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Soil Suitability Analysis for Crop Planning in Kheragarah *Tehsil* of Agra District, Uttar Pradesh

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Soil suitability is prerequisite for sustainable agriculture and it plays a pivotal role in crop production especially in degraded lands. In this study, an attempt was made to assess the soil suitability of Kheragarah *tehsil* for production of major crops during *rabi* and *kharif* seasons. Six pedons of the *tehsil* were studied for their physical and chemical properties and their suitability for growing wheat, maize, cotton and barley. All pedons were found to be moderate to deep in soil depth, well to poorly drained, slightly to strongly alkaline (pH 7.98 - 9.43), slightly to highly saline (EC_e 1.81- 7.23 dS m^{-1}), low in organic carbon (1.1-2.7 g kg^{-1}), CEC medium to high [19.7 - 24.4 cmol(p^+) kg^{-1}]. The calcium carbonate content ranged from nil to 14.3%. Soils were low in available N (72.0 to 220.0 kg ha^{-1}), low to high in available P (3.7–15.0 kg ha^{-1}) and medium to high in available K (153.0 - 361.6 kg ha^{-1}). However, the soils were adequate in available Fe and Mn but low in available Zn and Cu content. The soil suitability analysis revealed that soils at P1 locations were moderately suitable for growing wheat and barley and marginally suitable for cotton and maize cultivations. The P2 soils were moderately suitable for wheat, maize and barley and marginally suitable for cotton. However, the soils of P3 and P5 were not suitable for growing any of the selected crops. But, P6 soils were moderately suitable for growing all selected crops whereas, P4 soils were highly suitable for all selected crops except maize.

Key words: Crop, degraded land, soil physical and chemical properties, soil suitability analysis, Kheragarah tehsil, Agra

Soil is the most valuable natural resource. It is at the heart of terrestrial ecology, but it is finite and non-renewable (Mustafa *et al*. 2011 a, b). As we have to meet the challenges of this century, new understandings and new technologies will be needed to protect the environment and at the same time, produce food and biomass to support society (Brady and Weil 2004). Systematic study of morphology and taxonomy of soils provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for different uses (Sehgal 1999; Samanta *et al*. 2011). A plethora of approaches have been followed in the past for analysis of the land suitability for different crops (Forkuo and Nketia 2011; Haldar 2013; Kihoro *et al*. 2013; Das and Sudhakar 2014). Generation of soil data base at regional scales is essential for various agricultural developmental activities in the area. The *tehsil* suffers from a variety of degradation such as salinity, waterlogging, ravines, degraded hills and rock quarries. Land suitability analysis for crop production becomes a paramount important aspect for enhancing agricultural production and productivity at regional settings. Keeping this in view, the present investigation was taken up to study the potentiality and limitations of soils of Kheragarh *tehsil* of Agra district for agricultural activities. In this study, an attempt was made to study the soil suitability of Kheragarah *tehsil* for production of the major crops during *kharif* and *rabi* seasons.

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Materials and Methods

Study area

The Kheragarh *tehsil* of Agra district, Uttar Pradesh, lies between geo-coordinates 26°44′31.43″

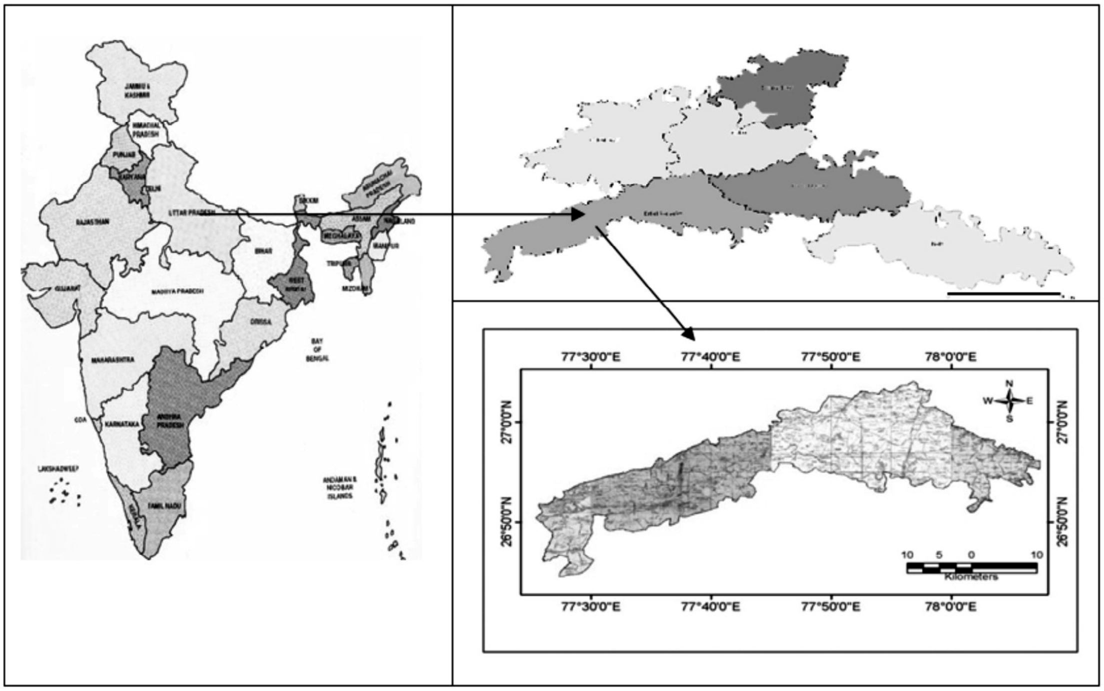

Fig. 1. location map of the study area

to 27°04′07′′ N latitude and 77°27′21.27′′ to 78°07′22.42′ E longitude and it covers an area of 80,000 ha. The study area is characterized by hot dry sub-humid to semi-arid transition with intense hot summer, cold winter and general dryness through the year except during July to September. The mean annual air temperature varies from 34 to 46 °C in summer and rising to 50 °C in the month of June. In winter (December - February), average temperature ranges from 6.5 to 13 °C besides a minimum of 4 °C during January. The area receives mean annual rainfall ranging between 600 to 1000 mm which is mostly received during south-west monsoon period. Unfortunately, the mean rainfall in winter is considered as insufficient for growing of *rabi* crops such as wheat, barley and sugarcane. Neem (*Azadirachta indica*), babul (*Acacia arabica*), dhak (*Butea monosperma*) and faras (*Tamarix* sp.) are the predominant species among the natural vegetation.

Soil sampling

Six representative profiles at different locations *viz.*,P1: Jhilra village, P2: NaglaTeja, P3: Aila village, P4: Rudou, P5: Iradatnagar village and P6: Nagla Hotio were studied for different land degradation features based on Soil and Land Use Survey of India report (SLUSI 2000) and information extracted from satellite image (FCC, May 2009, 1:50,000 scale). Horizon-wise samples were collected from soil profiles and analyzed for physical and chemical properties using the established standard analytical methods.

Analysis of soil samples

Particle size analysis was undertaken by international pipette method as described by Black (1965). Soil bulk density (BD) was determined using the core soil sampler as described by Black (1965). Free $CaCO_3$ was estimated using a rapid manometric method using Collin's Calcimeter (Williams 1949). The electrical conductivity of the saturated soil paste extract (EC_e) was determined using Elico conductivity bridge (CM 82T) following the procedure given by Jackson (1973). Soil reaction was determined in 1:2 suspension using standard pH meter (Jackson 1973). The method described by Bower *et al.* (1952) was used for cation exchange capacity (CEC) estimation. Soil organic carbon (OC) was estimated using the Walkley and Black wet oxidation method (Walkley and Black 1934). Available nitrogen (N) was estimated using Kjeldahl distillation method (Subbaiah and Asija 1956). The $NaHCO_3$ extractable phosphorus (P) was estimated by ascorbic acid method (Watanabe and Olsen 1965) and quantified by spectrophotometer. Available potassium (K) was extracted by 1*N* ammonium acetate solution at pH 7

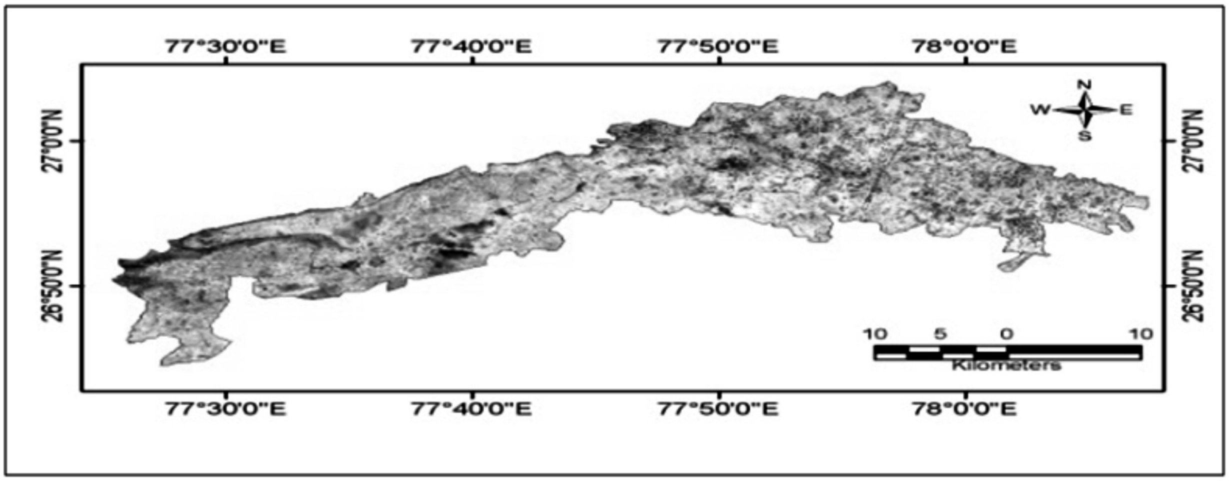

Fig. 2. False colour composite (FCC) of May, 2009 of the study area

as described by Jackson (1973) and determined by flame photometer. The DTPA-extractable micronutrients iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted from the soil samples by 0.005*M* DTPA at pH 7.3 according to Lindsay and Norvell (1978) and the concentration of the micronutrients was estimated by atomic absorption spectrophotometer (AAS). Soil suitability evaluation was carried out following the FAO framework (FAO 1976) and as per guidelines described by Sys *et al.* (1991).

Geospatial data analysis and ground truthing

The IRS-P6 LISS III satellite data of dry season (May, 2009; path: 097, row: 052) was interpreted with the help of survey of India (SOI) topo-sheets No. 54E/16, 54F/5, 54F/6, 54F/9, 54F/13, 54I/4 and 54J/1 of 1:50,000 scale for extracting information, preparation of base maps and navigation purposes during ground truth (Fig. 2).

Results and Discussion

Soil Characteristics

The characteristics of soils as weighted means are presented in table 1. Granulometric data indicated that the clay content varied from 15.88 to 35.95%. Silt content of all pedons exhibited an irregular trend with depth and ranged between 10.00 and 55.76%. In general, sub-surface horizons exhibited higher clay and silt content as compared to surface layer which may be due to illuviation process occurring during soil development. The reverse is true in case of sand as it is higher in surface layers than the sub-surface layers and ranged between 13.52 and 74.12%. The loamy texture was predominant in the study area followed by sandy loam in P4, silty clay loam in P3 and clay loam in P1 locations.

Bulk Density

The bulk density in different pedons varied from a minimum of 1.4 Mg m^{-3} to a maximum value of 1.7 Mg m^{-3} and showed an increasing trend with depth. This might be attributable to more compaction of finer particles, low organic matter content and less aggregation besides high organic carbon content in deeper layers (Rao *et al.* 2008).

Water Holding Capacity

Water holding capacity of different pedons ranged from 1.00 to 15.7%. These variations were due to the difference in depth, clay, silt and organic carbon content and also might be due to the illuviation and eluviations of finer fractions in different horizons (Leelavathi *et al.* 2009).

Physicochemical Properties

Soils are slightly to strongly alkaline with pH in the range of 7.98-9.43 and increased with depth. The high values of pH would be attributed to high base saturation and exchangeable sodium percentage. The ECe values varied from a minimum value of 1.81 to a maximum value of 7.23 dS m^{-1}, suggesting that the soils are slightly to strongly saline (Table 1).

Organic Carbon

Generally, the OC content of all pedons was low (1.1 to 2.7 g kg^{-1}, and decreased with depth in all profiles (Table 1). The decrease of OC with depth is attributed to the addition of plant residues and

Table 1. Soil-site characteristics (weighted means)

Character	Pedon					
	P1	P2	P3	P4	P5	P6
Slope (%)	1-3	1-3	3-8	1-3	15-30	1-3
Erosion	e_0	e_2	e_2	e_1	e_4	e_0
Flooding	F_2	F_2	F_3	F_2	F_4	F_1
Drainage	Mod. well	Well	Poor	Well	Well	Mod. well
Sand (%)	29.49	31.00	13.52	74.12	37.49	40.75
Silt (%)	34.56	44.43	55.76	10.00	39.51	37.00
Clay (%)	35.95	24.57	30.72	15.88	23.00	22.25
Texture	cl	l	sicl	sl	l	l
BD (Mg m^{-3})	1.6	1.70	1.70	1.60	1.40	1.60
WHC	4.0	7.4	1.0	13.7	15.7	12.3
$CaCO_3$ (%)	0.0	0.9	1.3	0.0	14.3	0.2
CEC [cmol(p^+)kg^{-1}]	22.8	21.5	24.4	19.7	22.1	23.7
BS (%)	77.6	63.4	92.6	46.7	94.0	51.7
OC (g kg^{-1})	2.7	2.2	2.2	1.6	1.1	2.0
EC_e (dS m^{-1})	7.23	3.15	5.46	1.81	6.17	2.12
pH	7.98	8.28	9.43	8.21	8.25	8.41
ESP (%)	19.7	8.2	56.4	3.8	8.8	5.0
Available N (kg ha^{-1})	220.0	186.0	120.0	131.0	72.0	188.0
Available P (kg ha^{-1})	15.0	9.0	5.3	14.0	7.0	3.7
Available K (kg ha^{-1})	280.0	183.3	237.3	189.0	361.6	153.0
DTPA-Fe	16.53	9.82	14.64	7.88	6.10	9.24
DTPA-Mn	12.48	15.66	20.41	14.57	1.11	13.85
DTPA-Zn	0.54	0.51	0.17	0.01	0.01	0.01
DTPA-Cu	0.63	0.14	0.58	0.04	0.07	0.10

farmyard manure (FYM) to surface horizons. However, the decrease of OC carbon with depth could be due to the prevalence of tropical conditions where the degradation of organic matter occurs at faster rates coupled with low vegetation cover, thereby leaving less OC in the soils (Nayak *et al*. 2002). The CEC values which correspond to clay content in the horizons, ranged between 19.7 and 24.4 [cmol(p^+) kg^{-1}] (Table 1). The base saturation varied from 46.7 to 94.0% and the exchangeable sodium percentage varied between 3.8 to 56.4 and the highest values were found in the surface and sub-surface layers in the profile of P3 soils.

Fertility Status

It was observed that the available N content varied from 72.0 to 220 kg ha^{-1} in the entire depth (Table 1). However, available N was found to be high at surface horizon and decreased gradually with soil depth which might be due to decreasing trend of organic carbon with depth (Prasuna Rani *et al*. 1992). The available P content in the horizons of the pedons indicates that the values varied from 3.7 to 15.0 kg ha^{-1} (Table 1). The highest available P content was noticed in the surface horizons and decreased periodically with depth and this might be due to the confinement of crop cultivation to the rhizosphere and supplementation of the depleted P through external sources *i.e*. fertilizers (Sharma *et al*. 2008). The available K content ranged from 153.0 to 361.6 kg ha^{-1} (Table 1). An irregular trend was noticed in the available K content in all pedons. This could be due to more intense weathering, release of liable K from organic residues, application of K-fertilizers and upward translocation of K from lower depths along with capillary rise of groundwater (Thangasamy *et al*. 2005). The results suggested that these soils contained sufficient amount of available K which may be attributed to the prevalence of K-rich minerals like illite and feldspars (Sharma *et al*. 2008).

Micronutrient Status

Available Zn (DTPA-Zn) content of study area was low (0.01–0.54 mg kg^{-1}) and all soils were classified as deficient. Pedons 2, 4, 5 and 6 were found to be deficient in available Cu except P1 and P3 soils where these values were 0.63 and 0.54 mg kg^{-1}, respectively. Available Mn content of these soils varied from a minimum value of 1.11 to a maximum value of 20.41 mg kg^{-1}, suggesting that these soils contained sufficient amount of available Mn. It was high in the surface horizons and gradually decreased

Table 2. Soil-site suitability criteria (crop requirements) for wheat

Soil–site characteristics	Suitability classes				
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable N1	N2
Topography (t)(slope, %)					
Plain, irrigated	0-1	1-3	3-8	>8	
Hilly, unirrigated	0-3	3-8	8-15	15-25	>25
Wetness (w)					
Flooding	F_0	F_1	F_2	F_3	F_4
Drainage Classes	well	Mod. well	Imperfect, excessive	Poor	V. poor
Soil (s)					
Texture (USDA)	l, cl, sil, scl	sc, sic, c, ls, sicl, sl	c^+	s, c^{++}	
AWC (mm m^{-1})	>200	150-200	100-150	50-100	<50
Depth (cm)	>100	50-100	25-50		<25
$CaCO_3$ (%)	3-10	10-25	25-50	50-75	>75
Soil fertility (f)					
(NPK rating) *	HHH	MMM	MLL	LLL	
OC (g kg^{-1}) surface soil	6-7	5-6	3-5	<3	
Soil Salinity/Sodicity (n)					
EC_e (dS m^{-1})					
Fine and mod-fine texture	<2	2-4	4-8	8-15	>15
Coarse and medium texture	<4	4-8	8-15	15-25	>25
ESP (%)					
Coarse and medium texture	<8	8-15	15-25	25-40	>40
Fine texture	<2	2-4	4-8	8-15	> 15
Base saturation	>80	50-80	35-50	<35	
pH (1:2.5)	6.5-7.5	7.6-8.5, 5.5-6.4	8.6-10, 4.5-5.4	>10, <4.5	

*H: high, M: medium, L: low, c+: clay (45-60%), c++: clay (>60 %)

with depth, which might be due to higher biological activity and organic carbon content in the surface horizons (Thangasamy *et al.* 2005). The available Fe content varied from 6.1 to 16.53 mg kg^{-1} and decreased with depth. It was observed that all soils contain sufficient amount of available Fe.

Suitability of soils for cultivation of crops

The landscape and soil characteristics of six pedons as summarized in table 1 were compared with the soil and site requirement of different crops (Tables 2, 3, 4 and 5). The data (Table 6) revealed that soils of pedon 1 were moderately suitable (S2) for growing wheat and barley and marginally suitable (S3) for cotton and maize cultivations. The P2 soils were moderately suitable (S2) for wheat, maize and barley and marginally suitable (S3) for cotton. However, due to low OC, available N and P contents besides high ESP and pH, the pedon 3 (P3) was not suitable for growing any of the selected crops. The suitability of these soils can be improved through application of gypsum in conjunction with surface and sub-surface drainage technology. Low OC and subsequently low available N were the major limitations for growing maize in pedon 4. In the contrary, this soil is suitable (S2/S3) for cultivation of wheat, cotton and barley. The suitability of P4 can further be improved through application of fertilizer and FYM. In pedon 5 (P5), low OC, available N and P contents are the major limitations which render the soils under not suitable classes (N1/N2). Also, flooding and topography are other limitations of these soils. All the selected crops were found to be moderately suitable for growing in pedon 6 (P6).

Conclusions

The study of physical and chemical properties of the soils of Kheragarah *tehsil* of Agra district, Uttar Pradesh, indicated that the soils were moderate to deep, well to poorly drained, slightly to strongly alkaline in soil reaction and slightly to highly saline as well as low to medium in organic matter content. Further, CEC was medium to high and traces to slight calcium carbonate ($CaCO_3$) content were observed in

Table 3. Soil-site suitability criteria (crop requirements) for cotton

Soil–site characteristics	Suitability classes				
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable N1	N2
Topography (t)					
Slope (%)	2-4	4-8	8-16	16-30	>30
Erosion	e0	e1	e2	e3	
Wetness (w)					
Flooding	F_0	F_1	F_2	F_3	F_4
Drainage classes	Well	Mod. well	Imperfect	Poor, excessive,v. excessive	
Soil (s)					
Texture (USDA)	l, cl, scl, sil	sl, sicl, sic, c(n-s)	c(s-s), ls		
Depth (cm)	>100	75-100	50-75	20-50	<20
$CaCO_3$ (%)	<6	6-15	15-25	25-35	>35
Soil fertility (f)					
(NPK rating)	HHH	MMM	MLL	LLL	
CEC [cmol(p$^+$) kg^{-1})]	>24	16-24	<16	-	
Base saturation	>80	50-80	35-50	20-35	<20
OC (g kg^{-1}) Surface soil	>8	8-4	4-2	<2	
Soil Salinity/Sodicity (n)					
ECe (dS m^{-1})	<2	2-4	4-6	6-8	>8
ESP (%)	<8	8-15	15-20	20-25	>25
pH (1:2.5)	5.5-7.5	7.6-8.5 5.0-5.4	8.6-9.0 <5.0		

c(n-s):non swelling clay, c(s-s): shrink swell clay

Table 4. Soil-site suitability criteria (crop requirements) for maize

Soil–site characteristics	Suitability classes				
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable N1	N2
Topography (t)					
Slope (%)	<1	1-3	3-5	5-8	>8
Erosion	e_0	e_1	e_2	e_3	
Wetness (w)					
Flooding	F_0	F_1	F_2	F_3	F_4
Drainage classes	Well	Mod. well	Imperfect	Poor, excessive, v. excessive	
Soil (s)					
Texture (USDA)	sic, c	sicl, cl	si, sil, sc, scl, l	sl, c, s, ls	
AWC (mm m^{-1})	>200	150-200	100-150	50-100	
Depth (cm)	>100	80-100	50-80	25-50	<25
$CaCO_3$ (%)	<5	5-10	10-20	>20	
Soil Fertility (f)					
CEC [(cmol(p$^+$) kg^{-1}]	>30	20-30	10-20	<10	
Base saturation	>80	50-80	35-50	<35	
O.C (g kg^{-1}) surface	>10.0	7.5-10.0	5.0-7.5	<5.0	
Soil Salinity/Sodicity (n)					
EC_e (dS m^{-1})	<1	1-2	2-4	4-8	
ESP (%)	<5	5-10	10-15	15-40	>40
pH (1:2.5)	6.5-7.5	7.6-8.0	8.1-9.0	>9.0 <6.5	

Table 5. Soil-site suitability criteria (crop requirements) for barley

Soil–site characteristics	Suitability classes				
	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable N1	N2
Topography (t)					
Slope (%)	<1	1-2	2-4	4-6	>6
Erosion	e_0	e_1	e_2	e_3	e_4
Wetness (w)					
Drainage classes	Well	Moderate	Imperfect	Poor	V. poor
Soil (s)					
Texture (USDA)	sic, sicl, si, sil, cl	sc, l	scl	sl	s
Depth (cm)	>90	50-90	20-50	10-20	<10
$CaCO_3$ (%)	3-20	20-30	30-40	40-60	>60
CEC [cmol(p^+) kg^{-1}]	>24	16-24	<16	-	
Base saturation	>80	50-80	35-50	<35	
OC (g kg^{-1}) Surface soil	<20	12-20	8.0-12.2	<8.0	
Soil Salinity/Sodicity(n)					
ECe (dS m^{-1})	<8	8-12	12-16	16-20	>25
ESP (%)	<15	15-25	25-35	35-45	

Table 6. Land suitability evaluation for various crops

Pedon	Crop			
	Wheat	Cotton	Maize	Barley
P1	S2	S3	S3	S2
P2	S2	S3	S2	S2
P3	N1	N2	N1	N2
P4	S2	S3	N1	S3
P5	N1	N2	N1	N1
P6	S2	S2	S2	S2

S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Currently not suitable, N2: Permanently not suitable

all the profiles except the ravinous lands, where it was very high. Regarding the availability of major nutrients, the soils were found to be low in available N, low to high in available P and medium to high in available K. As regards to the availability of micronutrients, it was observed that soils were adequate in available Fe and Mn but deficient in available Zn and Cu except two profiles which were sufficient in available Cu.

The soil suitability analysis when matched with the soil requirements of the major crops grown in the region revealed that P1 soils (Jhilra village) were moderately suitable for growing wheat and barley in *rabi* and marginally suitable for cotton and maize cultivations in *kharif* growing season. While the P2 soils (Nagla Teja) were moderately suitable for wheat, maize and barley and marginally suitable for cotton. Due to certain limitations, the soils of P3 (Aila village) and P5 (Top of ravine, Iradatnagar village) were not suitable for any of selected crops. P4 soils (Rudou) were suitable for all selected crops except maize. All afore mentioned crops were moderately suitable for growing in P6 soils (Nagla Hotio village).

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