.

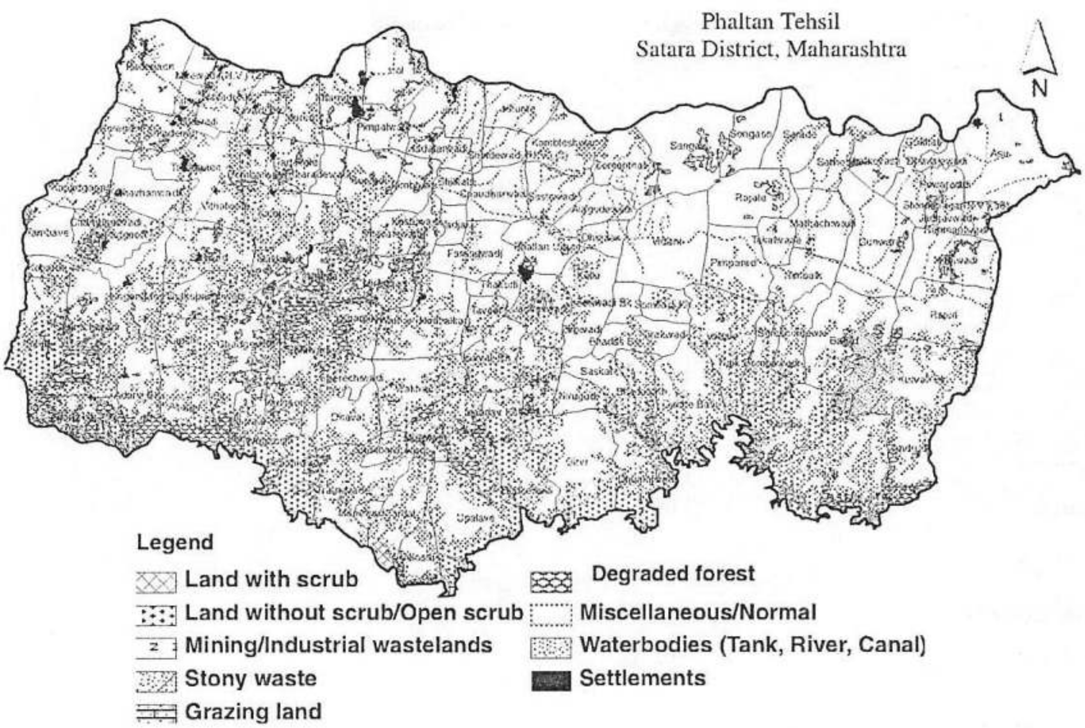

Fig. 3. Wasteland map of Phaltan tehsil overlaid with village boundary.

Village level prioritization

Village-wise area of different categories of wasteland are estimated and are grouped as high, medium and low based on their per cent proportion to wasteland (Table 4). There are 19 villages covering 228.28 sq km area, where per cent wasteland to village area is more than 50 per cent and are classified as high priority villages (11.89% of the wasteland). These village calls for immediate attention from wasteland development point of view.

Table 4. Village-wise area under different priority of management

Priority of management	No. of Villages	Total area of village (Km^2)	Total Wasteland (Km^2)	% Wasteland to TGA
High	19	228.28	140.04	11.89
Medium	30	335.37	159.90	13.58
Low	70	614.04	45.98	3.90
TOTAL	119	1177.69	345.92	29.37

About thirty villages of the tehsils have been categorized under medium priority, wherein wasteland proportion varies from 25 to 50 per cent. This group support about 13.58 per cent of wasteland of the area. The rest 70 villages, which comes under low priority zone, exhibits intensive agriculture supported by deep black soils. In these villages wasteland percentage are under threshold value of 25 per cent and needs to be judiciously managed to maintain the crop productivity. Priority-wise villages are shown in figure 4.

Fig.4. Priority villages for wasteland management

Management of wastelands at village level

Prioritization of Wastelands based on deteriorating natural resources in the villages form the strong basis for taking up developmental activities. Soil and water conservation through watershed development program needs to be undertaken to bring wastelands under green cover. Afforestation programme, fuel and fodder plantations, silvipasture, agro-forestry and horticultural development need to be encouraged at village level. Renovation and augmentation of water sources, desiltation of tanks for drinking water and irrigation and locale specific conservation measures should be encouraged with people's participation. These activities need to be undertaken in phase manner in priority villages. The study may help resource manager and decision makers to guard the soil and conserve water to increase the biomass for living beings by adopting developmental plans on priority basis. Action plans can be generated village/watershed-wise, allowing sufficient scope for reclamation/ development of wastelands.

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Characteristics and classification of the soils of Sirohi district of Rajasthan

R.S.GARHWAL[1], F.M. QURESHI AND J.D.GIRI[2]

Department of Soil Science and Agricultural Chemistry,
Rajasthan College of Agriculture, Udaipur-313001, India
[1]Directorate of Groundnut Research, Ivnagar Road, Junagadh-362 001, India
[2]Division of Remote Sensing Applications, NBSS&LUP, Nagpur-440 033, India

Abstract: Ten representative pedons occurring on six landforms in Sirohi district were studied for their morphological, physical and chemical properties. The soils on steeply sloping side slope were very shallow, dark brown in colour, gravelly sandy loam with fine, weak sub angular blocky structure. The water holding capacity, water retention at 0.03 and 1.5 MPa and available water content was higher in the soils of nearly level pediment and plain as compared to other landforms. Relatively higher value of pH (8.8-9.3), E.C. (0.58-2.18 dSm^{-1}) and calcium carbonate (95.2-132.3 g kg^{-1}) were observed in the soils of the undulating pediment (P3) as compared to the soils on gently sloping pediment (P5). The soils of steeply sloping side slope (P1) and nearly level to very gently sloping pediment (P6) have been classified as Loamy-skeletal and Loamy Lithic Ustorthents respectively, and soils of gently sloping pediment (P5) as Loamy Lithic Haplutepts at sub-group level. Soils of undulating pediment (P3), nearly to very gently sloping pediment (P7), nearly level pediment and nearly level plain (P 9 and P10) have been grouped as Fine-loamy Typic Haplustepts and soils of undulating pediment (P2) as Coarse-loamy Typic Haplustepts.

Additional key words: *Characterisation, classification, soil morphology, soil taxonomy*

Introduction

Soils are considered as integral part of the landscape and their characteristics are largely governed by the landforms on which they have developed. The landform sequence plays an important role in formation and development of soils. The relationship between soils and physiographic features has been widely accepted by soil scientists and physiographers the world over (Daniel *et al.* 1970). Murthy (1982) pointed out the importance of soil-physiographic relationship in soil survey and mapping, as it provides a fair understanding of variability across the landscape needed for sustainable agricultural planning and with this background, the present study was undertaken.

Materials and Methods

Sirohi district (24°20' to 25°17' N; 72°16' to 73°10' E) is situated in south-west of Rajasthan, covering an area of 5203 sq.km. Agriculture is the dominant occupation for majority of the population. The western part of the district comprises of sandy desert and the northwest portion is mostly rocky, with pre-dominantly sandy loam soils. The scattered hills are the marked feature of the Midwest ranges. The area around the mountain ranges is level and sandy. The main geological formations are granite gneiss, quartzite and slate. The climate of the district is semi-arid with annual rainfall of 638 mm. The mean maximum and minimum temperature are 32.3°C and 19.1°C, respectively. The moisture regime of the district is *ustic* but at places bordering the desert, the moisture regime is *aridic*. A transect was selected in the southwest part of Sirohi district having six landforms *viz.* steeply sloping side slopes (15-25%), undulating pediments (8-15%), gently sloping pediment (3-5%), nearly level to very gently sloping pediment (1- 3%), nearly level pediment (0-1%) and nearly level plain (0-1%) in Aravalli landscape. Representative pedons on each landform was studied for morphological characteristics and horizon-wise soil samples were collected for laboratory analysis. The samples were processed and analysed following standard laboratory procedures.

Results and Discussion

Morphological characteristics

The soils of steeply sloping side slopes (P1) are very shallow, dark brown in colour and have gravelly sandy loam texture with weak aggregation (Table 1). The soils of undulating pediments (P2 and 3) are shallow to moderately deep, dark brown to very dark brown, and sandy loam to sandy clay loam in texture with medium sized, weak to moderately strong structure. The soils of gently sloping pediments (P4 and 5) are shallow to deep, dark brown to very dark brown with sandy loam (P4) to clay texture (P5) with weak to strong, medium structure. The soils occurring on very gently sloping pediments (P6 and 7) are shallow (P6) to deep (P7), dark brown and have sandy clay loam texture with fine to medium, weak to moderate structure. The clay loam soils of nearly level pediment (P8) are very dark brown, with medium moderately strong structure. The soils occurring on nearly level plain (P9 and 10) have dark brown, sandy clay loam (P9) to clay loam (P10) texture and medium moderately strong aggregates.

Table 1. Morphological characteristics of soils

Depth (cm)	Horizon	Matrix colour (moist)	Texture	Structure	Porosity (%)
P1: Loamy-skeletal Lithic Ustorthent (Steeply sloping side slopes, 30-50% slope)					
0-15	A1	7.5YR 5/3	gsl	f1sbk	46.0
15+	R	Hard quartzite rock			
P2: Coarse-loamy Typic Haplustept (Undulating pediments, 8-15% slope)					
0-22	Ap	7.5YR 3/4	sl	m1sbk	40.8
22-49	Bw1	7.5YR 3/4	sl	m1sbk	39.8
49-77	Bw2	7.5YR 3/4	sl	m1sbk	38.3
77-102	BC	7.5YR 3/4	gsl	m1sbk	36.7
102+	Cr	Weathered quartzite rock			38.9
P3: Fine-loamy Typic Haplustept (Undulating pediment, 8-15% slope)					
0-16	Ap	10YR 4/3	scl	m2sbk	43.7
16-33	Bw1	10YR 4/3	scl	m2sbk	41.9
33-53	BC	10YR 4/3	scl	m2sbk	39.9
53+	Cr	Weathered granite-gneiss/quartzite			41.9
P4: Fine Typic Haplustept (Gently sloping pediments, 3-5% slope)					
0-15	Ap	10YR 3/2	cl	m3sbk	42.7
15-36	Bw1	10YR 3/2	C	m3sbk	49.1
36-59	Bw2	10YR 3/2	C	m3sbk	47.7
59-84	Bw3	10YR 3/2	C	m3sbk	46.4
84-120	BC	10YR 3/3	gl	Massive	40.9
120+	Cr	Weathered granite/quartzite			45.4

P5: Loamy Lithic Haplustept (Gently sloping pediments, 3-5% slope)					
0-15	Ap	7.5YR 3/4	sl	m1sbk	45.1
15-33	Bw1	7.5YR 3/4	sl	m1sbk	40.7
33-48	BC	7.5YR 3/4	gsl	m1sbk	40.0
48+	Cr	Weathered granite/quartzite			41.9
P6: Loamy Lithic Ustorthent (Very gently sloping pediment, 1-3% slope)					
0-18	Ap	7.5YR 3/4	scl	f1sbk	45.3
18-35	AC	7.5YR 3/4	gscl	-	41.6
35+	R	Hard granite-gneiss/quartzite rock			
P7: Fine-loamy Typic Haplustept (Very gently sloping pediments, 1-3% slope)					
0-15	A1	7.5YR 4/4	gsl	m1sbk	43.2
15-37	Bw1	7.5YR 3/4	scl	m2sbk	41.1
37-59	Bw2	7.5YR 4/4	gscl	m2bk	37.5
59-85	BC	7.5YR 4/4	gscl	Massive	37.6
85+	Cr	Weathered granite-gneiss/quartzite			39.9
P8: Fine-loamy Typic Haplustept (Nearly level pediment, 0-1% slope)					
0-19	Ap	10YR 3/4	scl	m2sbk	39.9
19-38	Bw1	10YR 3/4	cl	m2sbk	40.8
38-63	Bw2	10YR 3/4	cl	m2sbk	39.7
63-88	Bw3	10YR 3/4	cl	m2sbk	38.2
88-106	Bw4	10YR 3/4	scl	m2sbk	38.2
106-136	BC	10YR 3/3	scl	Massive	37.6
136+	Cr	Weathered quartzite			39.1
P9: Fine-loamy Ustic Haplocambid (Nearly level plains, 0-1% slope)					
0-16	Ap	7.5YR 3/4	scl	m2sbk	42.1
16-33	Bw1	7.5YR 3/4	scl	m2sbk	41.1
33-54	Bw1	7.5YR 3/4	scl	m2sbk	41.1
54-68	Bw3	7.5YR 3/4	scl	m2sbk	37.1
68-87	Bw4	7.5YR 3/4	scl	m2sbk	36.9
87-117	BC	7.5YR4/4	gscl	massive	36.9
117+	Cr	Weathered granite-gneiss			39.3
P10: Fine-loamy Ustic Haplocambid (Nearly level plains, 0-1% slope)					
0-16	Ap	7.5YR 3/4	cl	m2sbk	42.5
16-33	Bw1	7.5YR 3/4	cl	m2sbk	42.5
33-54	Bw2	7.5YR 3/4	cl	m2sbk	40.9
54-68	Bw3	7.5YR 3/4	cl	m2sbk	39.3
68-87	Bw4	7.5YR 3/4	cl	m2sbk	38.1
87-117	BC	7.5YR 3/4	gscl	massive	37.2
117+	Cr	Weathered granite-gneiss			39.9

Physical characteristics

The sand content (Table 2) of the soils ranged from 37.1 per cent (P4) to 71.5 per cent (P1) while silt content ranged from 15.5 per cent (P7) to 26.5 per cent (P8). In general, the clay content was higher in soils occurring on gently sloping pediments, nearly level pediments (P8) and nearly level plains (P10). Young and Hamma (2000) and Sarkar *et al.* (2001) have also found higher clay content in soils occurring on gentler surfaces. The bulk density ranged from 1.4 Mgm^{-3} (P9 and 10) to 1.7 Mgm^{-3} (P2) and increased with depth. The water retention at 0.03MPa ranged from 0.2m^3m^{-3} (P2) to 0.5m^3m^{-3} (P3, P6 and P9) and at 1.5 MPa it ranged from 0.1m^3m^{-3} (P2) to 0.3m^3m^{-3} (P6). In general, the amount of water retained was higher in soils with higher clay content. The positive relationship between clay content and the amount of water retained at 0.03 and 1.5 MPa has also been recorded by Nagar *et al.* (1995) and Balpande *et al.* (2007). The maximum water holding capacity (MWHC) ranged from 15.8 per cent (P8) to 44.9 per cent (P4).

Table 2. Physical Properties of soils

Depth (cm)	Horizon	Particle size class (%)			Density ($Mg\ m^{-3}$)		Water retention (m^3m^{-3})		MWHC (%)
		Sand	Silt	Clay	B.D	P.D	0.03MPa	1.5MPa	
P1: Loamy-skeletal Lithic Ustorthent (Steeply sloping side slopes, 30-50% slope)									
0-15	A1	71.5	15.5	13.0	1.4	2.6	0.2	0.16	37.6
15+	R	Hard quartzite rock							
P2: Coarse-loamy Typic Haplustept (Undulating pediments, 8-15% slope)									
0-22	AP	63.7	20.0	16.3	1.5	2.6	0.2	0.1	35.3
22-49	Bw1	58.2	22.7	17.0	1.6	2.6	0.2	0.1	37.2
49-77	Bw2	63.2	22.5	16.3	1.6	2.6	0.2	0.1	35.7
77-102	BC	63.7	21.5	14.8	1.7	2.7	0.2	0.1	31.6
P3: Fine-loamy Typic Haplustept (Undulating pediment, 8-15% slope)									
0-16	Ap	52.0	21.6	26.4	1.5	2.6	0.5	0.3	40.3
16-33	Bw1	52.5	21.9	25.5	1.5	2.6	0.4	0.3	38.4
33-53	BC	50.3	22.2	27.4	1.6	2.6	0.5	0.3	38.4
P4: Fine Typic Haplustept (Gently sloping pediments, 3-5% slope)									
0-15	Ap	45.7	21.6	32.6	1.5	2.6	0.3	0.1	41.2
15-36	Bw1	37.1	23.3	39.6	1.5	2.6	0.4	0.1	42.6
36-59	Bw2	38.2	21.3	40.4	1.5	2.6	0.4	0.2	44.9
59-84	Bw3	39.8	19.4	40.6	1.5	2.6	0.3	0.1	39.1
84-120	BC	43.2	25.9	30.9	1.6	2.7	0.4	0.2	38.3

P5: Loamy Lithic Haplustept (Gently sloping pediments, 3-5% slope)									
0-15	Ap	63.1	23.5	13.3	1.4	2.6	0.3	0.1	34.8
15-33	Bw1	63.4	23.9	12.7	1.6	2.6	0.3	0.1	37.6
33-48	BC	65.5	20.3	14.2	1.6	2.6	0.3	0.2	32.3
P6: Loamy Lithic Ustorthent (Very gently sloping pediment, 1-3% slope)									
0-18	Ap	56.6	20.2	23.1	1.4	2.6	0.5	0.3	38.2
18-35	AC	42.3	24.6	33.0	1.6	2.7	0.5	0.3	36.5
P7: Fine-loamy Typic Haplustept (Very gently sloping pediments, 1-3% slope)									
0-15	A1	63.5	20.2	16.3	1.5	2.6	0.4	0.2	30.4
15-37	Bw1	56.8	19.2	23.9	1.5	2.6	0.4	0.2	34.6
37-59	Bw2	59.4	17.4	23.2	1.6	2.6	0.4	0.2	33.5
59-85	BC	62.1	15.5	22.3	1.6	2.6	0.5	0.2	31.6
P8: Fine-loamy Typic Haplustept (Nearly level pediment, 0-1% slope)									
0-19	Ap	58.5	20.1	21.3	1.5	2.4	0.3	0.2	38.7
19-38	Bw1	44.1	26.4	29.4	1.5	2.5	0.3	0.2	44.5
38-63	Bw2	46.1	23.4	30.5	1.5	2.5	0.3	0.2	15.8
63-88	Bw3	45.8	22.0	32.2	1.6	2.5	0.3	0.2	41.6
88-106	Bw4	56.2	16.6	27.2	1.6	2.5	0.3	0.	38.5
106-136	BC	57.8	16.2	26.0	1.6	2.6	0.4	0.3	36.4
P9: Fine-loamy Ustic Haplocambid (Nearly level plains, 0-1% slope)									
0-16	Ap	58.0	18.3	23.6	1.4	2.4	0.5	0.2	36.3
16-33	Bw1	57.7	19.7	22.6	1.4	2.4	0.4	0.3	37.6
33-54	Bw2	54.0	20.5	25.4	1.4	2.4	0.4	0.2	39.6
54-68	Bw3	56.9	18.4	24.7	1.5	2.4	0.4	0.2	35.2
68-87	Bw4	57.6	18.1	24.3	1.6	2.4	0.5	0.3	36.5
87-117	BC	63.2	15.6	21.2	1.6	2.6	0.3	0.2	30.9
P10: Fine-loamy Ustic Haplocambid (Nearly level plains, 0-1% slope)									
0-16	Ap	43.9	23.6	32.5	1.4	2.4	0.4	0.2	40.6
16-33	Bw1	40.7	25.5	33.8	1.4	2.4	0.3	0.1	42.2
33-54	Bw2	44.1	23.2	32.7	1.4	2.4	0.4	0.2	44.5
54-68	Bw3	42.3	23.3	34.4	1.5	2.4	0.4	0.1	43.6
68-87	Bw4	43.6	22.2	32.2	1.6	2.4	0.3	0.1	39.3
87-117	BC	50.7	23.2	26.1	1.6	2.6	0.2	0.1	32.6

Chemical characteristics

The pH of the soils ranged from 6.9 (P4 and P5) to 9.3 (P3) and was related to the amount of bases with pH being higher in soils occurring on gentler slopes (Table 3). The electrical conductivity of the soils ranged from 0.02 dSm^{-1} (P1) to 2.18 dSm^{-1} (P3). The organic carbon content ranged from 0.16 per cent (P1) to 0.72 per cent (P4). In general, the organic carbon content was higher in surface soils and decreased with depth. The calcium carbonate content ranged from 8.6 g kg^{-1} (p7) to 132.3 g kg-1(P3). In general the calcium carbonate content increased with depth (West *et al.* 1988). Among the exchangeable cations, Ca^{2+} and Mg^{2+} were the dominant cations. The cation exchange capacity (CEC) ranged from 18.6 c.mol (+) kg^{-1}(P1) to 33.3 cmol(+) kg^{-1}(P3) depending upon clay content of the respective horizons. Pal *et al.* (1999) and Challa *et al.* (2000) have also reported similar findings.

Table 3. Chemical properties of soils

Depth (cm)	Hori-zon	pH (1:2.5)	EC dSm^{-1} (1:2.5)	OC (%)	CaCO3 (g kg^{-1})	Exchangeable bases [cmol(p+)kg-1]				CEC cmol (p+) kg^{-1}
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
P1: Loamy-skeletal Lithic Ustorthent (Steeply sloping side slopes, 30-50% slope)										
0-15	A1	7.0	0.02	0.16	11.5	11.2	6.0	0.4	0.5	18.6
P2: Coarse-loamy Typic Haplustept (Undulating pediments, 8-15% slope)										
0-22	AP	8.2	0.06	0.50	23.7	11.2	8.0	0.7	0.9	21.7
22-49	Bw1	7.8	0.04	0.48	25.0	13.8	8.8	0.81	0.9	24.9
49-77	Bw2	7.9	0.05	0.44	27.3	15.0	10.9	0.7	0.8	28.2
77-102	BC	8.9	0.07	0.39	36.6	13.6	9.8	0.5	0.7	25.3
P3: Fine-loamy Typic Haplustept (Undulating pediment, 8-15% slope)										
0-16	Ap	8.9	0.58	0.51	95.2	17.6	6.8	1.2	0.7	27.2
16-33	Bw1	9.2	1.17	0.51	115.5	20.3	10.4	0.9	0.8	33.3
33-53	BC	8.8	2.18	0.41	132.3	18.7	8.9	1.1	1.2	31.1
P4: Fine Typic Haplustept (Gently sloping pediments, 3-5% slope)										
0-15	Ap	6.9	0.12	0.30	10.5	12.0	5.5	0.4	0.5	19.4
15-36	Bw1	7.2	0.04	0.72	12.5	14.0	6.8	0.6	0.5	22.7
36-59	Bw2	7.8	0.06	0.62	16.9	13.2	7.6	0.4	0.7	22.9
59-84	Bw3	7.6	0.05	0.49	20.5	12.6	10.5	0.6	0.7	23.5
84-120	BC	7.7	0.05	0.24	43.2	13.8	9.2	0.4	0.5	24.8
P5: Loamy Lithic Haplustept (Gently sloping pediments, 3-5% slope)										
0-15	Ap	6.9	0.04	0.51	12.5	9.8	7.6	0.3	0.4	19.1
15-33	Bw1	6.9	0.03	0.65	15.6	12.4	8.4	0.2	0.6	22.7
33-48	BC	6.9	0.06	0.38	21.2	11.4	7.5	0.2	0.6	20.8
P6: Loamy Lithic Ustorthent (Very gently sloping pediment, 1-3% slope)										
0-18	Ap	8.1	0.25	0.45	65.3	13.2	7.8	0.4	0.8	23.2
18-35	AC	8.0	0.29	0.37	30.2	14.4	8.4	0.6	0.8	25.3

P7: Fine-loamy Typic Haplustept (Very gently sloping pediments, 1-3% slope)										
0-15	AI	7.5	0.08	0.44	9.5	14.0	5.0	0.6	0.8	21.8
15-37	Bw1	7.2	0.09	0.45	9.0	15.6	6.4	0.7	0.9	24.6
37-59	Bw2	7.3	0.08	0.38	8.6	16.2	7.5	0.8	0.8	25.7
59-85	BC	7.6	0.12	0.30	13.5	15.6	4.6	0.7	0.7	22.8
P8: Fine-loamy Typic Haplustept (Nearly level pediment, 0-1% slope)										
0-19	Ap	7.6	0.06	0.61	12.5	11.2	6.8	0.4	0.5	19.3
19-38	Bw1	7.6	0.06	0.55	17.3	12.8	7.6	0.4	0.5	21.7
38-63	Bw2	7.7	0.05	0.43	19.2	13.0	8.2	0.6	0.7	23.2
63-88	Bw3	7.6	0.06	0.32	19.2	13.6	8.8	0.7	0.7	24.6
88-106	Bw4	7.7	0.07	0.29	13.5	14.2	9.6	0.5	0.6	25.4
106-136	BC	8.3	0.13	0.23	20.4	13.8	7.0	0.4	0.4	22.4
P9: Fine-loamy Ustic Haplocambids (Nearly level plains, 0-1% slope)										
0-16	Ap	7.4	0.10	0.68	13.0	13.6	6.8	0.4	0.5	21.6
16-33	Bw1	7.8	0.15	0.71	15.3	15.6	7.3	0.4	0.6	24.6
33-54	Bw2	8.2	0.09	0.65	16.5	15.8	7.9	0.6	0.7	25.7
54-68	Bw3	8.2	0.10	0.63	11.6	16.4	7.6	0.7	0.8	26.3
68-87	Bw4	8.3	0.19	0.41	12.6	17.6	8.8	0.3	0.4	27.6
87-117	BC	8.4	0.20	0.23	20.6	16.2	5.2	0.1	0.4	22.8
P10: Fine-loamy Ustic Haplocambid (Nearly level plains, 0-1% slope)										
0-16	Ap	7.6	0.16	0.63	12.2	11.6	6.8	0.4	0.6	20.2
16-33	Bw1	7.6	0.13	0.45	13.4	12.4	7.2	0.7	0.8	21.8
33-54	Bw2	7.7	0.12	0.41	15.6	12.4	5.0	0.3	0.6	19.3
54-68	Bw3	7.6	0.11	0.30	11.9	11.6	5.6	0.6	0.8	19.7
68-87	Bw4	7.8	0.10	0.27	11.9	14.8	8.4	0.4	0.5	25.5
87-117	BC	7.8	0.19	0.23	14.5	14.0	5.8	0.6	0.7	21.6

Soil classification

The soils of Sirohi district possessed *ustic* and *aridic* soil moisture regimes, *hyperthermic* soil temperature regime and mixed mineralogy. The soils of the pedon 1 and 6 have been classified as loamy-skeletal (P1, gravels >35%), and loamy (P6) Lithic Ustorthents by virtue of having lithic contact, ochric epipedon and absence of any sub-surface diagnostic horizon. Pedon 5 had lithic contact within 50 cm and cambic sub-surface horizon and hence classified as Lithic Haplustepts at sub-group level with loamy (texturual family class) and P2 as Typic Haplustepts (no lithic contact) but coarse-loamy textural family class. The pedons P3, P 4, P7 and P8 have been classified as Typic Haplustepts with fine-loamy (P3, P7 and P8) and fine (P4) textural family class. The pedons P9 and 10, due to *aridic* moisture regime, and the presence of cambic horizon, are placed in Cambids sub-order. These pedons have been classified as Haplocambids at great group level. As these pedons remain dry in all parts of the moisture control section for less than threefourths of the time and have a moisture regime bordering on *ustic*, these soils are classified as fine-loamy, Ustic Haplocambids.

It may be concluded that the present study may help in better understanding of soil-water relationship and in turn productivity of soils and crops.

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Effect of fertilizer and tillage on productivity and nutrient uptake in rainfed wheat *(Triticum aestivum)* in an Alfisol

SANJEEV K. SANDAL, KAPIL SAINI, ANIL KUMAR, NAVEEN KUMAR and SANJAY K. SHARMA

Department of Soil Science, C.S.K. Himachal Pradesh Agricultural University, Palampur-176 062, India

Abstract: Field experiments were conducted at the experimental farm of CSK HPKV, Palampur during *rabi* 2006-07 and 2007-08 for evaluating the effects of fertilizer recommendations and prescription based yield targets of wheat grown with varying tillage operations under rainfed condition. The treatments comprised of fertilizer recommendation approaches with three yield targets of 15, 25 and 30 qha^{-1}(T_{15}, T_{25} and T_{30}), state level dose (SLD), soil test based (STB) and different tillage operations. Results indicated that the grain and straw yields were higher in T_{30} as compared to soil test-based, state level doses. T_{15} and $T_{25.}$ Among the tillage operations, application of Lantana *spp.* as mulch @ 15 tha^{-1} on dry weight basis to previously standing okra crop at recede of monsoon and sowing of succeeding wheat with minimum tillage (M+MT) was found to be the best over conventional tillage (CT). The T_{30} yield target with conservation of moisture by mulching and sowing of wheat with minimum tillage (M+MT) had significantly higher grain yields and N, P and K uptake in grain and straw as compared to other treatment combinations.

Additional key words: *Rainfed wheat, tillage operations, fertilizer recommendations, target yield, B:C ratio, nutrient content and uptake*

Introduction

Wheat (*Triticum aestivum*) is an important *rabi* crop of Himachal Pradesh. The average productivity of wheat in the state is low (13.7 q ha^{-1}) compared to the national average productivity (27.6 q ha^{-1}). The doses of NPK fertilizer are generally recommended as state level doses (SLD) for irrigated and rainfed conditions without considering the available nutrient status of a given soil. Soil test-based fertilizer recommendations provide adequate and balanced nutrition to plants. The soil-test-based fertilizer recommendations are calculated by increasing or decreasing the state level doses by 25 per cent depending upon the soil fertility classes (low, medium and high). The major disadvantage of this system is that the medium range has wide variability in their values. Prescription-based fertilizer recommendations provide a scientific basis for balanced fertilization between soil and fertilizer nutrients to achieve a pre-determined yield target compared to general soil test- based recommendations. In this approach, three factors, *viz.*, (a) nutrient requirement in kgha^{-1} of grain of a particular crop, (b) efficiency of nutrients from soil available nutrients and (c) efficiency of nutrients from added fertilizer, are calculated by conducting standard test crop experiment. Further, these parameters are used to develop fertilizer adjustment equations under irrigated conditions (Ramamoorthy *et al.* 1967). However, uncertainty of rains on year to year basis is one of the major limitations to develop such equations under rainfed conditions.

Application of locally available biomass such as *Lantana, Eupatorium* etc. as mulch in previous standing *kharif* crop at the recede of monsoon for conserving and carry-over post monsoon residual moisture till sowing time of wheat and sowing of wheat with minimum tillage have been recommended for optimum utilization of conserved soil moisture which resulted in proper germination and establishment of rainfed wheat (Acharya and Kapur 1993; Sandal and Acharya 1997). This practice not only conserved seed-zone moisture but also modified thermal regimes leading to increase in wheat yield. It also maintains friable soil structure and over the year increase in the population of earthworm had also been observed (Acharya *et al.* 1998). If these techniques modify hydro-thermal regimes then the outcome of different fertilizer recommendations approaches are expected to be different under rainfed conditions. Considering the above, present investigation was undertaken to study the effect of various fertilizer doses and tillage operations on the yield of wheat under rainfed conditions.

Materials and Methods

The present study was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the year 2006-07 and 2007-08.The area lies in Palam Valley (32°06' N; 73°03' E) at an elevation of 1290 m above MSL in Kangra district, Himachal Pradesh which represents the mid hills sub-humid agro-climatic zone of the state in North Western Himalaya. The soil (0.015 m layer) of the experimental field is silty clay loam. The soils are rich in clay content with accumulation of sesquioxides. Taxonomically, the soils are classified as Typic Hapludalf (Verma 1979). The soil was acidic (pH 5.6), low in available N (259 kg ha^{-1}), high in available P (46 kg ha^{-1}) and medium in available K (226 kg ha^{-1}).The CEC and organic carbon was 12 C mol (P^{+}) kg^{-1} and 0.92 per cent respectively.

The treatments comprised of a) fertilizer recommendation approaches - state level dose (SLD), soil test-based (STB) and three yield targets of 15, 25 and 30 qha^{-1}(T_{15}, T_{25} and T_{30}) and b) tillage operations - conventional tillage (CT) and application of *Lantana* as mulch @ 15 tha^{-1} on dry weight basis to previously standing okra crop at recede of monsoon and sowing of succeeding wheat with minimum tillage (M+MT). The treatments were replicated thrice in a randomized block design.

The fertilizer doses for various fertilizer recommendation approaches except SLD were calculated based on initial soil test values of N, P and K obtained under each treatment (Table 1). In STB, N dose was increased by 25 per cent whereas, P was decreased by 25 per cent during 2006-07 and 2007-08. However, K dose remain unchanged during 2006-07 but decreased by 25 per cent during 2007-08. In prescription-based fertilizer doses, N was applied to all the targets during both the years; K was applied to 25 and 30 qha^{-1} targets during 2006-07 and to all the targets during 2007-08. No P was applied to any target during both the years (Table 1). Half of N and complete P and K were applied as basal and the remaining N was given in two equal splits around maximum tillering and flowering stages of wheat.

Table 1. Initial soil nutrient status and calculated fertilizer doses in rainfed wheat

Fertilizer Recommendation approach	Initial nutrient status (kg ha^{-1})						Fertilizer doses (kg ha^{-1})					
	2006-2007			2007-08			2006-2007			2007-08		
	N	P	K	N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
SLD	261.7 (± 3.9)*	37.8 (±3.9)	224.5 (±14.5)	252.8 (±5.7)	31.4 (±4.0)	228.3 (±16.7)	80	40	40	80	40	40
STB	263.3 (± 4.5)	41.2 (±4.7)	228.4 (±21.9)	260.0 (±3.8)	32.6 (±5.3)	253.8 (±14.9)	100	30	40	100	30	30
T_{15}	258.0 (±3.3)	35.4 (±4.6)	232.0 (±10.8)	205.4 (±6.4)	31.3 (±2.8)	176.8 (±9.7)	43	0	0	49	0	3
T_{25}	255.5 (±6.0)	42.8 (±3.4)	226.7 (±10.9)	197.9 (±5.9)	32.9 (±3.4)	178.9 (±12.2)	67	0	18	99	0	27
T_{30}	260.7 (±3.1)	43.3 (±3.8)	230.9 (±13.1)	202.5 (±7.4)	30.8 (±3.0)	180.0 (±12.7)	116	0	30	123	0	39

The fertilizer adjustment equations:
$FN = 4.91\,T - 0.12SN$, $FP_2O_5 = 7.86\,T - 5.16SP$ and $FK_2O = 2.44\,T - 0.19\,SK$ where, FN, FP_2O_5 and FK_2O are fertilizer doses in $kgha^{-1}$, 'T' is the yield target and SN, SP and SK are the soil test values for N, P and K respectively.
*Values in parenthesis indicate standard deviations

The grain and straw yield of wheat were recorded at harvest and expressed in q ha^{-1}. Per cent deviation was determined with respect to grain yield. B:C ratio was calculated as the ratio of earning from grain yield and the cost of fertilizers. The plant samples *viz.*, grain and straw were analyzed for per cent N, P and K contents following standard procedures (Jackson 1973). The grain and straw yields were used to compute nutrient uptake in plants.

Results and Discussion

Yields

The grain and straw yields of wheat were higher under soil test-based (STB) fertilizer recommendations as compared to state level dose (SLD). Among the yield targets, T_{30} showed highest grain and straw yield compared to T_{25} and T_{15} during both the years. Verma *et al.* (2007) also reported an increase in grain and straw yield with the increase in prescription-based fertilizer doses on farmer's field. Conservation tillage (M+MT) significantly increased grain and straw yield of rainfed wheat as compared to conventional tillage (CT) because of better hydro-thermal regime leading to better root and shoot growth (Table 2). Similar findings have also been reported by Sharma *et al.* (2005) and Islam *et al.* (2005). Among treatment combinations, M+MT with T_{30} recorded maximum grain yield might be due to the effects of soil test-based prescription of fertilizer doses and moderation of hydro-thermal regimes. CT with T_{15} gave minimum grain yield (Table 2).

Table 2. Effect of fertilizer recommendation approaches and tillage operations on grain and straw yield of rainfed wheat

Fertilizer	Grain yield (q ha^{-1})						Straw yield (q ha^{-1})					
Recommen	2006-2007			2007-08			2006-2007			2007-08		
dation approach	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean
SLD	32.60	35.17	33.88	26.72	30.51	28.62	48.53	50.87	49.70	38.91	41.12	40.02
STB	36.07	36.40	36.23	27.00	34.41	30.71	50.77	52.47	51.62	41.13	46.64	43.89
T_{15}	18.33	21.93	20.13	11.09	17.22	14.16	31.93	32.30	32.12	28.32	31.06	29.69
T_{25}	23.83	38.33	31.08	21.53	24.34	22.94	36.30	54.90	45.60	36.13	42.24	39.19
T_{30}	32.00	42.47	37.23	29.63	34.71	32.17	45.70	61.20	53.45	27.25	36.84	32.05
Mean	28.57	34.86		23.19	28.24		42.65	50.35		34.35	39.58	
CD (P= 0.05)												
T		1.44			1.62			2.21			2.47	
F		2.27			2.42			3.49			3.73	
TXF		3.22			3.18			4.94			5.23	

Per cent deviation and B.C Ratio

The per cent deviation values in grain yield among all the yield targets were positive and considerably higher under M+MT compared to CT where the deviation values were negative during both the years (Table 3). The favourable per cent deviation obtained under M+MT was due to higher soil water, better root and shoot growth which ultimately increased the biological yields in all the yield targets. Sandal *et al.* (2007) also reported favourable effects of conservation tillage in bringing the per cent deviation either within range or over estimation of yield targets under rainfed condition.

The B.C ratio calculated by dividing the cost of produce with cost of seed and fertilizers added indicated that STB and SLD had lower B.C ratio as compared to all yield targets during both the years. This was due to less doses of applied among yield targets as compared to SLD and STB (Table 3). The Maximum B:C ratio was obtained for T_{15} yield target during both the years due to less doses of fertilizers.

Table 3. Effect of fertilizer recommendation approaches and tillage operations on per cent deviation and B:C ratio in rainfed wheat

Fertilizer	Per cent deviation from pre-fixed target						B:C ratio					
Recommen	2006-2007			2007-08			2006-2007			2007-08		
dation approach	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean
SLD	-	-	-	-	-	-	2.44	2.62	3.20	2.00	2.28	2.14
STB	-	-	-	-	-		3.10	3.13	3.12	2.36	3.01	2.69
T_{15}	+22.2	+46.2	+34.2	-26.1	+14.8	-5.7	12.32	14.71	13.46	6.43	9.93	8.18
T_{25}	-4.7	+53.3	+24.3	-13.9	-2.6	-8.2	8.93	14.34	11.64	5.46	6.14	5.80
T_{30}	+6.7	+41.6	+24.1	-1.2	+15.7	+7.2	6.92	9.24	8.08	4.96	6.90	5.93
Mean	-	-	-	-	-	-	6.74	8.81		4.24	5.65	

Cost of wheat grains = Rs.6.30 kg^{-1}

Cost of Fertilizers: N=Rs.10.92 kg^{-1}; P_2O_2 = Rs.24.37 kg^{-1} and K_2O = Rs.7.72 kg^{-1}

Table 4. Effect of fertilizer recommendation approaches and tillage operations on N, P and K uptake in rainfed wheat (2006-08)

Fertilizer Recommendation Approaches	Nitrogen uptake (kg ha^{-1})						Phosphorous uptake (kg ha^{-1})						Potassium uptake (kg ha^{-1})					
	Grain			Straw			Grain			Straw			Grain			Straw		
	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean	CT	M+MT	Mean
SLD	65.0	74.2	69.7	17.5	20.2	18.8	10.1	11.2	10.6	1.3	1.4	1.3	14.5	20.7	17.5	39.3	43.2	41.3
STB	69.7	80.4	75.0	18.8	21.8	20.5	11.4	13.1	12.4	2.3	2.5	2.4	13.9	19.1	16.4	42.3	52.5	47.3
T_{15}	32.4	44.0	38.2	12.1	13.9	13.0	5.1	6.9	6.0	0.9	1.0	0.9	7.9	10.6	9.3	19.0	31.0	24.7
T_{25}	50.1	71.8	60.8	15.2	21.4	18.2	7.3	11.0	9.2	1.1	1.5	1.3	12.5	16.9	14.9	35.5	59.7	46.6
T_{30}	68.7	88.8	78.4	15.7	23.5	19.7	9.9	13.1	11.5	1.1	2.0	1.7	17.9	24.3	21.2	38.7	61.8	49.6
CD (P=0.05)																		
T		3.6			1.1			0.4			0.3			1.6			4.7	
F		5.4			1.7			0.7			0.4			2.5			7.4	
TXF		7.6			2.3			1.1			0.6			3.6			10.6	

Nutrient uptake

The nutrient uptake during 2006-7 and 2007-08 was averaged and mean values are given in table 4. The mean NPK uptake values were higher under STB as compared to SLD except for potassium uptake in wheat grains. Higher N and K uptake was primarily due to higher biological yields and nutrient concentration. The low fertilizer use under state level recommendations was due to imbalanced application of N,P and K as these treatments did not take into consideration either the crop nutrient requirement or initial soil-test values. T_{30} showed highest nutrient uptake among all the fertilizer recommendations, except for phosphorus, which was highest under STB because of P application at sowing. Optimization of fertilizer use *i.e.* balanced fertilization, based on targeted yield concept has also been explained by Verma *et al.* (2002). Conservation of moisture by mulching and sowing of wheat with minimum tillage (M+MT) significantly increased the N, P and K uptake in grains and straw as compared to conventional tillage (CT). Turner and Asseng (2005) obtained increased fertilizer use in wheat by minimum tillage.

Conclusion

From the present study it can be concluded that T_{30} yield target with conservation of moisture by mulching and sowing wheat with minimum tillage (M+MT) had significantly higher grain yields and higher N,P and K uptake in grain and straw as compared to rest of the treatment combinations.

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Soil resources assessment for crop planning in Medak district, Andhra Pradesh

B.A.DHANORKAR, ARTI KOYAL, D.S. MOHEKAR[1], L.G.K.NAIDU, R.S.REDDY AND DIPAK SARKAR[1]

National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-5600024, India
[1]National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, India

Abstract: An attempt was made to assess the soil resources of Medak district and their fertility in Andhra Pradesh. Ten major soils covering 64 per cent area of the district were analysed for their physical and chemical properties. These soils were shallow to deep, calcareous with Vertic properties, medium deep red clay, medium deep red gravelly loam, shallow black gravelly clay, shallow red loam, alluvial clay and deep red clay. Soils were well to moderately well drained and differ widely in soil reaction (pH 5.0 to pH 9.3) but low in organic carbon. The CEC of soils varied from <6 cmol(+) kg^{-1} to >40 cmol(+) kg. Besides, one thousand seven hundred surface samples from 2.5 km grid interval were collected and analysed for macro and micronutrient status. About 43.2 per cent of area was low, 37.3 per cent medium and 13.2 per cent high for available nitrogen. Nearly 80.1 per cent area had low available phosphorus and 12.6 per cent as high. The available potassium was low in 41.3 per cent and medium in 50.9 per cent area. Based on the basis of soil morphology, fertility, physical and chemical properties and climate situation, suggestions were made for sustainable crop planning in the district.

Additional key word: *Soil fertility, physic-chemical properties, long term fertility changes, suggested land use*

Introduction

The comprehensive knowledge of soil resources is essential for maintaining soil health, productivity on sustained basis. The growing of high yielding varieties under intensive agro-inputs has resulted in deficiency of nutrients. Agriculture is the main occupation of nearly 75 per cent of the population in the Medak district. About 42 per cent of the area is under cultivation mostly as rainfed. Irrigated area covers an area of 1,36,445 ha (14%). The yield(s) of different crops in the district are low as compared to state average (Reddy *et. al.* 2005). Keeping these into consideration, the present investigation was undertaken to characterize and classify the soils to suggest viable crop plan.

Material and Methods

Medak district (17°27' to 18°18' N 77°28' to 79°10' E) cover an area of 9,71,086 ha with an average annual rainfall of 890 mm of which about, 76 per cent is received during south west monsoon period. There is wide variation in geology *viz.* granite and granite-gneiss, basalt, laterite and alluvium, and also in physiography and vegetation. The district has 45 revenue mandals and 12 agricultural divisions.

The surface soil samples (1700) were collected at 2.5 km grid interval covering all the mandals in the district and analysed for macro and micronutrients. The available nitrogen was estimated using alkaline permanganate method as described by Subbaiah and Asija

(1956). Available phosphorous was determined by Olsen method (Olsen *et.al.* 1954) and Bray's method (Black 1965) and available potassium was determined by flame photometry after extraction with neutral normal ammonium acetate solution (pH 7.0). Soil pH, organic carbon, particle-size distribution and CEC were determined using standard procedures (Jackson 1973).

Results and Discussion

Physical and chemical properties of dominant soils

The soils of Medak district are very shallow (Nagalgidda series) to very deep (Chitkul, Kadirabad, Kasireddipalli and Uplingapur series). Very shallow soils are distributed in Narayankhed, Zaheerabad, Shankarampet and Ramayampet agricultural divisions. Very deep soils (Kadirabad, Kasireddipalli, and Uplingapur series) occur in all the divisions of the district. The organic carbon content in the soil varied from 0.11 to 1.17 per cent (Table 1) and decreased with depth. Soils vary widely in texture of the control section and ranged from gravelly red loam (Manasapalle series) to clay (Kasireddipalle series). Gravelly red loamy soils and fine soils are distributed in all the agricultural divisions of the district. Soils in the district are well drained (Chinnaloni, Kondalaswamy, Manasapalli, Nagalgidda, Nemlimet and Uplingapur series) to moderately well drained (Chitkul, Kadirabad, Kasireddypalli and Tadamanur series). They differ widely in reaction (pH 5.0 to 9.3). Black soils are non-gravelly clay except shallow black soils of Nagalgidda series which is fragmental (>90 per cent gravels). Majority of red soils are gravelly in nature except Uplingapur series. The CEC of the soils ranged <6 cmol (+) kg $^{-1}$ to very high >40 cmol (+) kg $^{-1}$.

Table 1. Physical and chemical properties of dominant soils and their distribution in agricultural divisions of Medak district

Soils	Depth (cm)	Horizon	pH	OC (%)	Texture (USDA)	Gravel (%)	CEC [cmol (+)kg^{-1}]	$CaCO_3$ Equiv (%)	Distribution in agricultural Divisions
Chinnaloni : Very-fine, smectitic, isohyoerthermic Vertic Haplustepts									
	0-10	Ap	6.9	1.17	c	-	65	-	Narayankhed, Zaheerabad
	10-28	Bw1	6.9	1.10	c	-	69.2	-	Shankarampet, Andole-
	28-49	Bw2	7.0	1.07	c	-	70	-	Jogipet
Chitkul : Fine, smectitic, isohyoerthermic Vertic Haplustepts									
	0-20	Ap	7.7	1.05	cl		25.1	2	Dubbak,Narsapur,
	20-40	Bw1	7.7	0.31	cl	-	23.6	-	Ramayampet,
	40-60	Bw2	7.6	0.30	cl	-	22.8	-	Gajwel,Medak&allagri.
	60-81	Bw3	7.6	0.26	cl	-	23.8	-	divisions except Zaheerabad
	81-113	Bw4	7.8	0.24	c	-	23.8	-	
	113-150	Bw5	8.1	0.24	cl	-	23.8	-	
Kadirabad : Fine, smectitic (calcareous), isohyoerthermic Typic Haplusterts									
	0-13	Ap	8.2	0.59	c	-	38.6	4	All Agricultural Divisions
	13-37	BA	8.2	0.45	c	-	38.7	4	
	37-74	Bss1	8.7	0.33	c	-	40.1	5	
	74-108	Bss2	8.4	0.33	c	-	44.5	5	
	108-120	Bss3	9.2	0.29	c	-	42.5	5	
	120-150	Bss4	9.2	0.21	c	-	48.8	9	

Kasireddipalli :Very-fine, smectitic (calcareous), isohyoerthermic Typic Haplusterts								
0-21	Ap	8.1	0.67	c	-	46.1	4	All Agricultural Divisions
21-48	BA	8.0	0.54	c	-	50.2	6	
48-71	Bss1	8.0	0.51	c	-	47.1	5	
71-91	Bss2	7.9	0.50	c	-	48.2	5	
91-117	Bss3	8.1	0.47	c	-	51.4	5	
117-138	Bss4	8.2	0.44	c	-	49.3	7	
138-150	Bss5	8.1	0.49	c	-	49.6	7	
Kondalaswamy: Fine, mixed, isohyoerthermic Typic Haplustalfs								
0-15	Ap	6.0	0.39	scl	8	7.9	-	All Agricultural Divisions
15-41	Bt1	7.3	0.47	gsc	15	12.8	-	
41-70	Bt2	7.5	0.33	gc	20	14.7	-	
Masanpalli : Loamy- skeletal, mixed,, isohyoerthermic Typic Haplustalfs								
0-11	A	6.3	0.31	gls	15	2.7	-	All Agricultural Divisions
11-24	Bt1	5.7	0.27	gsl	35	3.8	-	
24-36	Bt2	5.6	0.25	gscl	50	7.1	-	
36-65	Bt3	5.1	0.33	gc	60	13.3	-	
Nagalgidda: Fragmental, smectitic, isohyperthermic Lithic Ustorthents								
0-18	A	6.6	3.62	gc	>90	41	-	Narayankhed, Zaheerabad Shankarampet, Ramayampet
Nemlimet : Loamy-skeletal, mixed isohyperthermic Paralithic Haplustalfs								
0-13	A	5.9	0.67	gsl	25	4.4	-	All Agricultural Divisions
13-28	Bt1	5.5	0.48	gsc	35	12.4	-	
28-48	Bt2	5.0	0.39	gc	45	18.8	-	
Tadamanur : Fine, mixed isohyperthermic Typic Haplustepts								
0-12	Ap	8.8	0.82	c	-	25.8	9	All Agricultural Divisions
12-28	Bw1	9.0	0.51	c	-	28.4	9	
28-45	Bw2	9.0	0.46	c	-	32.2	9	
45-62	Bw3	9.1	0.35	c	-	31.3	10	
62-83	Bck	9.3	0.11	gc	25	17.9	31	
Uplingapur : Fine, mixed, isohyperthermic Rhodic Paleustalfs								
0-14	A	5.9	0.28	s	-	1.0	-	All Agricultural Divisions
14-46	Bt1	5.4	0.18	sc	5	6.5	-	
46-96	Bt2	5.2	0.22	sc	10	8.3	-	
96-130	Bt3	5.7	0.16	gsc	15	9.6	-	
130-150	Bt4	5.7	0.12	sc	10	7.7	-	

Available macro and micronutrient status

Available nitrogen

Data showed that nitrogen is low in 43.23 per cent, medium in 37.34 per cent and high in 13.21 per cent (Table 2) in soils. The soils with low to medium in available nitrogen were extensive in Siddipet, Zaheerabad, Ramayampet, Dubbak, Shankarampet, Narsapur, Gajwel, and Andole-Jogipet agricultural divisions and high available nitrogen in the parts of Sadasivpet, Zaheerabad, Gajwel, Dubbak and to a limited extent in other divisions (Reddy *et al.* 2005). The relatively high nitrogen content in these soils could be attributed to more usage of nitrogenous fertilizer and also organic manures under intensive cropping like irrigated rice, sugarcane, commercial crops and vegetables.

Available phosphorus

The data showed that the major area (80.18%) of the district is low in available phosphorus and (13.48%) as high. Almost all the soils in Siddipet, Narayankher, Zaheerabad, Narsapur, Dubbak, Ramayampet, Medak, Shankarampet and Gajwel divisions had low available phosphorus (Table 2). Soils with high phosphorus status were concentrated in Sadasivpet, Sangareddy and Andol–Jogipet agricultural divisions. It might be due to increased use of phosphate fertilizers under intensive agriculture (Naidu *et al.*2002).

Available potassium

Data indicated that 41.3 per cent area is grouped under low, 50.9 per cent under medium, 2.75 per cent under high (Table 2). Soils with low potassium were distributed in Sadashivpet, Zaheerabad, Sangareddy, Narayankher, Dubbak, Siddipet, Narsapur, Ramayampet, divisions and of medium potassium were found in Gajwel, Medak, Siddipet, Narayankher, Ramayampet, Dubbak, Zaheerabad, Andole –Jogipet and Shakarampet divisions. Soils with high available potassium were found in Gajwel, Andole-Jogipet and Dubbak divisions.

Table 2. Changes in soils fertility in Medak district

Divisions	Nitrogen		P_2O_5		K_2O		Mandals
	1990	2002	1990	2002	1990	2002	
Sangareddy	L	M	M	H	H	L	Sangareddy,Patancheru, Ramchandrapuram
Sadashivpet	L	M	L	H	H	L	Kohir,Munipally,Sadashivpet, Kondapur
Zaheerabad	M	L	L	L	H	M	Zaheerabad, Nyalkal, Raikod, Jharasangam
Narayankhed	L	M	L	L	H	M	Narayankhed,Kangati, Manur,Kalher
Medak	L	M	L	L	M	M	Medak, Kulcharam.Papanampet
Jogipet	L	L	L	L	H	M	Jogipet, Pulkal Hatnur
Shankarampet	L	L	L	L	H	M	Shankarampet,Regode, Tekmal, Alladurg
Narsapur	M	M	L	L	H	M	Narsapur, Shivampet, Kodipally, Jinnaram
Ramayampet	L	L	L	L	H	M	Ramayampet, Chegunta, Eldurti, Shankarampet
Siddipet	L	L	L	L	H	M	Chinnakodur, Siddipet, Kondpak, Nangnoor
Dubbak	L	L	L	L	H	M	Dubbak,Tupran,Doulatabad,Mirdoddi
Gajwel	L	L	L	L	H	M	Gajwel,Wargal,Mulag, Jagdevpur

Naidu et al. (2002), Naidu et al. (2011)

Table 3. Interpretation of soils for various uses

Soils	LCC*	Descriptions	Major constraint	Present land use	Suggested land use
Chitkul Kadirabad Kasireddipalli	IIws-IIIws	Good to moderately good cultivable land for sustainable agriculture	Impeded drainage, slow permeability, high shrink swell potential, severe tillage problem, moderate to strong salinity and sodicity,, low available N and P	paddy, sugarcane, sorghum sunflower pigeon pea maize	Bengal gram, sorghum, maize, cotton, sunflower, groundnut, soybean, black gram , green gram as rainfed or rice, sugarcane, chillies, flowers, vegetables., guava, banana, turmeric, ginger
Chinnaloni	IIIes	Moderately good cultivable land for sustainable agriculture	Shallow rooting depth, slow permeability, high shrink-swell potential, moderate erodability, low N and P	Sorghum, pigeonpea, chickpea, sunflower, safflower, green gram , sesame	Black gram, green gram, sorghum, silvipasture under irrigated environment
Kondalaswamy	IIIes	Moderately good cultivable land for sustainable agriculture	Rooting depth, sub-surface gravelliness, low available P	Sorghum paddy, chillies, sugarcane, green gram	Castor, pearlmillet, black gram, green gram, Hort; jujube, custard apple, ramfal, drum stick
Manasapalli Nemlimet	IIIes-IVes	Moderately to fairy good cultivable land for sustainable agriculture	Very shallow to shallow rooting depth, somewhat excessively drained, strongly acid, low available P	Ecalyptus plantaions, reserved forest	Aforestation with improved forest trees
Nagalgidda	VIes	Land not suitable for agriculture	Very shallow rooting depth, very high surface and sub-surface cobbles, moderate slope and severe erodability, low available N and P	Pasture	Pasture and grass land development, aforestation with improved tree species.
Tadamanur	IIs	Good cultivable land for sustainable agriculture	Strongly alkaline,, high lime content, moderately slow permeability, low available P	Paddy, maize, chillies, vegetables	Sunflower, black gram, maize, cotton, sorghum, bengal gram, coriander, chillies, safflower, soybean, guava, sapota, banana, pomegranate
Uplingapur	IIIes	Moderately good cultivable land for sustainable agriculture	Strongly acid, moderate slope, moderate erodability, low available P	Red gram, sorghum, sunflower, groundnut, sugarcane, paddy	Castor, bengal gram, green gram

**Land capability classification (LCC) based on criteria outlined by Klingebiel and Montgomery (1961). Suggested land use based on Reddy et al.(2005) and criteria suggested by Naidu et.al. (2006).*

Long Term Soil Fertility Changes in the district

The data indicated that in the year 1990, all the divisions had low available nitrogen (Table 2) except Narsapur and Zaheerabad divisions. In the year 2002, Sangareddy, Sadashivpet, Narayankhed and Medak showed build up in available nitrogen which could be attributed to more usage of nitrogenous fertilizers and FYM under irrigated rice and sugarcane and commercial crops in these divisions.

Available phophorous

The available phosphorous was low in all the divisions of the district in the year 1990 except Sangareddy division. Similar trend was observed in the year 2002 in all the divisions except in Sangareddy and Sadashivpet divisions which showed build up of available phosphorous. This may be attributed to increased use of phosphatic fertilizers for irrigated rice, sugarcane and commercial crops (Table 2).

Available potassium

The available potassium in the district was high in all the divisions in (1990) except Medak division. Potassium status after a decade (2002) showed depletion trend in all the divisions. The possible reason attributed to K depletion may be due to less use of potassic fertilizers by farmers (Table 2).

It has been observed that under the intensive agriculture (Table 3) there is either stability or built up of available nitrogen. There are no changes in available phosphorus in most of the agricultural divisions except Sangareddy and Sadashivpet (Table 2). Available potassium showed decreasing trend in all the agricultural divisions whether it is under intensive agriculture or rainfed agriculture (Naidu *et.al.* 2011).

Based on potential and constraints of the soils (land capability classification) and present land use, viable land use plan has been suggested (Table 3).

Conclusions

The present study concludes that in Medak district majority of soils have moderate to good potential for agriculture. Present and past fertility status in the soils of the district warrants for modification in fertilizer recommendations which should be site-specific. Suggested land use based on potential and constraints of the soil would be helpful for getting economic returns. The above information on soil resources and fertility status will provide database for district level planning.

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Need for developing user friendly soil maps: A case study of Andhra Pradesh

L.G.K. NAIDU, V. RAMAMURTHY, S. SRINIVAS, R.S. REDDY AND DIPAK SARKAR[1]

National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore-560 024, India
[1]National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, India

Abstract: To meet the clientele requirement, there is need for developing user friendly soil maps which is simpler and easy to comprehend. As a case study, soil map of Andhra Pradesh with 238 soil map units as associations of soil families have been interpreted and regrouped into 15 soil management units (SMU) based on aforesaid soil parameters *viz*. soil texture, depth, clay content, drainage, presence of gravel and calcium carbonate and mineralogy. These 15 SMU require different management inputs and conservation needs. The brief description of these management units are described in an easily understandable format for various users of soil resource maps and soil survey reports.

Additional key words: *Soil management units, soil maps, user friendly, mapping units*

Introduction

Soil surveys provide a scientific inventory of soil resources their characteristics and distribution. The present soil resource maps brought out by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) have a lengthy legend and highly technical with taxonomic terms which are difficult to understand by the different users. Number of mapping units were minimum in Manipur state (20), followed by Nagaland (36), Kerala (38), Tripura (43), Arunachal Pradesh (46), Sikkim (69), Assam (84), Himachal Pradesh (95), Karnataka (121), Punjab (124), Jammu and Kashmir (140), Odisha (159), Bihar (175), Haryana (199), Andhra Pradesh (238), Tamil Nadu (285), Uttar Pradesh (321), Maharashtra (356), Gujarat (370), Rajasthan (375), and Madhya Pradesh (undivided) (852). Soil information users and researchers need a soil map with manageable numbers of map units to understand and develop management practices for different crops. In this context, grouping of similar soils based on their management domain will become handy to users. With the advent of computer technology and the ability to process information rapidly, there is a concerted effort by scientists to refine the techniques of manipulating information. Land resources and other related information together with a decision support system, with proper spatial information, can be used more specifically to infer the potentials of the land system (Bouma *et al.* 1995), and consequently, the area can be grouped into more homogeneous parcels of land, which have similar management requirements. These are referred to as Soil Management Units (SMUs). Therefore, an attempt has been made to translate the basic soil resource map of Andhra Pradesh into simpler user friendly soil map that can be understood by all the intended users.

Materials and Methods

The soil map of Andhra Pradesh published by NBSS&LUP (Reddy *et al.* 1996) had 238 map units which represents 6 orders, 11 sub-orders, 18 great groups and 26 sub-groups (Fig.1). On the other hand, user friendly map (management domain map) was generated based on the principles of similar soils (USDA 1975) and common soil-site parameters (Table 1), referred by different user's (Naidu *et.al.* 2004), considering soil depth, texture, drainage, gravelliness and calcareousness, which affect the soil behaviour and management responses. The basic soil resource map at sub-group level (Fig.1) and user friendly soil map (Fig. 2) with corresponding legends are presented below for comparison.

Table 1. User's criteria for different interpretative purposes

Soil - site parameters	User	Purpose
Soil texture, depth, clay content, drainage, presence of gravel in the sub-soil	Agronomists	Crop planning/schedule of irrigation
Soil texture, soil reaction, presence of calcium carbonate, mineralogy	Agronomists and soil scientists	Fertilizer management and recommendation
Drainage, salinity, sodicity, soil reaction		Land reclamation
Soil depth, texture, drainage, depth and presence of gravel & calcium carbonate	Horticulturists/ Foresters	Plantation of forest *spp.* and horticultural crops
Soil depth, soil texture, drainage, clay content & type, salinity, sodicity, depth of gravel occurrence and slope	Engineers	Laying of septic tanks, underground drainage for sewage disposal, civil construction works & Roads and soil conservation works
Simple map and easy understandable terminology	Extension workers	Transfer of farming technology.
	Planners	Planning and implementation of different programmes
	Farmers	Management of farm

Source: Naidu *et.al.* (2004)

Results and Discussion

The basic soil resource map of Andhra Pradesh has 238 soil units described with lengthy legend and highly technical soil taxonomic terms. The whole legend runs into number of pages which discourages the users. Hence, the anticipated demand for these maps is found to be far less than the expected. Therefore a map with 26 dominant soils (subgroup level) and corresponding legend is illustrated to indicate merits and demerits of basic soil map to different users (Fig.2).

Legend -Soil Map (Subgroup level)

1. *Typic Paleustalfs*: Deep, well drained, strongly acid to neutral, loam to clayey soils on 3 to 10% slopes with moderate erosion (8, 72,866 ha; 3.1% of TGA)
2. *Rhodic Paleustalfs*: Moderately deep, well drained, slightly acid to neutral, gravelly loam to gravelly clay soils on 3 to 10% slopes with moderate to severe erosion (19,86,911 ha; 7.2%)
3. *Kandic Paleustalfs*: Very deep, well drained, slightly acid to neutral, highly gravelly clay soils on 3 to 10% slopes with moderate erosion (1, 58,099 ha; 0.6%)
4. *Typic Rhodustalfs:* Moderately deep to deep, well drained, medium acid to neutral, gravelly loam to gravelly clay soils on 3 to 10% slopes with moderate erosion (21, 11,105 ha; 7.6%)
5. *Typic Haplustalfs*: Slightly deep, shallow to deep, well drained , medium acid to neutral, loam to grav-

elly loam and gravelly clay soils on 1 to 10% slopes with moderate erosion (32,18,151 ha; 11.7%)

6. *Paralithic Haplustalfs*: Shallow, somewhat excessively drained, gravelly clay soils on 33 to 50% slopes (hill ranges) with severe erosion (3,35,737 ha; 1.2%)

7. *Ustic Haplargids*: Shallow to slightly deep, well drained, gravelly clay soils on 3-10% slopes with severe erosion (3,94,433 ha; 1.4%)

8. *Ustic Haplocambids*: Shallow to moderately shallow, excessively drained, gravelly clay soils on 8 to 15% slopes (hills and ridges) with severe erosion (3,95,571 ha; 1.4%)

9. *Ustertic Haplocambids*: Deep, well drained, clayey soils on 1 to 3% slopes with slight erosion (1,30,251 ha; 0.4%)

10. *Typic Ustipsamments*: Very deep, excessively drained, neutral to mildly alkaline, sandy soils on 3 to 5% slopes (8,72,866 ha; 3.1% of TGA)

11. *Typic Ustorthents*: Deep, excessively drained, gravelly loam soils on 3 to 10% with severe erosion (1,89,990 ha; 0.07 %)

12. *Lithic Ustorthents*: Shallow, well drained, neutral, clayey soils on 3 to 5% slopes with severe erosion and stony surface here and there (12,36,770 ha; 4.5%)

13. *Paralithic Ustorthents*: Shallow, somewhat excessively drained, gravelly loam soils (hills and ridges) with severe erosion (8,12,781 ha; 2.9 %)

14. *Typic Sulfaquepts*: Deep, imperfectly drained, strongly saline mangroves (63359 ha; 0.2%)

15. *Typic Tropaquepts*: Very deep, poorly drained, calcareous clayey soils on 0 to 1 % slopes with shallow water table (82,818 ha; 0.3 %)

16. *Typic Haplustepts*: Deep, well drained, clayey soils on 1 to 3 % slopes with slight erosion (4,369,731 ha; 15.9 %)

17. *Paralithic Haplustepts*: Shallow, well drained, medium acid to neutral, gravelly clay soils on 3 to 15% slopes with moderate erosion (8,52,656 ha; 3.1%)

18. *Lithic Haplustepts*: Shallow, excessively drained, gravelly loam soils on 3 to 10 % slopes with moderate erosion (9,15,751 ha; 3.3 %)

19. *Aquic Haplustepts*: Deep to very deep, imperfectly drained, mild to strongly alkaline, calcareous clayey soils in valleys on 0-3% slopes (11,21,367 ha; 4.0%)

20. *Vertic Haplustepts*: Moderately deep to deep, moderately well drained, moderately to strongly alkaline soils on 0-3% slopes with moderate erosion (21,86,462 ha; 7.9%)

21. *Typic Agriustolls*: Moderately deep, somewhat excessively drained, gravelly loam to gravelly clay soils on 33 to 50% slopes with severe erosion (5,53,735 ha; 2.0%)

22. *Typic Haplusterts*: Deep to very deep, moderately well drained, moderately to strongly alkaline, calcareous/non-calcareous soils on 0-3% slopes with moderate erosion (22,24,534 ha; 8.0%)

23. *Leptic Haplusterts*: Moderately deep, moderately well drained, calcareous soils on 1 to 3 % slopes with slight erosion (3,77,084 ha; 1.3 %)

24. *Aridic Haplusterts*: Very deep, moderately well drained, calcareous soils on undulating lands with moderate erosion (32,585 ha; 0.1 %)

25. Chromic Haplusterts: Deep to very deep, moderately well drained, calcareous soils on 1 to 3 % slopes with slight erosion (3,18,327 ha; 1.1 %)

26. Entic Haplusterts: Very deep, moderately to imperfectly drained, calcareous/non calcareous soils on 1 to 3 % slopes with shallow water table (95,780 ha; 0.3 %)

27. Rock lands (19,66,877 ha; 7.1 %)

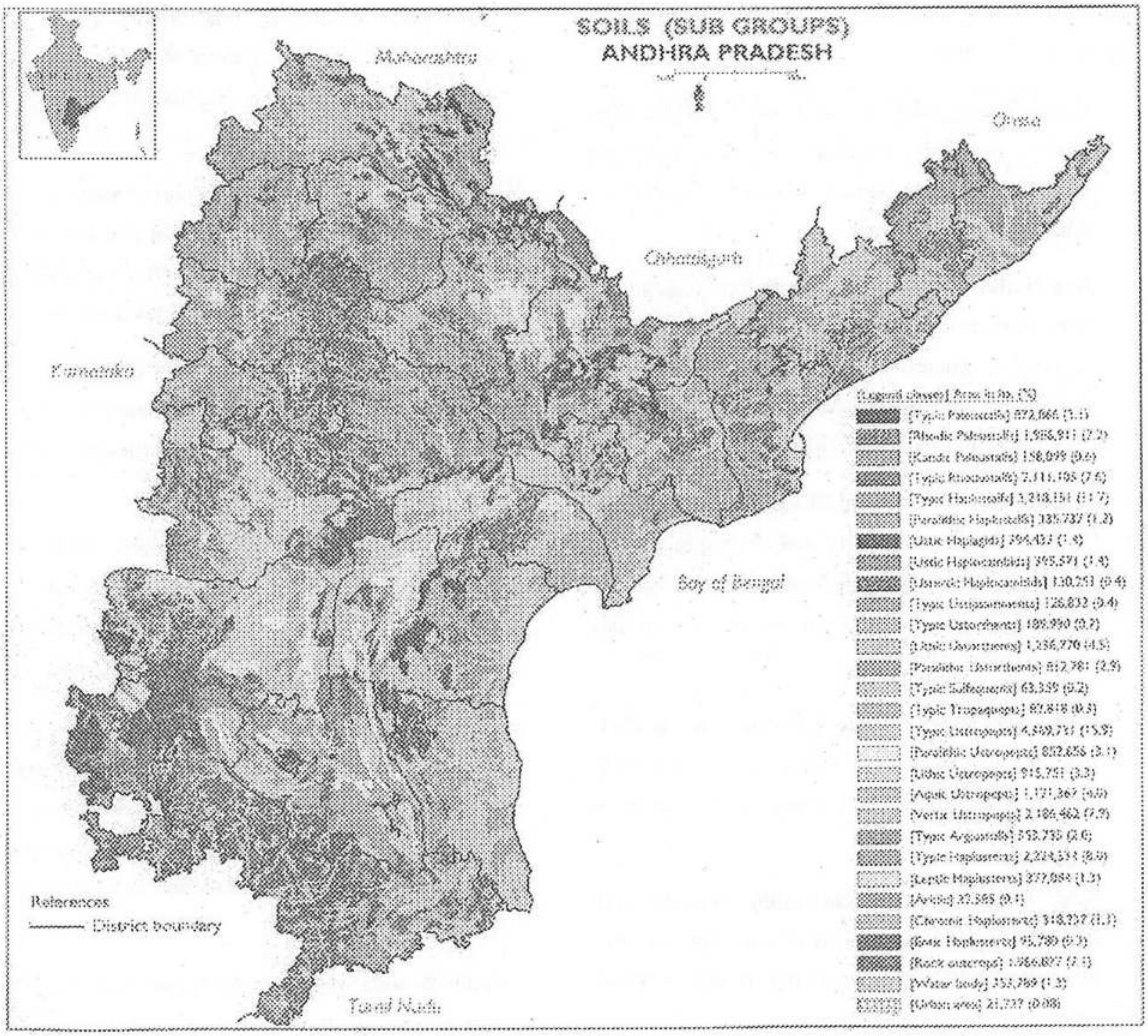

Fig.1. Soil map of Andhra Pradesh (sub-group level)

Overall, the extent of use of maps by different users has been found to be at minimal. Because the soil legend at sub-group level is very generalized at a higher level of soil classification wherein soil units 1, 2, 4, 21 had soils with textural variability. Similarly, soil units 4, 5, 7, 8, 19 had different depth classes. In soil unit 22 and 26, calcareous and non-calcareous soils are clubbed. Therefore, the utility of soil map got restricted. To overcome these limitations, the basic soil map (238 units) was re-grouped considering the principles of similar soils and user's set of criteria for different purposes in to 15 soil management units (Fig. 2), which are easy to comprehend by the users.

The details of user friendly soil map and associated legend is described below.

Legend – User friendly soil map(Resource management domain)

Coastal sandy soils: Very deep, excessively drained, neutral to mildly alkaline, sandy soils (Typic Ustipsamments) occurring on gently sloping sand dunes all along the coast

Red shallow gravelly loam soils: Very shallow to shallow, somewhat excessively drained, slightly acid to neutral, gravelly loam soils (Loamy-skeletal Paralithic Ustorthents) occurring on moderately to strongly sloping hills and ridges

Red gravelly loam soils: Moderately deep to very deep, well drained, slightly acid to neutral, gravelly loam soils (Loamy-skeletal Rhodic Paleustalfs/Typic Haplustalfs/ Rhodustalfs) on moderately sloping lands

Red loamy soils: Deep to very deep, well drained, medium acid to neutral, loamy soils (Fine-loamy Typic Haplustalfs/Typic Paleustalfs) in valleys on very gently sloping plains

Red shallow gravelly clay soils: Shallow, well drained, slightly acid to neutral, gravelly clay soils (clayey-skeletal, Lithic Haplustepts/Rhodustalfs) on gently to moderately sloping lands

Red gravelly clay soils: Moderately deep, well drained, slightly acid to neutral, gravelly clay soils (Clayey-skeletal Typic Rhodustalfs/Haplustalfs/ Rhodic Paleustalfs) on gently to moderately sloping lands

Red clayey soils: Moderately deep to very deep, welldrained, medium acid to neutral, clayey soils (Fine Typic Rhodustalfs/Haplustalfs/Paleustalfs) on gently to moderately sloping lands

Colluvio-alluvial clay soils: Moderately shallow to deep, welldrained, neutral to mildly alkaline, clayey soils (Fine Typic Haplustepts) in valleys// plains

Colluvio-alluvial calcareous clayey soils: Deep to very deep, imperfectly drained, mild to strongly alkaline, calcareous, clayey soils (Fine Aquic/Typic Haplustepts) occurring on nearly level valleys

Shallow black soils: Shallow, well drained, neutral, clayey soils (Clayey, smectitic, Lithic Ustorthents) occurring on gently sloping lands with stony surface in patches

Deep black soils: Deep to very deep, moderately welldrained, moderately to strongly alkaline, cracking clay soils (Very-fine/Fine Typic Haplusterts/ Vertic Haplustepts) in nearly level valleys and very gently sloping plains

Deep calcareous black soils: Deep to very deep, moderately well drained, moderately to strongly alkaline, soils (Very-fine/Fine Typic Haplusterts/Vertic Haplustepts) in nearly level valleys and very gently sloping plains

Lateritic soils: Very deep, well drained, slightly acid to neutral, gravelly (clay soils (Clayey-skeletal, kaolinitic Typic Haplustalfs/Kandic Paleustalfs) occurring on gently sloping plains/very gently sloping plateaus

Red, calcareous clayey soils: Moderately deep to deep, well drained, calcareous, clayey soils (Fine Typic Haplustalfs/Typic Paleustalfs) on very gently sloping plains

Rocky lands

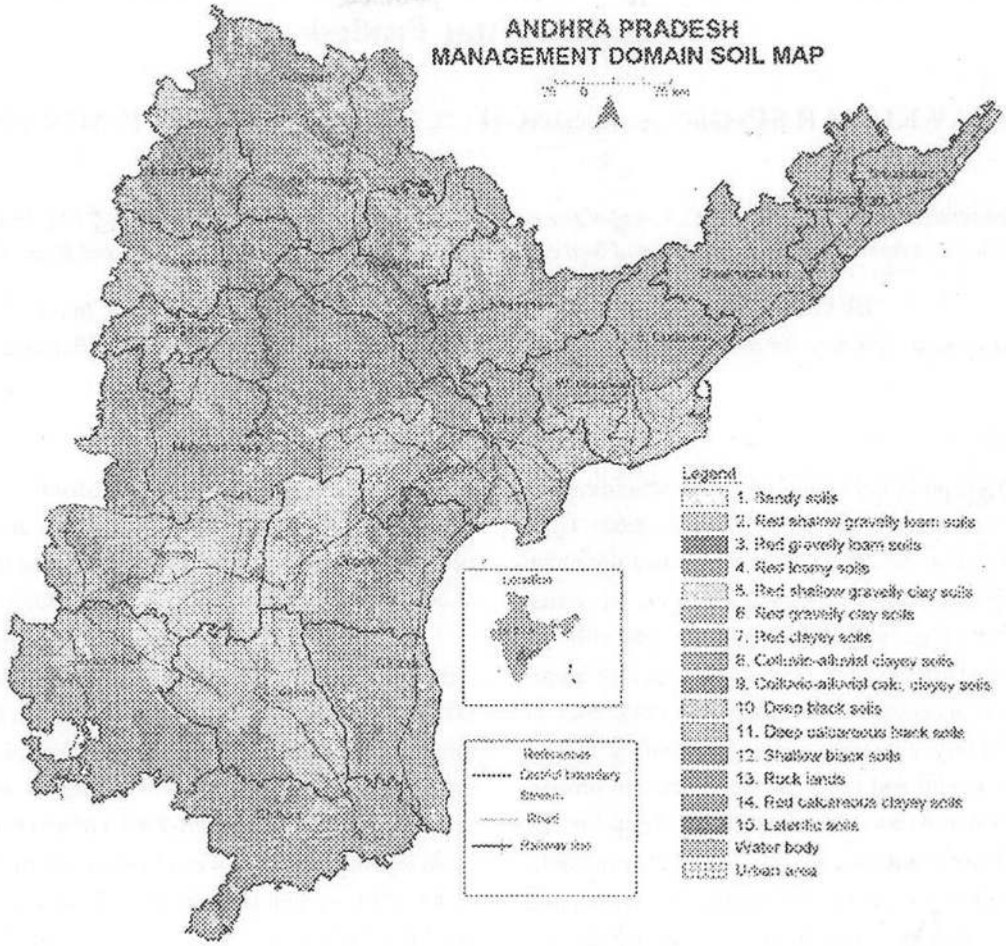

Fig. 2. User friendly soil (Resource management domain) map of Andhra Pradesh

Conclusions

From the study, it can be concluded that user froendly soil map has less number of soil units (15) as compared to the basic soil resource map (238 units) and the mapping units are simple and easily understandable language for all categories of users.

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Short Communication

Distribution of micronutrient cations in soils of different districts of eastern Uttar Pradesh

SANJAY KUMAR SINGH[1], A. K. SINGH[2], S. K. SINGH[3] AND H. P. AGRAWAL[4]

[1]*Department of Soil Science, T.C.A. Rajendra Agricultural, University, Muzaffarpur-843 121, India*
[2]*Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema-797106, India*
[3]*KVK, Rajmata Vijayaraje Sindhia, Krishi Vidhyalaya, Gwalior-474 002, India*
[4]*Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, India*

Widespread deficiency of micronutrient cations has been observed in different districts of eastern Uttar Pradesh (Singh *et al.* 2009). Rice-wheat is a dominant cropping system in the Indo-Gangetic plains. Increased production of crops per unit area per unit time utilizing high yielding varieties that require high input of micronutrients has accentuated micronutrients deficiency in soils. Availability of micronutrients is influenced by their distribution in soil and other physico-chemical properties of soil (Sharma and Chaudary 2007). Thus, knowledge of status of micronutrient cations and their relationship with soil characteristics is helpful in understanding the inherent capacity of soil to supply these nutrients for crop utilization. Therefore, present investigation was undertaken in five important rice-wheat growing districts of eastern Uttar Pradesh and their relation with important soil physico-chemical properties.

About 299, 352, 506, 251 and 85 composite surface soil samples (0-15 cm) from Varanasi, Jaunpur, Gazipur, Chandauli and Bhadohi, respectively belonging to Udic Halustepts (dominant) and Halaquepts, Haplaquepts, Fluvaquepts and Vertic Haplustepts were collected. The soils were sandy loam to sandy clay loam in texture. The important characteristics of soil *viz.* pH, EC, organic carbon and $CaCO_3$ were determined by following standard procedure (Jackson 1973). The available Cu, Fe and Mn were extracted using di-ethylene triamine penta-acitic acid (DTPA) (Lindsay and Norvell 1978) and their concentration was determined using Atomic Absorption Spectrophotometer (Model, UNICAM-969). Simple correlation was carried out between micronutrient content and different soil properties as per procedure given by Panse and Sukhatme (1961).

The soil physico-chemical properties are presented in (Table 1). The data (Table 1) indicated that DTPA- Zn in soils of Varanasi ranged from 0.10 to 4.5 mg kg^{-1} with a mean value of 0.76 mg kg^{-1}. There was a positive correlation between available Zn and organic carbon (r=0.064). The DTPA-Zn decreased with increase in pH due to formation of calcium zincate in presence of high $CaCO_3$ content (Bansal and Takkar 1985). Considering 0.6 Zn mg kg^{-1} as the critical level of zinc deficiency (Takkar and Mann 1975), 38% soil samples had DTPA-Zn below 0.5 mg kg^{-1}. The DTPA-Cu in the Varanasi soils varied between 0.6-5.7 mg kg^{-1} with the mean value 2.22 mg kg^{-1} (Table 1). The soil samples had DTPA-Cu more than critical level (0.2 mg kg^{-1}). The DTPA-Fe in soils varied from 2.5 to 105.6 mg kg^{-1} with a mean value of 29.84 mg kg^{-1}. Only 1% soil samples had DTPA-Fe below 5 mg kg^{-1}, 10% between 5 and 10 mg kg^{-1} and others more than 10 mg kg^{-1}. The DTPA-Mn in soils of Varanasi varied from 1.0-61.6 mg kg^{-1} with a mean value 15.62 mg kg^{-1}. Considering 1.0 mg kg^{-1} as critical level of Mn deficiency (Lindsay and Norvell 1978), all soil samples had sufficient amounts of available Mn. The DTPA-Mn was non-significantly correlated with pH, EC and $CaCO_3$ and positively correlated with organic carbon content.

Table 1. Important physico-chemical properties of the soils in different districts of eastern Uttar Pradesh

Soil properties	Varanasi soils		Jaunpur soils		Ghazipur soils		Chandauli soils		Bhadohi soils	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
pH (1:2)	6.5-9.2	7.67	6.2-9.8	7.99	6.5-9.3	7.90	6.3-10.5	7.72	6.6-10.90	7.87
EC (dSm^{-1})	0.10-2.20	0.27	0.15-0.53	0.28	0.04-0.82	0.29	0.03-1.18	0.30	0.05-0.98	0.21
O.C. ($g\ kg^{-1}$)	1.0-8.4	4.5	3.2-6.9	4.9	0.5-13.2	4.5	0.5-8.3	2.9	1.6-7.2	4.9
$CaCO_3$ (%)	0.50-12.5	4.19	0.83-7.60	4.42	0.50-17.0	4.87	0.50-15.5	4.54	2.0-10.0	6.27
DTPA-Zn ($mg\ kg^{-1}$)	0.10-4.5	0.76	0.20-2.8	1.16	0.10-9.2	1.69	0.30-5.4	1.38	0.30-2.9	0.93
DTPA-Cu ($mg\ kg^{-1}$)	0.60-5.7	2.22	0.60-7.3	2.20	0.10-10.5	2.74	1.30-10.7	4.28	1.2-7.8	3.07
DTPA-Fe ($mg\ kg^{-1}$)	2.5-105.6	29.84	3.2-202.1	45.47	5.0-141.7	41.21	10.0-197.6	73.72	5.8-161.2	42.94
DTPA-Mn ($mg\ kg^{-1}$)	1.0-61.6	15.62	1.4-114.4	17.70	6.0-98.30	32.76	1.5-85.5	40.12	6.5-83.6	37.38

The DTPA-Zn in soils of Jaunpur district ranged from 0.20 to 2.8 mg kg^{-1} with a mean value of 1.16 mg kg^{-1} (Table 1). There was a positive correlation between DTPA-Zn and organic carbon (r=0.054). Nearly 21% soil samples were found below the critical level of zinc and 42% and 35% were between 0.5-1.0 and 1.0 to 2.5 mg kg^{-1}, respectively (Table 2). The DTPA-Cu in the Jaunpur soils varied between 0.60-7.3 mg kg^{-1} with the mean value 2.20 mg kg^{-1}. The mean value of available Cu was much higher than critical level 0.2 mg kg^{-1} (Follotte and Lindsay 1970). The DTPA-Fe in the soils varied from 3.2 to 202.1 mg kg^{-1}. Considering 4.5 mg kg^{-1} DTPA-extractable Fe as the critical level (Lindsay and Norvell 1978), about 4% soil samples of Jaunpur district were deficient in DTPA-Fe. The mean of DTPA-Mn was 17.70 mg kg^{-1}. Three per cent soil samples had DTPA-Mn below 5 mg kg^{-1} and remaining 20% between above 5 and below 10 mg kg^{-1}.

DTPA-Zn in soils of Ghazipur district ranged from 0.10 to 9.2 mg kg^{-1} with a mean value of 1.69 mg kg^{-1} (Table 1). Nearly 16% soil samples were deficient, 37% marginal and 47% sufficient in available Zn content in these soils. Singh *et al.* (2009) reported that DTPA-Zn was affected by organic carbon content. A negative relationship was observed with pH indicating that availability of Zn decreases with increase in soil pH. A majority of soils samples had DTPA-Cu between 1.0 - 2.5 mg kg^{-1} (Table 2). Nearly 1% soil samples contained Cu below 0.5 mg kg^{-1}. The DTPA-Cu in soils of Ghazipur district exhibited a positive correlation (r=0.048) with organic carbon (Table 3). The DTPA-Fe content in soils varied from 5.0 to 141.7 mg kg^{-1}. About 83% soil samples contained >20 mg kg^{-1} DTPA-Fe. The DTPA-Mn in soils varied from 6.0-98.30 mg kg^{-1} with a mean value 32.76 mg kg^{-1}. Majority of soil samples (98%) contained Mn >10 mg kg^{-1}.

Available Zn in soils of Chandauli district ranged from 0.30 to 5.4 mg kg^{-1} with a mean value of 1.38 mg kg^{-1} (Table 1) and positively correlated (r0.056) with organic carbon content (Table 3). About 47% soil samples had DTPA-Cu ranging from 0.5-1.0 mg kg^{-1}. The DTPA-Cu in Chandauli soils varied from 1.30 to 10.7 mg kg^{-1} and 94% soils samples had available Cu >2.5 mg kg^{-1}. DTPA-Fe varied from 10.0 to 197.6 mg kg^{-1} with a mean value of 73.72 mg kg^{-1}.

Table 2. Distribution of micronutrients in soils of different districts of eastern Uttar Pradesh

Micronutrients (mg kg^{-1})

Districts	Zinc								Copper							
	0.0-0.5		0.5-1.0		1.0-2.5		>2.5		0.0-0.5		0.5-1.0		1.0-2.5		>2.5	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Varanasi	115	38	111	37	62	21	11	4	0	0	19	6	151	51	129	43
Jaunpur	72	21	148	42	124	35	8	2	0	0	41	12	162	46	149	42
Ghazipur	82	16	187	37	203	40	34	7	3	1	10	2	218	43	275	54
Chandauli	14	6	120	47	102	41	15	6	0	0	0	0	15	6	236	94
Bhadohi	12	15	47	55	25	29	1	1	0	0	0	0	26	31	59	69

Districts	Iron								Manganese							
	0-5		5-10		10-20		>20		0-3		3-5		5-10		>10	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Varanasi	3	1	29	10	80	27	187	62	3	1	6	2	70	23	220	74
Jaunpur	14	4	37	11	73	20	228	65	2	1	7	2	69	20	274	77
Ghazipur	1	0.5	7	1.5	79	15	419	83	0	0	0	0	6	1	500	99
Chandauli	0	0	2	1	8	3	241	96	1	0.5	1	0.5	6	2	243	97
Bhadohi	0	0	1	1	18	21	66	78	0	0	0	0	1	1	84	99

No. – Number of composite soil samples

Table 3. Correlation coefficients of available cationic micronutrients with soil properties

Micro-nutrients	Varanasi soils				Jaunpur soils			
	pH	EC	OC	$CaCO_3$	pH	EC	OC	$CaCO_3$
Zn	-0.016	-0.068	0.064	-0.062	-0.032	-0.038	0.054	-0.054
Cu	-0.058	0.181	0.010	-0.046	-0.062	-0.162	0.102	-0.054
Fe	-0.182	0.032	0.076	-0.026	-0.168	-0.086	0.124	-0.072
Mn	-0.168	-0.102	0.038	-0.082	-0.132	-0.108	0.136	-0.128
	Ghazipur soils				Chandauli soils			
Zn	-0.086	-0.076	0.182	-0.142	-0.048	-0.106	0.089	-0.046
Cu	-0.032	-0.154	0.048	-0.068	-0.018	-0.129	0.014	-0.059
Fe	0.132	0.068	0.186	-0.104	-0. 105	-0.016	0.056	-0.186
Mn	-0.146	-0.134	0.189	-0.067	-0.042	-0.056	0.036	-0.076
	Bhadohi soils							
Zn	-0.104	-0.089	0.162	-0.122				
Cu	-0.082	-0.146	0.068	-0.168				
Fe	0.162	0.088	0.146	-0.094				
Mn	-0.148	-0.164	0.169	-0.107				

The DTPA-Zn in the Bhadohi soils varied from 0.3 to 2.9 mg kg^{-1} with the mean value 0.93 mg kg^{-1}. Nearly 15% soil samples were deficient in Zn content whereas, 55% were below the sufficiency. DTPA-Cu in Bhadohi soils ranged from 1.2 to 7.8 mg kg^{-1} with a mean value of 3.07 mg kg^{-1} (Table 1). There was a positive correlation between available Cu and organic carbon (r=0.064). The majority of soil samples (69%) had DTPA-Cu above 2.5 mg kg^{-1}. The DTPA-Fe content varied from 5.8 to 161.2 mg kg^{-1} and DTPA-Mn varied from 6.5-83.6 mg kg^{-1} (mean value 37.38 mg kg^{-1}). Nearly 99% of the sample had DTPA-Mn above 10 mg kg^{-1} (Table 1).

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Short Communication

Distribution of zinc and iron in relation to soil properties of Banswara district, Rajasthan

R.S. MEENA[1] AND A.K. MATHUR[2]

[1]*National Bureau of Soil Survey and Land Use Planning (ICAR), Regional Centre, Udaipur-313 001, India*
[2]*Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, MPUAT, Udaipur-313001, India*

Micronutrients are important for maintaining soil and crop health and also for increasing productivity of crops (Rattan *et al.* 2009). Increased removal of micronutrients as a consequence of adoption of high yielding varieties (HYVs) and intensive cropping caused decline in the level of micronutrients in soil. The present study highlighted the influence of soil properties on the availability of zinc and iron in soils of Banswara district, Rajasthan.

The Banswara district of Rajasthan is quadrangular in shape and undulating in nature. The central and western plains are cultivated. The temperature varies between 25°C to 45°C with mean annual rainfall of 972 mm.

Five hundred composite surface soil samples (0-15 cm) from cultivated lands were collected from 125 villages located at different locations in Banswara district. The dominant crops are sorghum, maize, soybean, castor and cotton in *kharif* season and wheat, mustard, barley, gram and poppy in *rabi* season.

Soil pH was measured in 1:2 soil water suspension using glass electrode pH meter. Electrical conductivity was measured in 1:2 soil water supernatant solutions with the help of conductivity bridge (Jackson 1973). The organic carbon was determined by rapid titration method (Walkley and Black 1934) and $CaCO_3$ by rapid titration method (Puri 1930). The available Zn and Fe in soil samples were extracted with DTPA (0.005 *M* DTPA + 0.01 *M* $CaCl_2$ + 0.1 M TEA, pH 7.3) as per the method described by Lindsay and Norvell (1978) and the concentration of Zn and Fe in the DTPA-extract was determined using atomic absorption spectrophotometer.

The physical and chemical properties of soils (range and mean) have been given in table 1.

Table 1. Physical and chemical properties, Zn and Fe status of soils

Soil characteristics	Range	Mean
Sand (%)	10.2-77.1	37.5
Silt (%)	7.0-50.9	29.9
Clay (%)	7.0-57.7	32.4
pH	7.01-8.17	7.50
EC (dSm^{-1})	0.34-0.79	0.56
OC ($g\ kg^{-1}$)	3.33-9.93	6.65
$CaCO_3$ ($g\ kg^{-1}$)	4.0-71.0	26.61
EC cmol (p^+) kg^{-1}	6.0-40.0	20.77
DTPA-Zn	0.40-2.27	0.81
DTPA-Fe	2.17-28.45	10.19

Data on DTPA-Zn in soils indicated that 33.2 per cent soil samples were deficient, 51.2 per cent marginal (0.6 to 1.2 mg kg^{-1}) and 15.6 per cent adequate (>1.2 mg kg^{-1}) against the critical limit of 0.6 mg kg^{-1}(Singh *et al.* 2003). The available Zn increased with increase in organic carbon (r = 0.719**), silt (r = 0.077) and CEC (r = 0.012) and decreased significantly with an increase in $CaCO_3$ (r = - 0.556**) and pH (r = -0.348**).

DTPA-Fe ranged from 2.17 to 28.45 mg kg^{-1}. Considering 4.5 as the critical limit suggested by Singh *et al.* (2003), 1.4 per cent soil samples were deficient (< 4.5 mg kg^{-1}), 23 per cent samples were marginal (4.5 to

7.5 mg kg^{-1}) and 75.6 per cent were adequate (> 7.5 mg kg^{-1}). The available Fe increased with increase in clay (r = 0.066) and organic carbon (r = 0.634**) but decreased significantly with an increase in $CaCO_3$ (r = -0.410**) content (Table 2).

Table 2. Correlation between soil properties and available micronutrients (Zn and Fe)

Soil characteristics	Available micronutrients	
	Zn	Fe
Sand	-0.116**	-0.034
Silt	0.077	0.013
Clay	0.103*	0.066
pH	-0.348**	- 0.160 **
EC	0.055	-0.023
OC	0.719**	0.634**
$CaCO_3$	-0.556**	-0.410**
CEC	0.012	0.064

** Significant at 5 per cent level and * Significant at 1 per cent level

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Short Communication

Micronutrient cations and their spatial variability in soils of Cuddalore district of Tamil Nadu

RASHMI BARUAH, S. THIYAGESHWARI AND S. MANI

Department of Soil Science, Tamil Nadu Agricultural University, Coimbatore-641 003, India

Increased production of crops per unit time utilizing high yielding varieties that require larger input of macronutrients has accelerated micronutrient deficiencies in soil. During 1990-2000, a conventional soil survey was conducted in erstwhile Cuddalore district (Cuddalore and Villupuram) indicated that 67.0% of the soils of the district were deficient in Zn, 4.0% in Cu and 26.0% in Fe. The present research work was taken as an effort to re-evaluate the micronutrient status of Cuddalore district of Tamil Nadu with the help of GIS and GPS techniques and their interrelationships with soil characteristics.

Cuddalore district (78° 42' to 80°12' E; 12°27' 30" to 11°10'45" N) in Tamil Nadu is bounded on north by Villupuram district, on the south by Nagapattinam district, on the west by Perambalur and Villupuram districts and on the east by Bay of Bengal. It comprises of 6 taluks, 13 blocks and 647 village panchayats covering an area of 3643.04 Sq.km. Soils of the district are mostly red loamy to red sandy but black cotton soils are also observed in few blocks towards north-west. Soil samples were collected at block level using available maps and their locations were recorded using GPS technique. Three soil samples from each village (647 villages) were collected from different blocks, processed and analyzed for pH and EC by employing the method given by Jackson (1973), organic carbon by Walkley and Black (1934), calcium carbonate by Piper (1966).The DTPA-extractable Fe, Zn, Mn, and Cu were extracted with diethelene tri-amine penta-acetic acid (DTPA) solution (Lindsay and Norvell 1978) and analysed with the help of atomic absorption spectrophotometer. The thematic maps were prepared using a vector based GIS software package ArcGIS9.2.

Data showed that the pH of the surface soils varied from 4.4 - 9.3 (Table 1), whereas, electrical conductivity were found to be normal (< 1.0dSm^{-1}), barring few pockets. The soils were low to high in organic carbon content (0.06-1.66 per cent) with a mean of 0.56 per cent and calcium carbonate content varied from 0.99 - 18.00 per cent with a mean of 8.17 per cent (Table 1).

Table 1. Range and mean values of physico-chemical properties of soils

Block Name	pH	EC (dSm^{-1})		OC (%)		$CaCO_3$ (%)	
	Range	Mean	Range	Mean	Range	Mean	Ranage
Bhuvanagiri	6.30-8.40	0.20	0.04-0.52	0.72	0.38-1.07	7.35	2.0-14.0
Keerapalayam	5.80-8.60	0.38	0.04-3.62	0.59	0.09-1.10	9.79	2.0-15.0
Kumaratchi	4.80-8.40	0.15	0.03-0.50	0.80	0.32-1.16	7.62	0.99-16.0
Parangipettai	5.10-9.20	0.70	0.07-6.24	0.58	0.12-1.10	9.08	3.0-15.0
Cuddalore	4.60-9.30	0.26	0.05-1.51	0.58	0.12-1.19	8.87	2.0-15.0
Kurinjipadi	4.85-8.36	0.25	0.05-3.03	0.66	0.07-1.66	8.65	2.0-17.0
Kattumunnarkoil	5.70-8.30	0.26	0.04-1.23	0.49	0.09-1.04	6.86	1.0-14.0
Annagramam	6.15-8.92	0.21	0.06-1.07	0.52	0.17-0.90	9.52	4.0-18.0
Panruti	4.46-8.99	0.28	0.06-0.96	0.52	0.17 – 0.84	7.16	2.0–16.0
Mangalore	4.40-7.90	0.14	0.05-0.46	0.56	0.06-0.99	8.93	2.0-15.0
Nallur	5.10-8.40	0.42	0.05-5.99	0.40	0.06-0.81	9.20	2.0-15.0
Kammapuram	6.20-8.30	0.30	0.02-1.44	0.41	0.09-0.81	5.80	1.0-14.0
Vridhachalam	6.80-8.50	0.33	0.06-5.09	0.50	0.12-0.93	6.55	1.0-14.0
Overall district	4.4-9.3	0.30	0.02-6.24	0.56	0.06-1.66	8.17	0.99-18.0
SD	0.90		0.49		0.23		3.29
CV (%)	12.40		163.58		41.19		40.31

The DTPA-Fe varied from 1.04 to 137.80 mg kg^{-1} with a mean of 26.20 $mgkg^{-1}$ (Table 2). Considering 4.5 mg Fe kg^{-1} as critical limit for Fe deficiency (Lindsay and Norvell 1978), 11.92 % of samples were found to be deficient dominantly in Annagramam block. DTPA-Fe was negatively correlated with pH (r= -0.349**).

Available Mn ranged from 0.86-127.51 mg kg^{-1} with a mean value of 19.44 mg kg^{-1}. Kurinjipadi block had the highest as well as lowest value of available Mn. Based on threshold value of manganese deficiency (Lindsay and Norvell 1978), only 0.53 % samples were found to be deficient. Mn showed negative significant relation with pH (r=-0.234**), and $CaCO_3$ (r=-0.159**), but positive correlation with OC (r=0.313**).

Table 2. Range and mean values of micronutrient cations

Block Name	Micronutrients (mg kg^{-1})							
	Fe		Mn		Zn		Cu	
	Mean	Range	Mean	Range	Mean	Range	Mean	Ranage
Bhuvanagiri	26.80	3.15-80.80	13.68	3.42-33.51	0.80	0.34-1.66	1.73	0.56-6.18
Keerapalayam	33.72	5.34-70.07	20.93	13.01-43.64	1.49	0.50-3.74	5.23	1.29-10.11
Kumaratchi	24.47	5.02-52.13	10.34	3.16-25.23	1.13	0.17-4.38	1.63	0.30-4.44
Parangipettai	34.74	4.56-112.72	23.50	2.52-48.90	1.19	0.22-3.54	4.05	0.26-10.28
Cuddalore	30.94	2.87-80.61	12.30	1.90-15.33	2.34	0.90-7.41	2.22	0.18-7.63
Kurinjipadi	40.06	1.64-111.46	38.56	0.86-127.51	2.75	0.41-8.95	1.16	0.07-3.71
Kattumunnarkoil	15.69	2.64-38.02	12.40	2.49-36.48	0.89	0.16-2.56	1.55	0.38-5.43
Annagramam	9.44	1.92-51.76	39.63	19.80-47.30	2.55	0.91-1.95	1.73	0.27-7.74
Panruti	32.89	4.09-83.21	16.98	1.08-26.47	1.51	0.25-3.71	4.53	0.50-9.72
Mangalore	33.11	5.83-102.60	17.01	3.32-45.44	1.29	0.34-5.66	1.34	0.42-3.24
Nallur	23.79	1.04-137.80	19.35	1.04-51.01	1.24	0.25-5.41	1.47	0.50-6.64
Kammapuram	17.24	6.24-36.42	14.97	3.17-33.33	1.06	0.20-5.06	1.63	0.68-9.24
Vridhachalam	15.21	3.76-42.60	12.51	2.90-35.42	1.03	0.20-6.36	1.60	0.65-4.26
Overall district	26.20	1.04-137.80	19.44	0.86-127.51	1.48	0.16-1.95	2.26	0.07-10.11
Deficiency (%)	11.92		0.53		49.92		32.19	
SD	21.94		12.43		1.17		1.90	
CV (%)	83.73		84.11		63.93		79.09	

DTPA-Zn in Cuddalore district was low (0.16 to 11.95 mg kg^{-1}). Considering the critical value for zinc deficiency as 0.6 mg kg^{-1} (Lindsay and Norvell 1978), about 50% samples were found to be deficient (Table 2). DTPA-Zn significantly positive and correlated with pH (r=0.159**) and OC (r=0.201**).

DTPA copper ranged from 0.07 to 10.11 mg kg^{-1} with a mean value of 2.26 mg kg^{-1}. Considering 0.2 mg kg^{-1} as critical limit of copper deficiency (Lindsay and Norvell 1978), 32.19% samples were found to be deficient (Table 2). DTPA-Cu has non-significant negative correlation with pH (r=-0.015) but positive correlation with $CaCO_3$ (r= 0.118**).

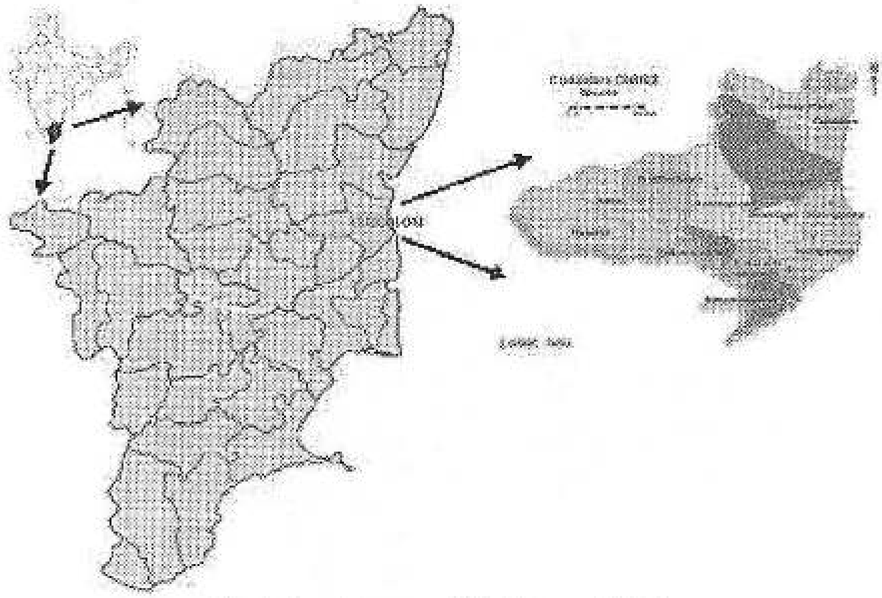

Fig 1. Location map of Cuddalore district

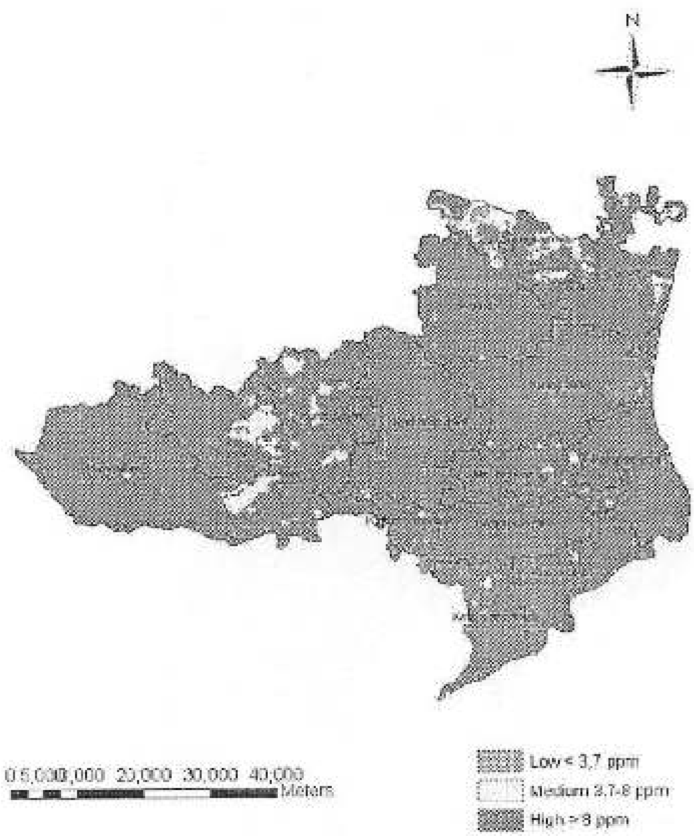

Fig 2. Available iron in Cuddalore district (at block level)

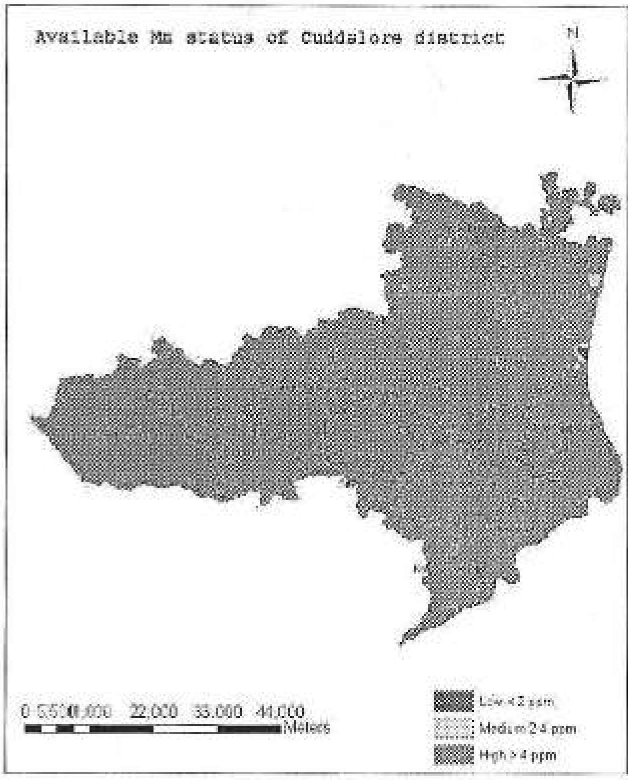

Fig 3. Available manganese in Cuddalore district (at block level)

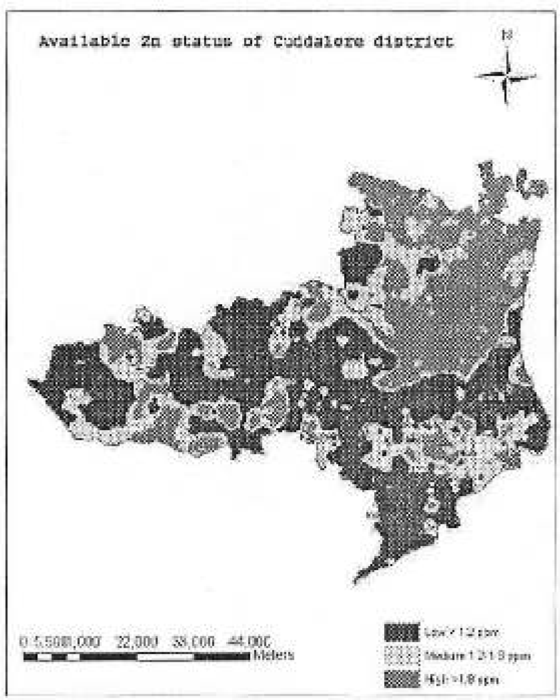

Fig 4. Available zinc in Cuddalore district (at block level)

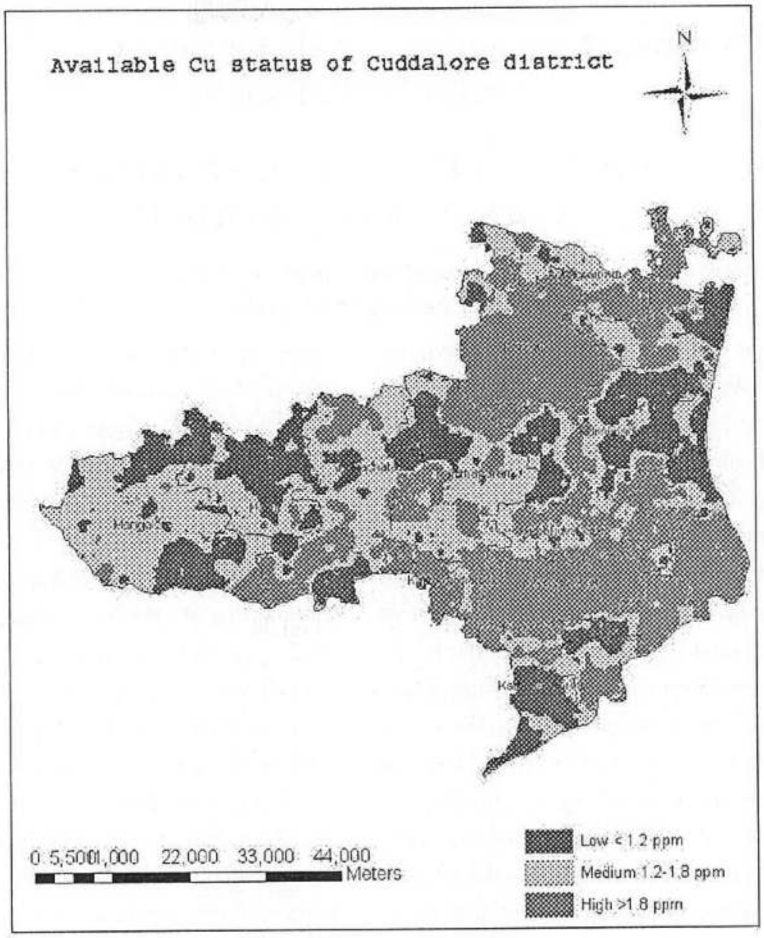

Fig 5. Available copper in Cuddalore district (at block level)

GIS-aided mapping of soil micronutrients

Based on soil micronutrients data obtained from different parts of Cuddalore district thematic maps for DTPA-extractable Fe, Mn, Zn and Cu were prepared using Arc GIS9.2 software (Fig. 1a, 1b, 1c, 1d).

The spatial distribution of micronutrients in Cuddalore district indicates that maximum area is deficient for zinc followed by copper barring Kurinjipadi and Cuddalore for Zn and Keerapalayam and Panruti for Cu. In case of Fe and Mn, Cuddalore district is sufficient except few pockets of Annagraman and Nallur for Fe and Kurinjipadi for Mn.

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Short Communication

Evaluation of various extractants for available potassium for french bean in acid soils of Manipur

HEROJIT SINGH ATHOKPAM, R.K. KUMARJIT SINGH, R.K. UMAKANTA SINGH AND NANDINI CHONGTHAM

Department of Soil Science and Agricultural Chemistry, Central Agricultural University, Imphal-795 004, India

French bean is an important vegetable-cum-pulse crop of India. With increasing cropping intensity and irrigation facilities, soil test-based fertilizer application is imperative to obtain good yields of the crop. A number of K extractants have been used from time to time to assess quantitatively the available K in soils but none of these has been found to be widely applicable (Prakash and Singh 1985). Review indicated that 1 *N* neutral NH_4OAc provided a good estimate of the availability of soil K to plants (Johnston and Groundling 1990). However, for rational and judicious use of fertilizer a sound soil testing programme is necessary based on critical limits. Such information is lacking for french bean (*Phaseolus vulgaris* cv. Contender) which is an important pulse crop of Manipur state. Therefore, the present study aims to find the most suitable extractant to measure the availability of K to french bean grown in acid soils and also to determine critical limits of available K in soil and plant.

Twenty five bulk soil samples (0-15 cm) were collected from five districts of Manipur. The physical and chemical characteristics of these soils (Table 1) were determined by standard methods (Jackson 1973; Khanna and Yadav 1979; Chopra and Kanwar 1976). The available K was determined by different extractants (Table 2). Two and half kilograms of soil were filled in earthen pots and K was applied @ 50 and 70 kg K_2O ha^{-1} through MOP. There were twelve treatments (to extract K) replicated thrice in a randomized design. A basal dose of 60 : 17.5 kg N:P ha^{-1} was applied in the form of urea and SSP. French bean cv. Contender seeds were sown and thinned to three plants after ten days. The plots were irrigated with distilled water as and when required. The crop was harvested at 40 days after sowing along with the roots. The plant samples were washed in water and dried in oven at 65^0 C for 48 hours and dry matter yield was recorded. The samples were then powdered and requisite quantities of the same were digested in nitric-sulphuric-perchloric acid mixture and K in the digest was estimated using flame photometer. Critical limits of soil and plant were worked out by the graphical procedure of Cate and Nelson (1965).

Table 1. Physical and chemical characteristics of the soils

Soil characteristics	Mean	Range
pH	--	4.94 – 6.11
EC (dSm^{-1})	0.23	0.06 – 0.95
Organic carbon ($g\ kg^{-1}$)	15.00	6.90 – 21.90
Total N (%)	0.23	0.10 – 0.36
Available N ($kg\ ha^{-1}$)	304.82	192.03 – 542.20
Available P_2O_5 ($kg\ ha^{-1}$)	16.90	7.86 – 32.92
CEC [cmol (p^+) kg^{-1}]	19.61	9.00 – 39.40
Ca [cmol (p^+) kg^{-1}]	3.61	1.40 – 7.05
Mg [cmol (p^+) kg^{-1}]	3.42	1.00 – 7.90
Silt (%)	22.97	11.84 – 34.00
Clay (%)	46.59	19.04 – 74.32

Table 2. Methods used for extraction of K from the soil

Extractants	Ratio	Shaking time	Reference
$1N$ NH_4OAc	1:5	30 min.	Woodruff and Mc Intosh 1960)
$0.01M$ HCl	1:2	30 min.	Woodruff and Mc Intosh (1960)
$0.13M$ HCl	1:5	1 min.	Woodruff and Mc Intosh(1960)
$0.75M$ HCl	1:3	5 min.	Jaworskin and Barber (1959)
$1N$ HNO_3	1:10	10 min.boiling	Wood and De Turk (1941)
$6M$ H_2SO_4	1:10	30 min.	Hunter and Pratt (1957)
Morgan's reagent (pH 7)	1:2	1 min.	Morgan (1941)
$0.5M$ $NaHCO_3$ (pH 8.5)	1:20	30 min.	Olsen *et al* (1954)
Modified Olsen's reagent ($0.5M$ $NaHCO_3$ + $0.01M$ Na-EDTA)	1:20	30 min	Olsen *et al* (1954)
Distilled water	1:10	30 min.	Mac Lean (1960)
$0.5M$ HOAc	1:20	Kept over night	Mac Lean (1960)
$1M$ NaOAc (pH 7)	1:5	5 min.	Mac Lean (1960)

The available K obtained by different extractants varied widely (Table 3). Based on the mean values of extractable K, the extractants were arranged in the order : $1N$ HNO_3 > $6M$ H_2SO_4 > $0.75M$ HCl > $1N$ NH_4OAc (pH7.5) > Modified Olsen > $0.5M$ HOAc > $0.5M$ $NaHCO_3$ (pH8.5) > $1M$ NaOAc (pH7.0) > Moran's reagent > $0.13M$ HCl > $0.01M$ $CaCl_2$ > distilled water. The $1N$ HNO_3 extracted more K than other extractants. The quantity extracted by $1N$ HNO_3 which comprised the non-exchangeable form as well, was higher than that obtained with weak acid and K adsorbed on exchange sites. This showed that strong acid solutions preferably non-chlorides extracted more amount of K than the weak acid solutions (Rathore *et al.* 2000, Bedi *et al.* 2002). Distilled water and $0.01M$ $CaCl_2$ extracted 18.3 mg kg^{-1} and 22.4 mg kg^{-1}, respectively.

Among the different K availability indices, K extracted by $1N$ NH_4OAc showed significant relationship with uptake parameters but $0.13M$ HCl did not show significant relationship with all the plant parameter observed. The sequence of K availability indices as showed by correlation studies (Table 4) was in the order: $1N$ NH_4OAc (pH7.0) > Modified Olsen reagent > $0.5M$ HOAc > $0.5M$ $NaHCO_3$ (pH 8.5) > $1M$ NaOAc (pH 7.0) > $0.01M$ $CaCl_2$ > $0.75M$ HCl > $6M$ H_2SO_4 > $1N$ HNO_3 > Morgan's reagent> distilled water > $0.13M$ HCl (Table 5) as also was reported by Kumar *et al.* (2004) in acid Alfisols of Chhotanagpur plateau in Jharkhand.

Table 3. Potassium extracted by various methods (mg kg^{-1})

Extractant	Range	Mean
1*N* NH_4OAc	90.0 – 195.0	137.4
0.01*M* $CaCl_2$	9.4 – 42.8	22.4
0.13*M* HCl	16.8 – 39.0	26.3
0.75*M* HCl	90.8 – 368.0	183.5
1*N* HNO_3	250.0 – 562.5	380.0
6*M* H_2SO_4	126.0 – 380.0	228.9
Morgan's reagent (pH7)	18.3 – 48.5	30.8
0.5*M* $NaHCO_3$ (pH8.5)	60.0 – 121.0	81.9
Modified Olsen's reagent (0.5*M* $NaHCO_3$ + 0.01*M* NaEDTA)	62.0 – 163.0	105.8
Distilled water	9.0 – 27.0	18.3
0.5*M* HOAc	72.0 – 154.0	104.3
1*M* NaOAc (pH7)	30.0 – 95.0	58.7

According to graphical procedure of Cate and Nelson (1965), the critical limit of soil K ranged from 26 ppm to 400 mg kg^{-1} depending upon the methods of K extraction. A high degree of correlation existed between 1*N* NH_4OAc extractable K and Bray's per cent yield (Table 4) and it indicated (Fig.1) that 145 mg^{-1} is the critical limit of available K in these soils. A soil was considered as non-responsive to K application when the Bray's per cent dry matter yield was more than 84 (Sharma and Singh 1990) and hence soils having less than 145 ppm of 1*N* NH_4OAc-K responded to K application. Thus, on the basis of the 1*N* NH_4OAc-K and dry matter yield of french bean, the soils were divided into three groups, *i.e.* deficient (<145 ppm K), marginal (145 - 160 ppm K) and adequate (>160 ppm K). Accordingly, 8, 15 and 2 soils can be rated as deficient, marginal and adequate in K supplying capacity in the studied soils. This categorization clearly indicates an increase in the average dry matter yield of plant with an increase in available K status of soil in the control treatment.

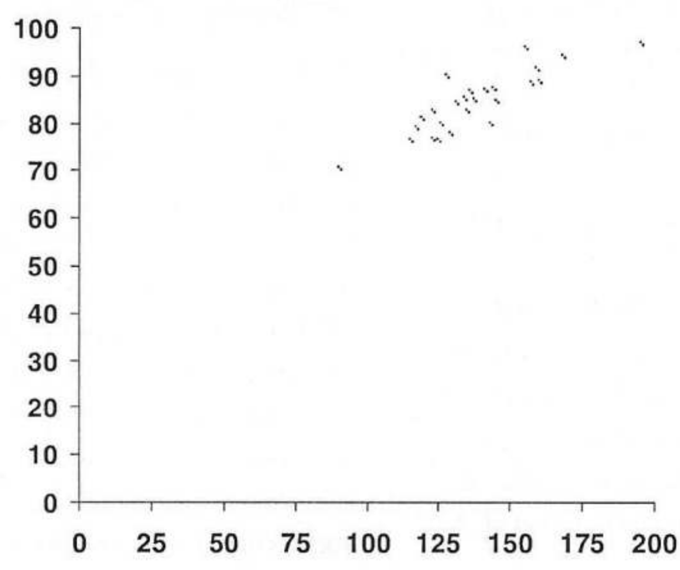

Fig.1. Relationship between soil K and relative yield of french bean

Table 4. Simple correlation co-efficient between the different forms of potassium and yield parameters of french bean

No.	Extractants	Dry matter yield (control)	K content (control)	K uptake (control)	Bray's % yield	Bray's % uptake
1.	1*N* NH_4OAc (pH 7)	0.869**	0.812**	0.849**	0.869**	0.821**
2.	0.5*M* $NaHCO_3$ (pH 8.5)	0.718**	0.609**	0.690**	0.665**	0.601**
3.	Modified Olsen's reagent	0.805**	0.705**	0.775**	0.706**	0.624**
4.	Morgan's Reagent	0.569**	0.527**	0.566**	0.481*	0.440*
5.	6*M* H_2SO_4	0.549**	0.504**	0.542**	0.580**	0.528**
6.	0.01*M* $CaCl_2$	0.671**	0.576**	0.649**	0.626**	0.556**
7.	0.75*M* HCl	0.656**	0.599**	0.664**	0.614**	0.572**
8.	1*M* NaOAc (pH 7)	0.661**	0.627**	0.663**	0.643**	0.657**
9.	1*N* HNO_3	0.437*	0.426*	0.427*	0.489*	0.384
10.	0.5*M* HOAc	0.687**	0.610**	0.664**	0.667**	0.549**
11.	Distilled water	0.445*	0.344	0.421*	0.389	0.432*
12.	0.13*M* HCl	0.205	0.196	0.222	0.220	0.260

** Significant at 1% level, * Significant at 5% level.

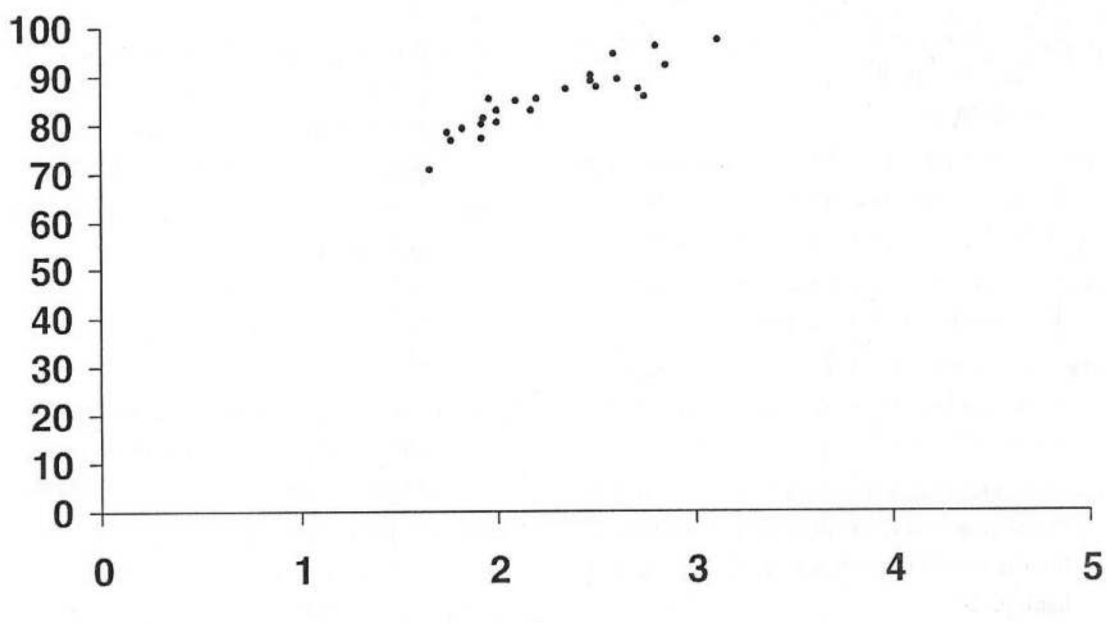

Fig.2. Relationship between K content and relative yield of french bean

Among the different extractants used (Table 2) 1*N* NH_4OAc showed the highest degree of significant positive relationship with dry matter yield (r=0.869**), plant K in control (r=0.812**), K uptake in control (r=0.849**), Bray's per cent yield (r=0.869**) and Bray's per cent uptake (r=0.821**) as shown in figure 2.

The result showed that the critical level of K concentration in french bean plant was 2.0 per cent according to the graphical procedure of Cate and Nelson (1965). However, partitioning the dimensional percentage yield *versus* K content in 40 days old french bean plants scattered into two groups. Thus, the present study lays emphasis on K fertilization on french bean plant on the basis of critical values in the soils and plants.

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Short Communication

Evaluation of sustainability of rainfed cotton yield under conventional and integrated nutrient management practices

P. TIWARY, M.V. VENUGOPALAN[1], D. BLAISE[1], S. CHATTERJI[1], T.K. SEN[1] AND N.R. TANDULKAR[1]

National Bureau of Soil Survey and Land Use Planning, Amravati Road, Nagpur – 440 003 , India
[1]Central Institute of Cotton Research, PB No. 2, Shankar Nagar P.O., Nagpur – 440 010, India

Before Green revolution, the indigenous varieties of field and commercial crops were grown under rainfed or partially irrigated conditions with little chemical fertilizer input. After the introduction of high yielding varieties through Green revolution in mid-sixties, Indian agriculture became highly dependent on chemical fertilizers and their inappropriate use resulted in imbalances in soil environment and health in the form of decline in soil organic matter, soil acidification and decline in level of micronutrients. These and other associated problems raise a question of sustainability of system highly dependent on fertilizer input. In Indian situation, sustenance of conventional practices (use of inorganic fertilizer) or integrated nutrient management (INM) practices for agricultural production is still debatable. For developing and evaluating suitable technologies for optimizing the fertilizer use supplemented with organic manures and crop residues, long term fertilizer experiments on different crops were initiated at different locations of the country (Nambiar1994). Data from long-term experiments have confirmed that the conjoint application of FYM with optimal soil test based NPK dose is a durable practice for sustaining higher crop productivity, improving soil quality and soil productivity.

Apart from nutrients, the rainfed crop yield is greatly influenced by the rainfall distribution during the growing period, hence in assessing the sustainability of crop yield the effects of rainfall on the yield should be considered. Singh *et al.* (1990) developed a procedure wherein the deviation of treatment mean 'Y_t' (over n years) and the overall standard deviation 'ó' (k treatments over n years) was compared with the maximum attainable yield 'Y_{max}' in an attempt to arrive at a sustainable yield index (SYI). But, this was derived without considering the effects of rainfall distribution on crop yields. Hence, a new statistical measure of sustainability yield index (SYI), which is a function of the estimate of error 'ó' derived from regression of crop yield through rainfall, has been developed (Vittal *et al.* 2002).

The long-term fertilizer experiment on rainfed cotton based cropping systems was initiated in 1986 at the research farm of the Central Institute of Cotton Research, Nagpur. Nagpur, located at 21°09' N latitude and 71°07' E longitude, has a dry sub-humid tropical climate with a mean annual rainfall of 1050 mm received primarily through southwest monsoon from June to September.The daily rainfall data, collected from the local meteorological observatory, were summed up for determining the rainfall during crop growing period (sowing to harvest). The monthly distribution of rainfall along with mean and coefficient of variation (CV) is presented in table 1.

Table 1. Monthly distribution of rainfall (mm)

Year	June	July	August	September	Post-Sept*
1986	201	252	296	114	125
1987	155	191	303	24	169
1988	211	295	446	303	79
1989	160	254	206	40	80
1990	241	228	334	99	90
1991	171	396	313	3	4
1992	95	276	346	120	61
1993	131	439	188	248	152
1994	127	761	315	317	230
1995	141	378	252	266	25
1996	16	403	194	155	120
1997	53	213	188	181	332
1998	140	172	346	167	203
1999	83	265	335	234	77
2000	178	399	251	121	10
Mean	140.2	328.1	287.5	159.5	117.1
CV (%)	42.8	44.8	25.6	61.9	76.1

*upto final harvest

Source: Venugopalan *et al.* (2003)

The soil of the experimental site is a medium deep Vertisols and its physical properties are given in table 2.At the start, the surface soil had a pH of 8.1, organic C of 4.2 g kg^{-1}, Olsen's extractable P of 6.1 mg kg^{-1} and 1N ammonium acetate extractable K of 253 mg kg^{-1} (Venugopalan *et al.* 2003).

Table 2. Physical properties of the soil at the experimental site

Depth (cm)	Sand (%) (2-0.05 mm)	Silt (%) (0.05-0.002 mm)	Clay (%) (< 0.002 mm)	Water retention (g/g)	
				0.33 bar	15.0 bar
0-15	3.0	44.0	53.0	0.38	0.17
15-30	1.0	42.0	57.0	0.37	0.17
30-45	1.0	38.0	61.0	0.35	0.16
45-60	1.0	39.0	60.0	0.35	0.16

Source: Venugopalan *et al.* (2003)

The experiments were conducted on two mono cropping systems of rainfed cotton, *viz*., *G. arboreum* (var. AKH4/AKA 8401) and *G. hirsutum* (var. LRA 5166/LRK 516) under 13 nutrient management practices (Venugopalan and Pundarikakshudu 1999). Depending upon the onset of monsoon and moisture availability, the crop was sown from 26th June to as late as 15th July of the year. There is possibility of yield reduction in the year of late sown crop, hence for evaluating the sustainability of the yield, only those years were considered, wherein the crop was sown between 26th June to 3rd July.

The evaluation of sustainability of cotton yield under different nutrient management practices was done using the sustainability yield index (SYI) expressed as

$$SYI = \frac{Y_t - \sigma}{Y_{max}}$$

where,

Y_t = Mean treatment yield (kg ha^{-1})

ó = Estimate of error (kg ha^{-1})

Y_{max} = Maximum yield (kg ha^{-1}) among the treatments over the selected years

The estimate of error was determined from the quadratic relationships between the rainfall and cotton yield (Vittal *et al.* 2002; Venugopalan *et al.* 2003) established for both the cotton species *G. arboreum* and *G. hirsutum*. As the crop yield depends on the interaction of nutrient supply and rainfall distribution, in the present study the estimate of error was determined for each treatment separately for both the cotton species and thus, the effect of rainfall distribution on cotton yield, to some extent, was negated.

In the concept of SYI, low values of standard deviation or estimate of error (ó) suggest sustainability of the system as ó measures the variation yield over the years caused by the soil and climatic factors under a particular nutrient management practice. If standard deviation or estimate of error (ó) is high, SYI will be low and thus indicates unsustainable management practice (Singh *et al.* 1990). Any crop management practice yielding SYI of more than 0.66 is considered as recommendable between 0.50 to 0.65 as highly promising and more than 0.33 as dependable (Vittal *et al.* 2002).

Trends in seed cotton yield indicated that mono-cropping of *G. arboreum* was superior to *G. hirsutum* in 8 out of 10 years especially in years experiencing normal rainfall (Fig. 1).

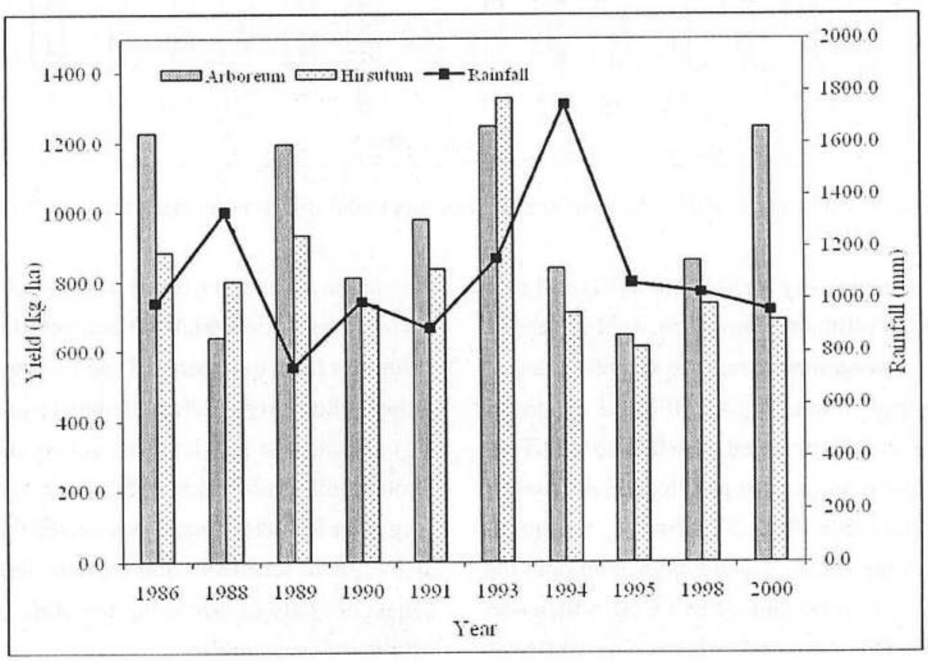

Fig. 1. Trends in the yield of two cotton species in relation to rainfall

Both, *G. arboretum* and *G. hirsutum* responded to higher NPK dose and the mean increase in yield with $N_{90}P_{45}K_{45}$ (T_{12}) over $N_{60}P_{30}K_{30}$ (T_6) was 19.4%, which was significant. Fertiliser doses for rainfed *G. arboreum* grown on Vertisols need to be enhanced from the current recommendation of 30:15:0. Substituting ½ N dose with FYM benefitted both the cropping systems at both levels. The average response with $N_{30}P_{30}K_{30}$ + 5 ton FYM (T_7) over $N_{60}P_{30}K_{30}$ (T_6) was 117 kg ha^{-1} and $N_{45}P_{45}K_{45}$ + 7.5 ton FYM (T_{13}) over $N_{90}P_{45}K_{45}$ (T_{12}) was 220 kg ha^{-1}. However, substituting the entire dose of N through FYM was not superior to substituting ½ dose of N through FYM or application of N alone (T_5 *vs* T_7 or T_{11} *vs* T_{13} or T_{12}) (Venugopalan *et al.* 2003). There were significant annual variations in the magnitude of response to nutrients (Fig. 2) resulting in high CV ranging from 22.7% to 35.6% in *G. arboretum* and 22.1% to 33.7% in *G. hirsutum*.

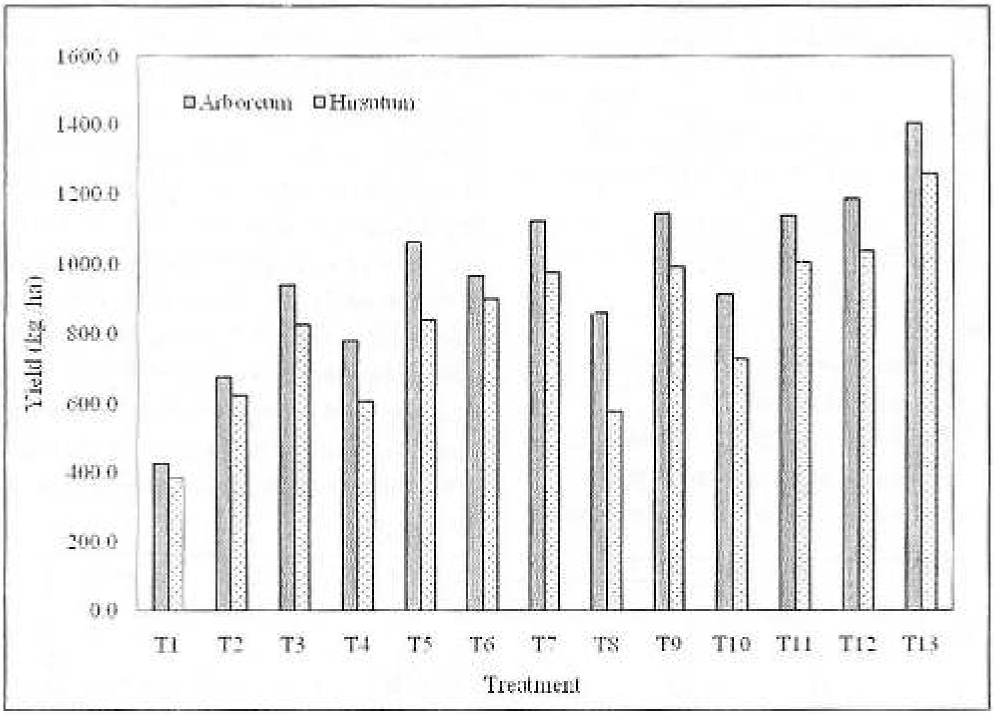

Fig. 2. Mean seed cotton yield of *G. arboreum* and *G. hirsutum* under different nutrient management combinations

The sustainability yield index (SYI) and estimates of error (σ) estimated for cotton yield under different nutrient management practices are presented in table 3.SYI ranged from 0.18 to 0.60 for *G. arboreum* whereas for *G. hirsutum* it ranged from 0.15 to 0.49.Thus across all nutrient management practices *G. Arboretum* was more sustainable. The SYI for T_{13} treatment ($N_{45}P_{45}K_{45}$ + 7.5 ton FYM) was the highest in both the cotton species. In *G. arboreum*, it was 0.60, which was more than 0.50 indicating highly promising treatment whereas in *G. hirsutum* it was 0.49, which was more than 0.33 indicating dependable treatment.Moreover the SYI values for INM treatments (T_7 and T_{13}) were higher than those of the corresponding chemical equivalents (T_6 and T_{12}) in both the species.Bhattacharyya *et al.* (2011), through soil organic carbon (SOC) simulation model and long term fertilizer data, also showed that combination of inorganic fertilizers and organic fertilizer (FYM) helped not only in increasing the SOC, but also in sustaining the crop yields.

Table 3. Sustainability index for two rainfed cotton species under different nutrient management practices

Nutrient management practice	*G. arboreum*		*G. hirsutum*	
	Estimate of error (σ), kg/ha	*SYI*	Estimate of error (σ), kg/ha	*SYI*
T_1 (N_0P_0*K_0*)	56.0	0.18	46.7	0.15
T_2 (N_{60})	81.2	0.28	68.9	0.25
T_3 ($N_{60}P_{30}$)	95.3	0.40	81.9	0.33
T_4 ($N_{60}K_{30}$)	98.0	0.32	67.7	0.24
T_5 ($N_0P_{30}K_{30}$ + 10 ton FYM)	114.0	0.45	78.8	0.34
T_6 ($N_{60}P_{30}K_{30}$)	93.4	0.41	96.6	0.36
T_7 ($N_{30}P_{30}K_{30}$ + 5 ton FYM)	119.6	0.48	87.6	0.40
T_8 (N_{90})	105.7	0.36	83.2	0.22
T_9 ($N_{90}P_{45}$)	108.1	0.49	118.9	0.39
T_{10} ($N_{90}K_{45}$)	109.4	0.38	96.2	0.28
T_{11} ($N_0P_{30}K_{30}$ + 15 ton FYM)	129.6	0.48	105.6	0.40
T_{12} ($N_{90}P_{45}K_{45}$)	93.2	0.52	130.4	0.41
T_{13} ($N_{45}P_{45}K_{45}$ + 7.5 ton FYM)	142.1	0.60	155.8	0.49

*as P_2O_5 and K_2O

In both the cotton species, application of P (T_3 or T_9) over N alone (T_2 or T_8) improved the sustainability and additional supplementation of K (T_6 or T_{12}) further improved the indices. Thus N alone may not sustain the cotton production and balanced application of P and K along with N is essential to sustain the production system.Integrated nutrient management treatments, where a 50 per cent of the N dose was applied through organics (T_7 and T_{13}), made the system more sustainable reinforcing the need of organics in rainfed cotton production.

Thus, it can be observed that the chemical fertilizers alone cannot give higher sustainable yield, but it should be supplemented with organic and green manures. The proper nutrient management practice not only gives higher sustainable yield, but also improves the soil environment and health.

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