



Soil Suitability Evaluation of Major Crops for Sustainable Land Use Planning in Kupti Watershed, Yavatmal District, Maharashtra

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This study presents soil suitability evaluation of two major crops grown in a Kupti watershed (11257 ha) located in Darwha block of Yavatmal district in Maharashtra. The study was warranted by continued persistence of the farmers to cultivate cotton and soybean crops during *khariif* season despite repeated failure of these crops especially cotton recently. The traditional sorghum crop that is now completely wiped out from this region was also evaluated to understand the farmers' choice of crops. The soil information was collected through survey at 1:10000 scale in the watershed. The FAO criteria were used in conjunction with soil suitability criteria suggested by NBSS and LUP. The investigations indicated that merely 4079.0 ha area representing 36.2 % of watershed are under moderately suitable (S2), 4006.0 ha (35.6 % of TGA) under marginally suitable (S3) and 649.1 ha (5.8 % of TGA) under not suitable (N) class to grow cotton. While numbers for sorghum show 5096 ha area (45.3 %) under S2; 2989.0 ha (26.6 %) under S3; and 649.1 ha (5.8 %) under N class. Soybean suitability evaluation showed 5138.0 ha (45.6 %) under S2; 2947.0 ha (26.2 %) under S3 class and 649.1 ha (5.8 %) under N class. Pigeonpea suitability evaluation showed 3421 ha (30.4 %) under S1; 1966 ha (17.5 %) under S2; 2698 ha (24.0 %) under S3 and 649.1 ha (5.8 %) under N class. The results validated the traditional sorghum crop popularity in the past and gain in area to soybean. The farmers appear to prefer cotton despite lower soil suitability ratings due to deprecation of other crops. These findings suggest that cotton is not well suited in the area and efforts are required to promote alternate crops and/or propagate soil specific varieties, agro-management such as mulching, life saving irrigation and broad bed furrow sowing to overcome bio-physical constraints.

Keywords: Soil-site suitability evaluation, rainfed crops, watershed, land use planning

Introduction

Land suitability evaluation is the pre-requisite for sustainable agricultural production. It involves evaluation of the criteria ranging from soil, terrain to socio-economic, market and infrastructure (Prakash 2003). Land evaluation for ecological regions and territories aims at creating a new good production power together with stability and sustainability (Jamal 2003). The evaluation relates to the environmental and socio-economic conditions of the area as it includes a consideration of inputs and projected outputs of production process.

According to the FAO general framework for land suitability evaluation (1976), the land suitability

classification consists of assessing and grouping the land types in orders and classes according to their capacity. Land evaluation portrays the suitability of the land for agriculture and other uses, wherein land is classified considering a number of soil characteristics, associated land features and environmental factors such as climate. Many researchers in India evaluated suitability of soils in diverse agro-ecologies for various field crops using categorized soil-site suitability for the respective crops as very highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) viz. sugarcane in Chittoor district, Andhra Pradesh (Devi and Naidu 2016), major crops across India (Naidu *et al.* 2006); turmeric in Wardha district, Maharashtra (Mandal *et al.*, 2008), assessed the suitability of shrink-swell soils for cotton, sorghum, pigeonpea, soybean and

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groundnut for soils of Selsura KVK research farm in Wardha district, Maharashtra (Jagdish Prasad *et al.*, 2009) rice and sugarcane and potato lateritic soils of Zaheerabad Mandal, Medak district, Telangana State. Similarly Singh *et al.*, (2013) evaluated the crop suitability for lateritic soils of Telangana state while Gandhi and Savalia (2016) evaluated suitability of wheat crop for calcareous basaltic soils of Girnar toposequence in Southern Saurashtra region in Gujarat.

This case study was initiated from the concern that farmers in Yavatmal district of Maharashtra continue to grow cotton crop on unsuitable soils despite state efforts to dissuade. Therefore the study aimed at quantification of area suited to grow prevailing cotton and soybean crops and recently vanished sorghum crop at soil series level.

Material and Methods

The study area *i.e.* Kupti watershed (fig 1) is located at 20° 15' 47" to 20° 20' 42" N and 77° 35' 27" to 77° 42' 54" E in Darwha block, Yavatmal district Maharashtra. Elevation of the watershed ranges from 330 to 470 m above MSL covering an area of 11257 ha. Agro-ecologically it is placed in 'hot moist to semi-arid AESR 6.3. Geologically, the area is mainly occupied by the Deccan trap formation known as basalt flows, which belongs to Sahyadri group of Ajanta and Chikhli formations. (District Resource Map, Yavatmal District, Maharashtra of Geological survey of India, 2001). The recent alluvium occurs in the river valley.

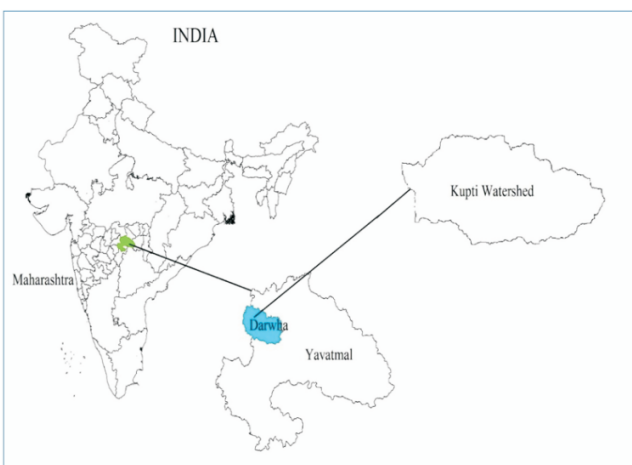


Fig. 1 Location map of Kupti watershed

The climate of study area is hot summer with dryness except during the south-west monsoon, cold season from December to February followed by hot season during March to May. The average annual rainfall of (2005-2015) is about 798 mm, temperature rises rapidly after February till May which is the hottest month of the year with mean daily maximum temperature 42.8° C during May and the mean daily minimum 21.2° C. After October, the day and night temperatures decrease rapidly. January is usually the coldest month with the mean daily maximum temperature at 29.6° C and the mean daily minimum at 13.9° C. The relative humidity ranges from 44.3 % to 54.6 %.

The soil water balance of the study area showed that the precipitation (P) exceeds the water need potential evapotranspiration (PET) from the month of June to September and is less than PET during rest of the year. The length of growing period (LGP) is about 180 days in a year exhibiting distinct moist, humid and dry period. The crop growing period starts during second fortnight of June and ends during second half of November.

The pre-dominant crops cultivated during *kharif* (2015-16) were sorghum, cotton and soybean with intercropped with pigeonpea. The area under agriculture land use was 7332 ha (73 % TGA), followed by forest area (1997 ha) and wastelands (720 ha). A land form map prepared from satellite image (LANDSAT-8) served as base map for ground truthing, compilation of soil data for generating soil map and other thematic maps. The boundaries of land units were verified and modified by field investigation. The morphological properties of soil profiles were recorded as per Soil Survey Staff (1951) and classified as per soil taxonomy (Soil Survey Staff, 2012). The analyses of 10 pedons were done to know physico-chemical properties and the suitability for different crops was evaluated based on the guidelines of FAO framework (FAO, 1976) as modified by Sys (1985) and the soil requirement as suggested by NBSS&LUP (1994). Actual suitability for each crop was worked out using soil properties while potential suitability was suggested based on the manageable limitations. For instance, limitations of low organic carbon could be overcome with manure application

and thus the suitability class could be improved. The suitability was mapped using ArcGIS software. Each pedon represents a soil series defined as “a group of soils having soil horizons similar in differentiating characteristics and arrangements within the series control section, except for features of the surface soils and have developed on similar parent material under comparable climate and geomorphic environment”.

Results and Discussion

Soil- site characterization

The morphological characteristics of soils of Kupti Nala watershed showed that most of the soils were very shallow to moderately deep with colour in hue 10 YR, value ranging from 3 to 5 and chroma 1 to 4 except few pockets in the study area with red soils. These soils vary from very dark brown to very dark grayish brown in colour. This may be due to reduction of iron under impeded drainage (Prasad *et al.*, 1989) and complexation and chelation of organic colloids on the surface of smectite (Singh *et al.*, 1994). The surface soils of all pedons have well developed sub angular blocky structure except pedon P5, which has angular blocky

structure. These pedons (P2, P3, P5 and P7) exhibit cracks, slickensides and pressure faces in the pedons.

Most of the soils were clay in texture (Table 1), with clay content ranging from 23.8 to 63.3 %. The silt content varied from 21.2 to 57.7 % and the sand content of soil varied from 2.2 to 38.7 %. The clay content remained uniformly high (>35%) throughout the pedons in soils belonging to order Vertisols or vertic subgroup. The soils were slightly acidic to slightly alkaline in reaction (6.66 to 8.66) and pH of the soils increased with depth. Higher pH in soils may be due to basaltic parent material, which is alkaline in nature (Chinchmalatpure *et al.*, 2000), higher content of calcium carbonate and accumulation of soluble salts were due to washing from upper elevation (Arnold and Venkateshwarlu, 1982). The EC of the soils is generally low and ranged from 0.11 to 0.27 dSm⁻¹. The organic carbon content of the soil varied from a minimum of 0.17 % in P10 to a maximum of 1.38 percent in pedon P1. The cation exchange capacity of the soils varied from 26.33 to 53.35 cmol (p+) kg⁻¹. The soils of watershed are high in base saturation, which varied from 91.9 to 126.7 %. The calcium carbonate content of soils ranges from 3.46 % to 14.46 % in surface horizons and increases with depth.

Table 1. Physico-chemical characteristics of soils of Kupti watershed

Horizon	Depth (cm)	Texture			AWC (%)	pH (1:2)	EC dSm ⁻¹	OC (%)	CaCO ₃ (%)	CEC Cmol(P+) ₁ kg ⁻¹	BS (%)
		Sand	Silt	Clay							
		(%)									
Ap	0-16	20.5	21.2	58.3	11.8	6.84	0.11	1.38	3.46	29.79	99.50
AC	16-41	23.4	30.6	45.9	13.4	6.80	0.20	0.78	4.83	38.80	93.92
Ap	0-13	3.0	43.4	53.6	13.3	6.68	0.15	0.45	3.81	42.13	97.37
BC	13-38	4.2	36.6	59.2	16.0	6.66	0.15	0.39	4.19	39.56	101.31
Ap	0-15	38.7	33.2	28.1	12.5	8.17	0.27	0.33	6.19	54.75	102.32
Bw1	15-39	23.1	41.2	35.7	17.0	8.39	0.25	0.31	14.94	54.43	102.54
Bw2	39-73	18.5	57.7	23.8	3.6	8.30	0.26	0.28	9.44	55.07	100.27
Ap	0-18	7.9	37.7	54.4	7.4	7.63	0.11	0.39	6.81	35.12	103.59
Ap	0-20	23.5	33.7	42.8	14.0	8.37	0.23	0.62	14.46	29.79	112.39
Bt1	20-38	16.7	31.5	51.8	14.6	8.44	0.21	0.39	18.08	38.80	103.84
Bt2	38-55	15.3	21.4	63.3	17.2	8.49	0.21	0.31	16.71	36.72	104.30
BtC	55-80	28.6	30.4	41.1	15.6	8.66	0.21	0.11	27.58	29.10	116.9
Ap	0-17	13.8	35.4	50.8	13.7	8.14	0.25	1.15	9.46	50.58	126.75
Bw1	17-27	21.2	25.4	53.4	12.0	8.38	0.18	0.76	10.96	51.96	105.29
Bss1	27-42	22.4	23.7	53.9	15.2	8.40	0.21	0.79	12.96	53.35	102.92
Bss2	42-67	21.8	30.5	47.7	18.3	8.45	0.21	0.68	20.46	52.66	105.53
BC	67-82	27.0	31.0	42.0	14.3	8.38	0.21	0.50	27.33	53.35	103.73
Ap	0-22	5.9	32.0	62.1	16.8	8.18	0.19	0.88	9.83	51.27	108.29
Bw1	22-39	4.9	32.4	62.8	23.6	8.33	0.19	0.65	11.33	49.89	103.19
Bw2	39-61	3.0	40.7	56.4	18.9	8.24	0.21	0.66	11.46	54.74	95.20
Bss	61-94	2.2	47.9	49.9	19.1	8.25	0.21	0.63	12.33	49.19	105.35
BC	94-114	24.7	36.7	38.6	16.2	8.26	0.20	0.18	23.33	39.49	118.84
Ap	0-18	34.0	29.9	36.1	8.6	8.33	0.20	0.46	5.58	26.33	109.87
Bw1	18-39	19.7	39.3	41.0	15.4	8.34	0.21	0.19	10.58	38.11	91.94
Bw2	39-71	11.9	30.0	58.1	15.2	8.42	0.20	0.24	16.08	42.26	109.32
Bw3	71-114	21.2	34.7	44.1	16.0	8.33	0.22	0.30	16.33	42.96	107.08
Bw4	114-145	29.1	25.7	45.2	9.9	8.42	0.23	0.16	27.58	34.64	134.30
Ap	0-12	19.0	27.6	53.4	11.4	8.26	0.22	0.65	7.96	48.50	99.73
Bw1	12-26	12.1	26.8	61.1	12.8	8.29	0.17	0.63	8.71	49.89	103.09
Bw2	26-52	20.6	32.6	46.8	13.3	8.34	0.18	0.59	9.96	49.19	102.44
Bss1	52-92	6.3	39.3	54.5	16.6	8.31	0.20	0.53	14.71	49.19	101.40
Bss2	92-132	12.1	38.7	49.2	18.4	8.39	0.22	0.59	16.46	51.27	99.82
BCK	132-150	26.7	31.2	42.2	9.8	8.53	0.21	0.27	28.08	38.11	110.39
Ap	0-16	30.9	29.2	39.9	12.5	8.12	0.21	0.17	7.81	44.26	103.98

AWC- Available water capacity, EC-Electrical conductivity, OC-Organic carbon,CEC- Cation exchange capacity
BS-Base saturation.

Site characteristics:

The site characteristics *viz.* elevation, slope, erosion and drainage and other relevant properties for crop suitability

evaluation are shown in table 2. Five different landforms namely plateau, pediment, escarpment, upper alluvial plain, and lower alluvial plains were identified (Table 3).

Table-2. Soil site characteristics (weighted means) selected for suitability evaluation for major crops

Soil site characteristics	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Site characteristics										
Slope (%)	3-5	1-3	1-3	8-15	5-8	1-3	1-3	1-3	1-3	>15
Erosion	e2	e1	e1	e3	e2	e2	e1	e1	e1	e3
Drainage	ED	WD	WD	WD	WD	MWD	WD	WD	MWD	WD
Soil characteristics										
Texture	c	sic	cl	c	c	c	sic	c	c	cl
Depth (cm)	41	38	73	18	80	82	114	145	150	16
CaCO ₃	4.30	4.06	10.58	6.81	19.85	16.90	11.36	13.51	11.57	7.81
CEC [cmol(p+) kg^{-1}]	35.29	40.44	54.79	35.12	33.08	52.40	51.10	39.24	49.21	44.26
OC (%)	1.01	0.41	0.30	0.39	0.34	0.77	0.70	0.29	0.58	0.17
BS (%)	96	100	101	103	110	103	103	105	101	104
EC (dSm ⁻¹)	0.17	0.15	0.26	0.11	0.22	0.22	0.20	0.21	0.20	0.21
pH (1:2)	6.82	6.67	8.30	7.63	8.50	8.36	8.25	8.36	8.31	8.12
ESP	5.17	2.45	1.77	0.97	2.64	1.46	1.96	2.45	1.52	1.54

ED-Excessively drained, WD-Well drained, MWD-moderately well drained

Based on the differences and similarities in soil properties, ten soil series were identified in the watershed (Table 3) *viz.* Kupti-1, Kupti-2, Kupti-3, Kupti-4, Kupti-5,

Kupti-6, Kupti-7, Kupti-8, Kupti-9 and Kupti-10. The salient characteristics, classification are presented in Table 4. The 10 soil series were further used as mapping units to prepare soil suitability map.

Table 3. Landform-soil relationship

Pedons	Landform unit	Land use	Image Characteristics	Soil series	Slope (%)	Soil characteristics	Soil taxonomy
P1	Plateau (P)	Single crop (s1)	Bluish green and pink with diffuse checkerboard pattern	Kupti-1	3-5	Shallow, somewhat excessively drained, dark reddish brown (5YR 3/4M), clayey soils with sever erosion.	<i>Lithic Ustorhents</i>
P2	Plateau (P)	Single crop (s2)	Bluish green and pink with bold checkerboard pattern	Kupti-2	1-3	Mod. shallow, well drained, dark reddish brown (5YR 3/2M), clay soils with moderate erosion.	<i>Vertic Haplustepts</i>
P3	Plateau (P)	Double crop (d)	Dark red tone with bold checker board pattern	Kupti-3	1-3	Mod. deep, well drained, brown (10YR 3/2M), clay loam soils with moderate erosion.	<i>Vertic Haplustepts</i>
P4	Pediment (D)	Single crop (s)	Bluish green and pink with diffuse checkerboard pattern	Kupti-4	8-15	Very shallow, well drained, Brown (10YR 3/2M), silt loam soils with moderate erosion.	<i>Lithic Ustorhents</i>
P5	Pediment (D)	Double crop (d)	Dark red tone with bold checker board pattern	Kupti-5	5-8	Mod. deep, well drained, dark greyish brown (10YR 4/2M), clay soils with moderate erosion.	<i>Typic Haplusterts</i>
P6	Pediment (D)	Forest (f)	Bluish green tone with some pink patches	Kupti-4	8-15	Very shallow, well drained, brown (10YR 3/2M), silt loam soils with moderate erosion.	<i>Lithic Ustorhents</i>
P7	Pediment (D)	Double crop (d)	Dark red tone with bold checker board pattern	Kupti-6	1-3	Mod. deep, mod. well drained, brown (10YR 3/2M), clay soils with moderate erosion.	<i>Typic Haplusterts</i>
P9	Upper Alluvial Plain (U)	Single crop (s)	Bluish green and pink with diffuse checkerboard pattern	Kupti-9	1-3	Deep, mod. well drained, brown (7.5YR 3/2M), clay soils with moderate erosion.	<i>Typic Haplusterts</i>
P8	Upper Alluvial Plain (U)	Double crop (d)	Dark red tone with bold checker board pattern	Kupti-8	1-3	Deep, well drained, brown (7.5YR 4/2M), clay loam soils with moderate erosion.	<i>Typic Haplustepts</i>
P7	Lower Alluvial Plain (L)	Double crop (d)	Dark red tone with bold checker board pattern	Kupti-7	1-3	Deep, well drained, brown (7.5YR 4/2M), clay loam soils with moderate erosion.	<i>Typic Haplusterts</i>
P10	Escarpment (E)	Wasteland (w)	Greenish blue with pink patches	Kupti-10	>15	Shallow, well drained, reddish brown (2.5YR 5/3M), clay loam soils with moderate erosion.	<i>Lithic Ustorhents</i>
P10	Escarpment (E)	Forest (f)	Bluish green tone with some pink patches	Kupti-10	>15	Shallow, well drained, reddish brown (2.5YR 5/3M), clay loam soils with moderate erosion.	<i>Lithic Ustorhents</i>

Table 4. Description and classification of soils of Kupiti watershed

Pedon No.	Series name	Series description	Taxonomic classification
P-1	Kupiti-1 (K-1)	shallow, dark reddish brown, clay, noncalcareous, extremely drained, severe eroded, gently sloping, plateau top	Clayey mixed, hyperthermic <i>Lithic Ustorthernts</i>
P-2	Kupiti-2 (K-2)	shallow, dark reddish brown, silty clay, noncalcareous, well drained, moderately eroded, very gently sloping	Clayey, smectitic, hyperthermic, <i>Vertic Haplustepts</i> .
P-3	Kupiti-3 (K-3)	moderately shallow, brown, clay loam, moderately calcareous, well drained, moderately eroded, very gently sloping	Fine smectitic, hyperthermic (calcareous) <i>Vertic Haplustepts</i>
P-4	Kupiti-4 (K-4)	very shallow, brown, clay, moderately calcareous, well drained, moderately eroded, moderately sloping	Clayey mixed, smectitic, hyperthermic <i>Lithic Ustorthernts</i>
P-5	Kupiti-5 (K-5)	moderately deep, dark grayish brown, clay, strongly calcareous, well drained, moderately eroded, gently sloping	Fine smectitic, hyperthermic <i>Typic Haplusterts</i>
P-6	Kupiti-6 (K-6)	moderately deep, brown, clay, strongly calcareous, moderately well drained, severe eroded, very gently sloping	Fine smectitic, hyperthermic <i>Typic Haplusterts</i>
P-7	Kupiti-7 (K-7)	deep, brown, silty clay, moderately calcareous, well drained, moderately eroded, very gently sloping	Fine, smectitic, hyperthermic <i>Typic Haplusterts</i>
P-8	Kupiti-8 (K-8)	deep, brown, clay, moderately calcareous, well drained, moderately eroded, very gently sloping	Fine, mixed, skeletal, hyperthermic, <i>Typic Haplustepts</i>
P-9	Kupiti-9 (K-9)	deep, brown, clay, moderately calcareous, moderately well drained, moderately eroded, very gently sloping	Fine, smectitic, hyperthermic <i>Typic Haplusterts</i>
P-10	Kupiti-10 (K-10)	very shallow, reddish brown, clay loam, moderately calcareous, well drained, moderately eroded, moderately steep sloping	Clayey, skeletal, mixed, hyperthermic <i>Lithic Ustorthernts</i>

Soil-site suitability evaluation of major crops

Soil-site suitability for cotton

Cotton being a long duration crop with deep rooting system shows significant yield decline in shallow soils with low moisture storage (PAWC <100 mm/m). Higher yields could however be obtained in deeper soils (PAWC 200 mm). It tolerates fairly wide range of soil pH conditions *i.e.* acidity and alkalinity (Munro, 1987). The field studies show that cotton is successfully grown in deep soils with good drainage (NBSS & LUP, 1987; Bhaskaret. *al.* 1987; Sehgal *et al.* 1989& 1990). A depth of 100 to 120 cm has been observed to be optimum, whereas <50 cm depth was considered

uneconomical to grow cotton (Bhaskaret *al.*, 1987). In view of the above, soil depth of 50 cm was considered critical below which cultivation of cotton becomes marginal or uneconomical.

Based on these criteria and limitations, the soil-site suitability of K-1 to K-10 series was worked out (Table 5). The overall suitability class for cotton showed that soil of K-4 and K-10 series are not suitable for growing cotton due to major limitations of depth and landform. The soils of K-1, K-2, K-3, K-5, and K-8 series are marginally suitable (S3) with limitations of fertility and soil depth, while the soils of K-6, K-7, K-9 series are moderately suitable (S2) for cotton cultivation with moderate limitation of calcareousness.

Table 5. Degree of limitations and suitability of soil series for growing cotton

Soil characteristics	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10
Climatic Characteristics										
Total Rainfall (mm)	1	1	1	1	1	1	1	1	1	1
Rainfall in Growing Season (mm)	1	1	1	1	1	1	1	1	1	1
Mean Temperature in Growing Season °C	1	1	1	1	1	1	1	1	1	1
Mean Relative Humidity in Growing Season (%)	1	1	1	1	1	1	1	1	1	1
Length of Growing Period (days)	1	1	1	1	1	1	1	1	1	1
Site Characteristics										
Slope (%)	2	1	1	4	3	1	1	1	1	4
Erosion										
Drainage	3	0	0	0	0	1	0	0	1	0
AWC (mm/m)	3	3	2	4	1	1	0	0	1	4
Surface Stoniness (%)	2	2	1	1	0	0	1	0	0	1
Soil Characteristics										
Texture (% clay)	1	1	1	1	1	1	1	1	1	1
Depth (cm)	3	2	1	4	1	1	0	0	0	3
CaCo ₃ % (100 cm)	0	0	1	1	2	2	2	2	2	1
Soil Fertility										
CEC (cmol(P+)/kg)	0	0	0	0	0	0	0	0	0	0
BS (%)	0	0	0	0	0	0	0	0	0	0
OC (0-20 cm)	0	3	3	3	2	0	1	3	2	3
EC (dS/m)	0	0	0	0	0	0	0	0	0	0
ESP (%)	0	1	1	1	1	1	1	1	1	1
pH (1:2.5)	0	0	1	1	1	1	1	1	1	1
Limitation	3sw	3sf	3f	4st	3t	2s	2s	3f	2sf	4st
Suitability	S3	S3	S3	N	S3	S2	S2	S3	S2	N

Nearly 4079.0 ha area representing 36.2 % of watershed are under moderately suitable (S2), 4006.0 ha (35.6 % of TGA) under marginally suitable (S3) and 649.1 ha (5.8 % of TGA) under not suitable (N) class. The soil site suitability map for cotton is shown in fig. 2. Limitations to suitability were noted

due to low AWC, OC and high calcium carbonate (Table 1, 5). These limitations could be overcome through management like irrigation and manure application to some extent and hence potential suitability class may change to higher class.

Nearly 5138.0 ha area representing 45.6 % of watershed are under moderately suitable (S2) while 2947.0 ha (26.2 % of

TGA) under marginally suitable (S3) class and 649.1 ha (5.8 % TGA) under not suitable (N) class. The soil site suitability map for soybean is depicted in fig. 3

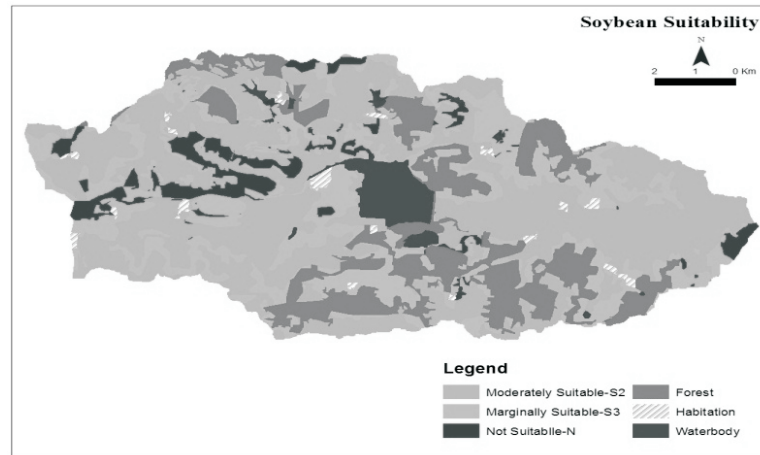


Fig. 3 Soybean suitability in Kupti watershed

Soil-site suitability evaluation for sorghum

Sorghum can withstand a higher temperature and drought and may be successfully grown under temperatures ranging from 22 to 32°C and in areas with annual rainfall of 400 mm to 1000 mm. Sorghum is cultivated on diverse soil types but the clay loam soils rich in humus is the most ideal (Singh, 1988). It withstands waterlogged conditions better than other crops. Moderately deep soils having more than 75 cm depth are better and the soils with depth less than 45 cm are not economical to grow sorghum (Gaikwad and Bhaskar, 1988). It has been observed that sorghum yields better in soils having suitable water capacity of 200 mm or more.

Based on the criteria and degree of limitation, the

soil-site suitability of soil series for sorghum has been worked out (Table 7). The overall suitability class for sorghum showed that the soils of K-4 and K-10 series are not suitable (N) for growing sorghum due to major limitation of soil depth and landform. The soils of K-1, K-2, K-5 series are marginally suitable (S3) due to severe limitation of drainage and PAWC. The site of other series are moderately suitable (S2) due to limitation of fertility. Organic carbon that could be overcome.

Nearly 5096 ha area representing 45.3 % of watershed are under moderately suitable (S2), 2989.0 ha (26.6 % of TGA) under marginally suitable (S3) and 649.1 ha (5.8 % of TGA) under not suitable (N) class for sorghum cultivation (Fig. 4)

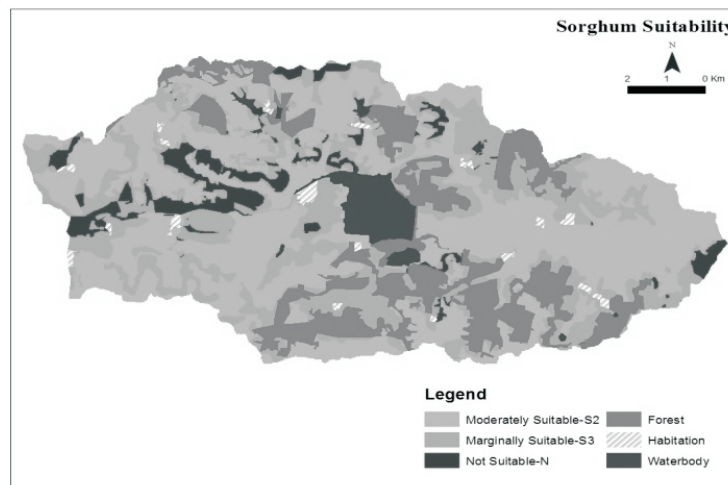


Fig 4. Sorghum suitability in Kupti watershed

Table 7. Degree of limitations and suitability of soil series for growing sorghum

Soil characteristics	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10
Climatic Characteristics										
Total Rainfall (mm)	1	1	1	1	1	1	1	1	1	1
Rainfall in Growing Season (mm)	1	1	1	1	1	1	1	1	1	1
Mean Temperature in Growing Season °C	1	1	1	1	1	1	1	1	1	1
Mean Relative Humidity in Growing Season (%)	1	1	1	1	1	1	1	1	1	1
Length of Growing Period (days)	1	1	1	1	1	1	1	1	1	1
Site Characteristics										
Slope (%)	2	1	1	4	3	1	1	1	1	4
Erosion										
Drainage	3	0	0	0	0	1	0	0	1	0
AWC (mm/m)	3	3	2	4	1	1	0	0	1	4
Surface Stoniness (%)	2	2	1	2	0	0	1	0	0	1
Soil Characteristics										
Texture (% clay)	1	2	1	1	1	1	2	1	1	1
Depth (cm)	2	1	1	3	1	1	1	0	1	2
Soil Fertility										
CEC (Cmol(P+)/kg)	0	0	0	0	0	0	0	0	0	0
BS (%)	0	0	0	0	0	0	0	0	0	0
OC (0-20 cm)	0	2	2	2	1	0	1	2	1	3
EC (dS/m)	0	0	0	0	0	0	0	0	0	0
ESP (%)	0	1	1	1	1	1	1	1	1	1
pH (1:2.5)	0	0	2	1	2	2	2	2	2	2
Limitation	3sw	3s	2sf	4st	3t	2f	2f	2f	2f	4st
Suitability	S3	S3	S2	N	S3	S2	S2	S2	S2	N

Soil-site suitability evaluation for pigeonpea

Based on the criteria and degree of limitation, the overall suitability for pigeonpea showed that (Table 8) the soil of series K-1 and K-5 are marginally suitable (S3) due to

limitations of depth and drainage. The soils of soil series K-2, K-3, K-6 and K-8 are moderately suitable (S2) due to minor limitations of fertility. The soil series K-7 and K-9 are highly suitable for growing pigeonpea.

Table 8. Degree of limitations and suitability of soil series for growing pigeonpea

Soil characteristics	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8	K-9	K-10
Climatic Characteristics										
Total Rainfall (mm)	1	1	1	1	1	1	1	1	1	1
Rainfall in Growing Season (mm)	1	1	1	1	1	1	1	1	1	1
Mean Temperature in Growing Season °C	1	1	1	1	1	1	1	1	1	1
Mean Relative Humidity in Growing Season (%)	1	1	1	1	1	1	1	1	1	1
Length of Growing Period (days)	1	1	1	1	1	1	1	1	1	1
Site Characteristics										
Slope (%)	2	1	1	4	3	1	1	1	1	4
Erosion										
Drainage	3	0	0	0	0	1	0	0	1	0
AWC (mm/m)	2	2	1	3	0	0	0	0	0	3
Surface Stoniness (%)	2	2	1	2	0	0	1	0	0	1
Soil Characteristics										
Texture (% clay)	1	0	1	1	1	1	0	1	1	1
Depth (cm)	3	2	2	4	2	2	1	0	0	3
Soil Fertility										
CEC (cmol(P+)/kg)	0	0	0	0	0	0	0	0	0	0
BS (%)	0	0	0	0	0	0	0	0	0	0
OC (0-20 cm)	0	2	2	2	1	0	0	2	1	3
EC (dS/m)	0	0	0	0	0	0	0	0	0	0
ESP (%)	2	1	0	0	1	0	0	0	0	0
pH (1:2.5)	0	0	1	1	1	1	1	1	1	1
Limitation	3sw	2sf	2sf	4st	3t	2s	1	2f	1	4t
Suitability	S3	S2	S2	N	S3	S2	S1	S2	S1	N

Nearly 3421 ha area representing 30.4 % of watershed are under highly suitable (S1), 1966 ha (17.5 % TGA) under marginally suitable (S3) and 649.1 ha (9.26 % of watershed) are under moderately suitable (S2), 2698 ha (24.0 % of TGA) under not suitable (N) class. The soil-site suitability map for pigeonpea is presented in figure 5.

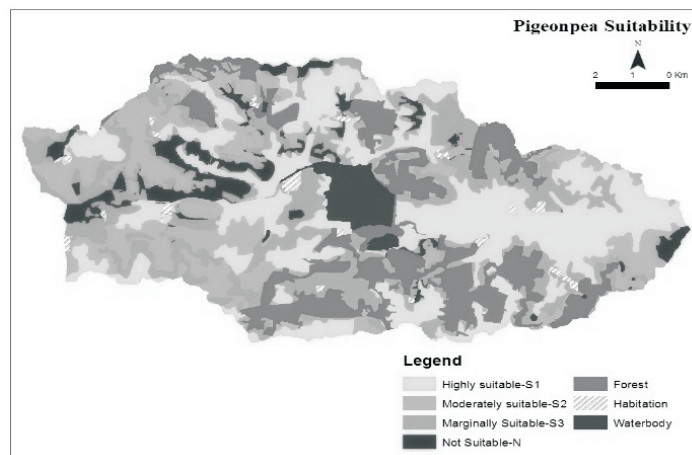


Fig 5. Pigeonpea suitability in Kupti watershed

Irrespective of the suitability ratings, the field reality shows that the farmers have stuck to cotton crop for more than four decades, while soybean has gained acceptance during last 9 years. The state efforts to introduce alternate crops have not succeeded. Irrespective of the crop choice, ridges or broad-bed furrow systems specifically recommended by ICRISAT for the Vertisols (soils in the watershed are either *Vertic Haplustepts* or *Haplusterts*) that helps in improving internal drainage while conserving moisture to mitigate effects of intermittent dry spells. If the farmers persist with cotton crop, the management practices should include ridge and broad bed configuration and the state must emphasize it. Secondly total rainfall received during the crop season in the study area is considered to be good. However, it is the phasic rainfall of 200-300 mm rainfall during July and August that should coincide with growth phases of cotton (FAO/UNEP, 1999). Dry spell during this period is likely to result in yield loss and hence mulching practices need to be adopted especially during critical phases. If the limitation of soil suitability is due to properties like slope, erosion, AWC, *etc.*, it can be rectified or improved by adopting suitable soil and water conservation measures and introducing life saving irrigations but if the limitations are of permanent type like soil depth it is impossible to convert those lands into better suitability classes than the prevailing one.

Implications for land use planning

The soil suitability evaluation showed that the prevailing crops in the area are grown mostly in moderately or marginally suitable soils. The soil suitability evaluation indicated a strong mismatch between scientific rationale and farmers' perspective. These results are in agreement with the reports by Patil *et al.* (2015). These results could also be attributed to insufficient information on soil hydraulic properties (Patil *et al.* 2010). Moderately suitable soils for cotton in the watershed occupy 2640 ha while during *khari* 2015-16, the area under cotton exceeded 2385 ha. The moderately suitable area (3300 ha) and actual cultivated area (3246 ha) correspond well. Mere 284 ha area was cultivated to sorghum as against 5096 ha in moderately suitable class. Thus monsoon variability will continue to be the most

significant factor affecting crop yields. The reluctance of the farmers to cultivate other crops like sorghum due to crop depredation could be tackled through controlling the wildlife menace and/or crop management including mulching practices, adoption of broad bed furrow sowing, life saving irrigation *etc.* During field interactions farmers opined that the crop choice is strongly influenced by crop depredation; the least vulnerable crops like cotton and soybean would continue to be favoured as long as existing forest and wildlife protection laws remain in force. While management practices could be advised to save the cotton crop despite bio-physical constraints, the state must consider review of the wild life protection policy as the Indian antelope and wild boar population seems to be overabundant and is growing very fast in the absence of any natural predator. The state department does not have authentic population details of these animals in the watershed or block. Almost two decades of unhindered wildlife population growth must be reviewed by the policy makers. In the absence of controlling measures the farmers would remain affixed to cotton crop despite state efforts to dissuade.

The suitability map shows spatial distribution of soils in different suitability classes. The map could be useful in framing policies such as villages/area suited for a particular variety. For instance, Bt cotton needs to be discouraged in the watershed and suitable straight varieties for medium and shallow soils could be propagated through extension. The map would assist in policy decisions like quantum of seeds to be made available, target area for a soil specific variety and thus reduce the distress caused by ill advised choices. Thus the studies on soil-site suitability for major crops of watershed indicated that soil and site characteristics of an area play a key role in determining the crop planning on a particular parcel of land.

The actual and potential suitability (Table 9) of the soils also varied depending upon kind of limitations. If the limitation is due to properties like slope, erosion, AWC, *etc.*, it can be rectified or improved by adopting suitable soil and water conservation measures and introducing lifesaving irrigations but if the limitations are of permanent type like soil depth it is impossible to convert those lands into better suitability classes than the prevailing one.

Table 9. Actual and potential soil-site suitability ratings for crops

Soil Series	Cotton		Soybean		Sorghum		Pigeonpea	
	A	P	A	P	A	P	A	P
K-1	S3	S2	S3	S3	S3	S3	S3	S3
K-2	S3	S2	S3	S2	S3	S2	S2	S2
K-3	S3	S1	S2	S1	S2	S1	S2	S2
K-4	N	N	N	N	N	N	N	N
K-5	S3	S3	S2	S2	S3	S3	S3	S3
K-6	S2	S1	S2	S2	S2	S1	S2	S2
K-7	S2	S1	S2	S2	S2	S1	S1	S1
K-8	S3	S1	S2	S2	S2	S1	S2	S1
K-9	S2	S1	S2	S2	S2	S1	S1	S1
K-10	N	N	N	N	N	N	N	N

A-actual P-potential

Conclusion

The soil suitability evaluation for prevailing crops in the study watershed showed a mismatch between scientific perception and field realities in cotton crop. The persistence of the farmers despite available options was attributed to crop depredation. It is recommended that policies need to be formulated based on the map to target spread of soil specific varieties. The strategies should be developed to control crop depredation in the long run, while management practices like mulching, adoption of broad bed furrow configuration and life saving irrigation are suggested as measures to reduce yield loss due to monsoon variability in the short run.

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