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Characterization, evaluation and management of Salai watershed in Nagpur district of Maharashtra using remote sensing and GIS techniques

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Abstract : Visual interpretation of False Colour Composites of IRS-1D LISS-III and PAN sharpened LISS-III in conjunction with Survey of India (SOI) toposheet (1:50000 scale) followed by ground truth observations helped in establishing physiography-soil-land use/land cover relationship and land evaluation in terms of land capability, land irrigability, soil productivity and soil-site suitability for sorghum and cotton. The land use/land cover identified were single crop, double crop, scrub-land and moderately dense forest. Physiographically, the area has been characterized into three major units viz. subdued table land, upper valley and isolated mound with pediments. Eight soil series were tentatively identified and mapped as series and association and grouped into five land capability sub-classes IIIs, IIIes, IVs, IVes and VIs and three land irrigability sub-classes 2d, 4s and 4st. The soils were extremely poor to good in productivity, moderately to marginally suitable for sorghum and moderately suitable to not suitable for cotton cultivation. The suggested land use map of the watershed contains areas delineated for intensive cultivation, agri-horticulture, silvipasture and afforestation.

Additional key words: *Soil survey and mapping, suitability evaluation, suggested agricultural planning*

Introduction

Remote sensing technology plays a significant role in understanding our ecosystem. Its uses have enhanced systematic characterization and assessment of soil resources in the recent past (Saxena *et al.* 2000). The information generated on landform, soil, land use/land cover can be evaluated using scientific approach for land capability, land irrigability and soil-site suitability classifications for major crops for better management and conservation of resources (Solanke *et al.* 2005; Shukla *et al.* 2009).

With this in view, an attempt has been made to characterize and evaluate the land resources of Salai watershed of Nagpur district of Maharashtra using IRS-1D LISS-III and PAN sharpened LISS-III data and GIS.

Materials and Methods

Study area

The Salai watershed (21°08' to 21°10' N latitudes and 78°33' to 78°36' E longitudes) is located in Katol tehsil of Nagpur district (988 ha) and occurs at an elevation of 460 to 500 m above MSL. The climate is sub-tropical dry sub-humid with mean annual temperature of 26.9°C and mean annual rainfall of 1050 mm. The soil moisture and soil temperature regimes are ustic and hyperthermic, respectively.

Methods

Geo-coded digital IRS-1D LISS-III and PAN sharpened LISS-III data of March 2002 and December 2002, respectively were visually interpreted in conjunction with Survey of India toposheet (55 K/12) to derive spatial information related to landform and land use/land cover of the watershed. Soil profiles were exposed in different physiographic units and studied for morphological characteristics (Soil Survey Division Staff, 2000). Horizon-wise soil samples were collected from typical pedons of the representative soil series for physical and chemical properties following standard methods (Jackson 1967). The pedons were classified as per Soil Survey Staff (1998).

The land use/land cover, physiography and soil thematic maps were digitized under GIS environment using Arc GIS 9.1. The land capability (Klingebiel and Montgomery 1961), land irrigability (AIS&LUS 1971) and soil productivity (Riquier *et al.* 1970) were grouped in different classes. The productivity index considers nine factors of soil productivity viz. soil moisture, drainage, effective depth, texture/structure, base saturation, soluble salt concentration, organic matter content, mineral exchange capacity/nature of clay and mineral reserve. Each factor is rated on a scale of 0-100, the actual percentages being multiplied by each other. The resultant index of productivity, also lying between 0 and 100 is set against a scale placing the soil in any one of five productivity classes *viz.* excellent (100-65), good (64-35), average (34-20), poor (19-8) and extremely poor to nil (7-0). The soil-site suitability evaluations were carried out for cotton and sorghum as per Sys *et al.* (1991) and NBSS&LUP (1994). The suggested land use map was prepared taking into account the physiography, soils, present land use/land cover and slope of the area.

Results and Discussion

Land use/land cover

The present land use/land cover map (Fig. 1a) prepared through interpretation of IRS-1D LISS-III and PAN sharpened LISS-III FCC indicated that agricultural land occupy 859.2 ha representing 86.9 per cent of the watershed of which 48.0 per cent area is under single crop and the remaining 38.9 per cent is under double crop. Scrubland/wastelands occupy 7.1 per cent, whereas moderately dense forest area occupies 9.5 ha (1.0 per cent) of the total area. Habitation, commercial area and waterbody occupy 1.5, 1.0 and 2.5 per cent of the total area, respectively.

Physiography and soils

Physiographically, the area has been delineated into three major units *viz.* undulating subdued table land, isolated mounds with pediment and upper valley which were further sub-divided based on slope and image characteristics. Based on physiography-soil relationship, eight soil series were tentatively identified. The soils (Salai, Khursapar-1, Khursapar-2, Khursapar-3), developed on very gently sloping undulating subdued table land are extremely shallow to shallow and well to somewhat excessively drained. The soils of Salai (Sl) and Khursapar-1 (Kh-1) are dark yellowish brown (10YR 3/4M) to brown (10YR 4/3M) in colour, loamy and moderate to severely eroded, whereas soils of Khursapar-2 (Kh-2) and Khursapar-3 (Kh-3) are dark brown (7.5YR 3/3M), clayey and moderately eroded. The soils of Khursapar-4 (Kh-4) are moderately deep, very dark brown (10YR 2/2M) in colour, clayey and slightly eroded, whereas soils of Khursapar-5 (Kh-5) are deep, very dark grayish brown (10YR 3/2M) with very fine textural family class and moderate erosion. These soils are moderately well drained and calcareous and occur on very gently sloping upper valley. The soils of Junapani-1 (Jn-1) and Junapani-2 (Jn-2) occurring on very gently/ gently sloping isolated mounds with pediment are extremely shallow to very shallow, somewhat excessively drained, dark brown (10YR 3/3M) in colour with loamy textural family class and are moderate to severely eroded. The physical and chemical properties of typical pedons representing different soil series are given in table 1 and table 2, respectively. The soil map showing soil series and their associations is depicted in figure 1b.

Table 1. Physical properties of soils

Horizon	Depth (cm)	Particle-size distribution (%)			B.D. ($Mg\ m^{-3}$)	Water retention (%)		AWC
		Sand (2.0-0.05mm)	Silt (0.002-0.05mm)	Clay (<0.002 mm)		33 kPa	1500 kPa	
Pedon 1 (Very gently sloping undulating subdued table land) Khursapar-1 series: Loamy, mixed Typic Ustorthents								
A	0-9	36.7	29.8	33.5	ND	33.04	14.45	18.58
Pedon 2 (Very gently sloping undulating subdued table land) Khursapar-2 series: Clayey, smectitic Lithic Ustorthents								
Ap	0-15	30.0	25.5	44.5	1.40	33.79	16.90	16.88
AC	15-45	33.5	24.3	43.2	1.49	42.75	22.98	19.77
Pedon 3 (Very gently sloping undulating subdued table land) Khursapar-3 series: Clayey, smectitic Typic Ustorthents								
A	0-11	36.5	25.0	38.51	1.64	31.33	16.25	15.08
Pedon 4 (Very gently sloping undulating subdued table land) Salai series: Loamy, mixed Lithic Ustorthents								
A	0-16	38.2	30.3	31.5	1.73	31.19	14.79	16.39
Pedon 5 (Very gently sloping upper valley) Khursapar-4 series: Fine, smectitic (calcareous) Vertic Haplustepts								
Ap	0-15	18.5	28.5	53.0	1.78	44.79	27.25	17.54
Bw	15-40	12.5	31.5	56.0	1.76	44.58	27.51	17.06
Bk1	40-63	22.3	20.7	57.0	1.75	39.19	24.08	15.11
Bk2	63-95	25.8	27.7	46.5	1.75	39.69	17.43	22.25
Pedon 6 (Very gently sloping upper valley) Khursapar-5 series: Very fine, smectitic (calcareous) Typic Haplusterts								
Ap	0-15	8.9	26.1	65.0	1.68	41.47	25.74	15.72
Bw	15-37	5.2	27.8	67.0	1.72	40.61	26.76	13.85
Bss1	37-76	4.7	28.8	66.5	1.73	42.20	27.17	15.02
Bss2	76-119	4.7	24.3	71.0	1.75	50.10	34.20	15.89
Bss3	119-150	4.2	23.8	72.0	1.76	52.11	35.92	16.18
Pedon 7 (Gently sloping isolated mounds with pediments) Junapani-1 series: Loamy-skeletal, mixed Typic Ustorthents								
A	0-8	48.2	26.5	25.5	ND	29.93	17.63	12.30
Pedon 8 (Very gently sloping isolated mounds with pediments) Junapani -2 series: Loamy, mixed Typic Ustorthents								
Ap	0-15	46.9	21.1	32.0	1.59	32.25	18.13	14.12

Table 2. Chemical properties of soils

Horizon	Depth (cm)	pH 1:2.5	EC 1:2.5 (dSm^{-1})	O.C. (%)	$CaCO_3$ (%)	Exchangeable cations				Sum of cations	CEC	Base saturation (%)
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}			
						----------cmol(p+)kg^{-1}----------						
Pedon 1 (Very gently sloping undulating subdued table land) Khursapar-1 series: Loamy, mixed Typic Ustorthents												
A	0-9	6.8	0.04	0.55	-	23.87	6.32	0.27	0.47	30.93	33.89	91.3
Pedon 2 (Very gently sloping undulating subdued table land) Khursapar-2 series: Clayey, smectitic Lithic Ustorthents												
Ap	0-15	6.7	0.07	0.79	-	30.6	7.71	0.47	1.23	40.01	41.38	96.7
AC	15-45	6.8	0.03	0.69	-	34.67	7.59	0.44	1.10	43.8	44.83	97.7
Pedon 3 (Very gently sloping undulating subdued table land) Khursapar-3 series: Clayey, smectitic Typic Ustorthents												
A	0-11	6.8	0.05	0.81		29.02	7.30	0.27	0.22	36.81	38.21	96.3
Pedon 4 (Very gently sloping undulating subdued table land) Salai series: Loamy, mixed Lithic Ustorthents												
Ap	0-16	7.4	0.03	0.47	-	19.78	4.11	0.25	0.05	24.19	25.69	94.2
Pedon 5 (Very gently sloping upper valley) Khursapar-4 series: Fine, smectitic (calcareous) Vertic Haplustepts												
A	0-15	8.0	0.12	0.88	5.96	39.98	5.99	0.77	1.08	47.82	49.84	95.9
Bw	15-40	8.0	0.11	0.81	6.73	41.35	8.80	0.61	0.83	51.59	53.06	94.2
Bk1	40-63	8.2	0.10	0.77	24.86	30.03	4.35	0.46	0.62	35.46	43.71	92.9
Bk2	63-95	8.3	0.10	0.28	24.93	26.24	8.26	8.36	0.36	35.22	38.19	92.2
Pedon 6 (Very gently sloping upper valley) Khursapar-5 series: Very fine smectitic (calcareous) Typic Haplusterts												
Ap	0-15	8.1	0.08	0.86	4.84	43.86	9.74	0.49	1.05	55.14	58.73	93.9
Bw	15-37	8.0	0.08	0.82	4.57	46.13	10.62	0.43	0.86	58.64	61.45	94.4
Bss1	37-76	7.9	0.08	0.81	3.06	44.10	10.35	0.54	0.82	55.81	58.12	96.0
Bss2	76-119	8.0	0.10	0.51	4.55	44.34	14.2	0.67	0.80	60.01	62.17	96.5
Bss3	119-150	8.0	0.10	0.44	3.86	44.85	15.0	0.69	0.78	61.32	62.84	97.8
Pedon 7 (Gently sloping isolated mounds with pediments) Junapani-1 series: Loamy-skeletal, mixed Typic Ustorthents												
A	0-8	6.8	0.06	0.60	-	19.23	5.38	0.18	0.28	24.81	26.05	95.5
Pedon 8 (Very gently sloping isolated mounds with pediments) Junapani-2 series: Loamy, mixed Typic Ustorthents												
Ap	0-15	6.6	0.04	0.50	-	20.63	5.12	0.16	0.04	25.95	28.12	92.3

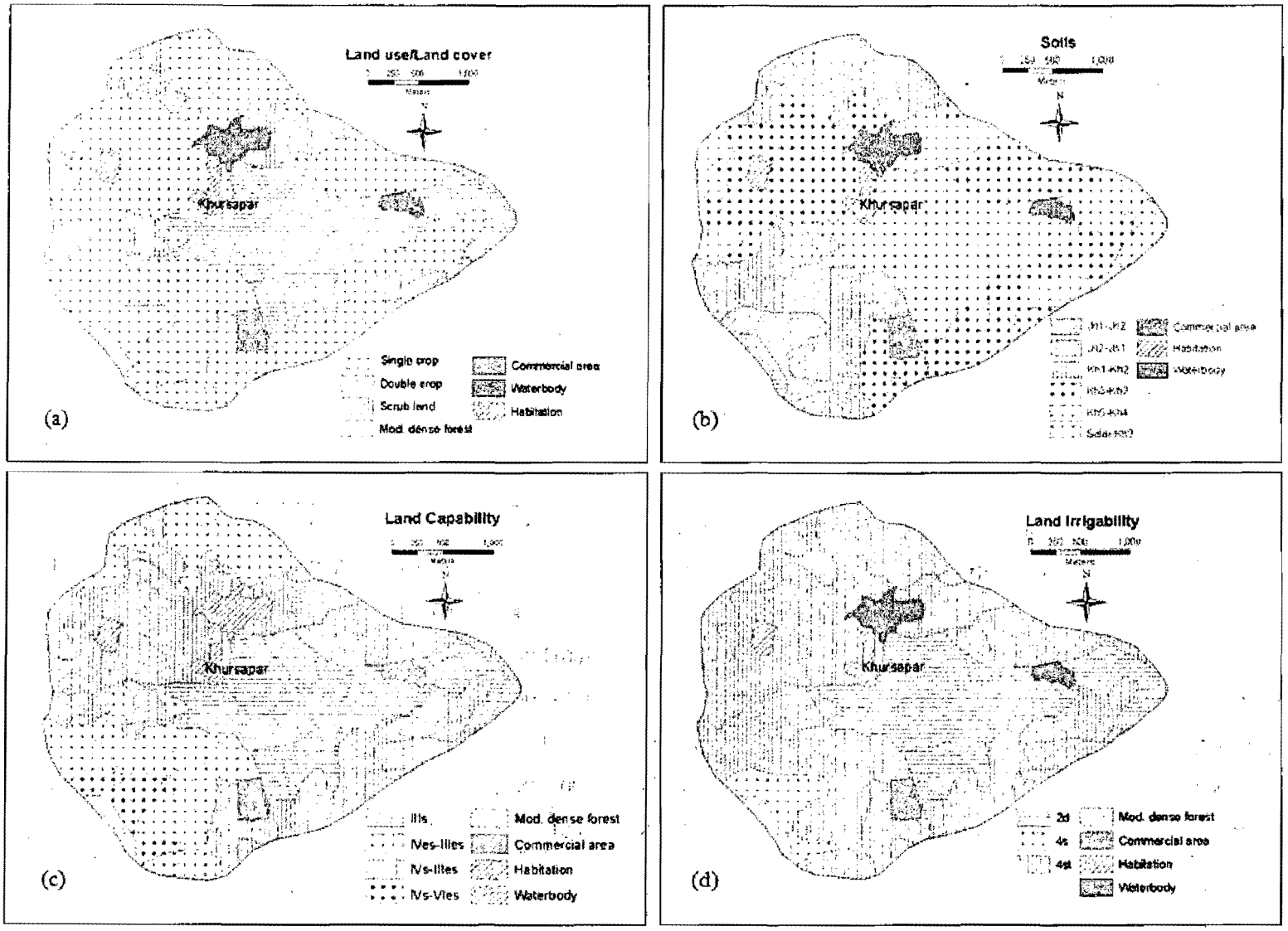

Fig. 1. Thematic maps of land use/land cover (a), soils (b), land capability (c) and land irrigability (d)

Table 3. Productivity indices (Rating class with assigned values) and productivity classes of soils of Salai watershed

Soil series	Soil moisture	*Drainage*	Effective soil depth	Texture/ structure	Base saturation	Soluble salts	Organic matter	Nature of clay	Mineral reserves	Productivity index	Productivity class
	H	*D*	P	T	N	S	O	A	M		
Kh-1	H_4a (50)	D_4 (100)	P_2 (20)	T_7 (100)	N_5 (100)	S_1 (100)	O_1 (85)	A_2 (95)	M_2C (95)	7.67	Extremely Poor
Kh-2	H_3a (50)	D_4 (100)	P_3 (50)	T_5a (60)	N_5 (100)	S_1 (100)	O_2 (90)	A_3 (100)	M_2C (95)	12.85	Poor
Kh-3	H_3a(50)	D_4 (100)	P_2 (20)	T_6a (80)	N_5 (100)	S_1 (100)	O_2 (90)	A_2 (95)	M_2C (95)	6.49	Extremely Poor
Sl	H_3a (50)	D_4 (100)	P_2 (20)	T_6a (80)	N_5 (100)	S_1 (100)	O_1 (85)	A_2 (95)	M_2C (95)	6.13	Extremely poor
Kh-4	H_3b (60)	D_3 (90)	P_5 (80)	T_5b (80)	N_5 (100)	S_1 (100)	O_2 (90)	A_3 (100)	M_3C (100)	31.10	Average
Kh-5	H_3b (60)	D_3 (90)	P_6 (100)	T_5b (80)	N_5 (100)	S_1 (100)	O_2 (90)	A_3 (100)	M_3C (100)	38.88	Good
Jn-1	H_3a (50)	D_4 (100)	P_2 (20)	T_6b (90)	N_5 (100)	S_1 (100)	O_2 (90)	A_2 (95)	M_2C (95)	7.31	Extremely Poor
Jn-2	H_3a (50)	D_4 (100)	P_2 (20)	T_6b (90)	N_5 (100)	S_1 (100)	O_1 (85)	A_2 (95)	M_2C (95)	6.90	Extremely Poor

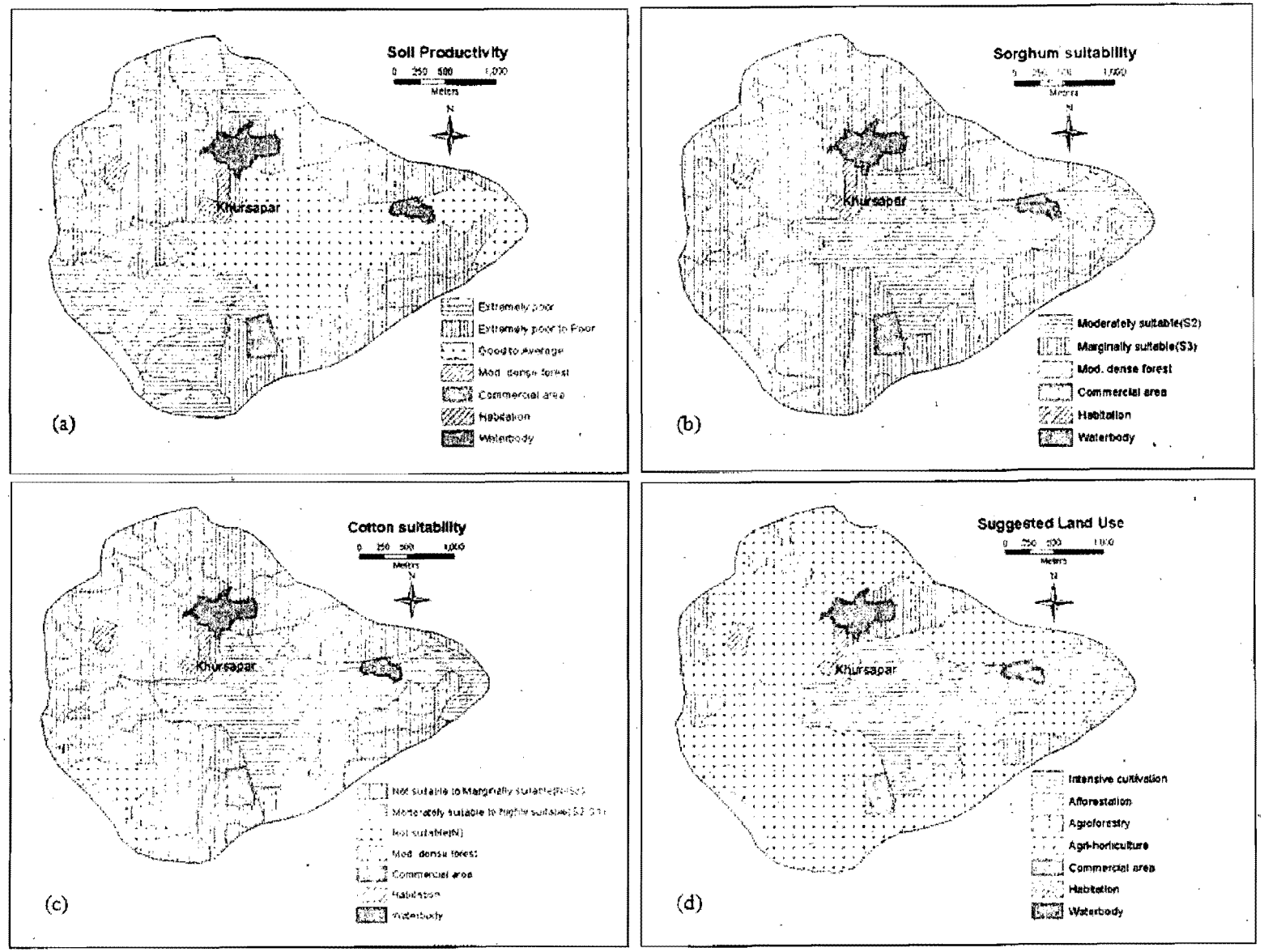

Fig. 2. Thematic maps of soil productivity (a), suitability for sorghum (b), cotton (c) and suggested land use (d)

Land capability, land irrigability and soil productivity

Five land capability sub-classes viz. IIIs, IIIes, IVs, IVes and VIes and three land irrigability sub-classes 2d, 4s and 4st were identified. The land capability and land irrigability maps with sub classes are depicted in figure 1c and figure 1d, respectively. The soils of Kh-5 are good in productivity (Table 3). These soils have moderate limitations of soil moisture, texture/structure and drainage. The productivity of soils of Kh-4 is average and has moderately severe limitations of soil moisture, effective soil depth, texture/structure and drainage. The soils of Kh-1, Kh-3, Jn-1, Jn-2, Sl and Kh-2 are extremely poor to poor in productivity with severe limitations of effective soil depth. The soil productivity map showing different productivity classes is depicted in figure 2a.

Soil site suitability for sorghum and cotton

Soil-site suitability evaluation for sorghum indicates that the soils of Kh-1, Kh-2, Kh-3, Sl, Jn-1 and Jn-2 are marginally suitable (S3) owing to moderate limitation of soil pH and erosion whereas, soils of Kh-4 and Kh-5 are moderately suitable (S2) due to moderate limitation of erosion (Fig. 2b). The suitability evaluation for cotton (Fig. 2c) indicates that the soils of Kh-4 and Kh-5 are moderately suitable with moderate limitations of erosion; the soils of Kh-2 series are marginally suitable due to severe limitation of soil depth, and the soils of Kh-1, Kh-3, Sl, Jn-1 and Jn-2 are unsuitable due to very severe limitation posed by soil depth. Yadav *et al.* (1999) also reported similar findings.

Suggested land use

The suggested land use map (Fig. 2d) of the watershed was prepared by integrating physiography, soil, land use/land cover and slope maps in GIS environment. The areas that are moderately dense or degraded forests have been suggested for afforestation. The area under double crop with assured irrigation having potential ground water is suggested for intensive cultivation including that of vegetables with provision of proper drainage, particularly in soils of Khursapar-4 series. The moderately deep to deep, moderately well drained, calcareous, clay soils occurring on very gently sloping upper valley may be cultivated for sorghum and cotton in kharif and wheat and gram on residual moisture/protective irrigation in rabi. Agri-horticulture may be preferred on very gently sloping undulating subdued table land and very gently sloping mounds with pediment associated with extremely shallow to shallow, well drained, loamy to clayey soils. These may be put to sorghum, *Citrus spp.* and papaya, if rain water is tapped for irrigation. The areas for silvipasture are recommended on very gently sloping undulating subdued table land, which at present, support scrubland. These lands may be put to use under multipurpose trees (MPTs) and afforestation (mostly teak).

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