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Characterization and evaluation of land resources for management of Savli micro-watershed in Wardha district of Maharashtra using geospatial technologies

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Abstract : Geocoded False Colour Composite (FCC) of IRS-P6 LISS-IV data was interpreted in conjunction with Survey of India (SOI) top sheet on 1:50,000 scale to extract information on existing land use/land cover, slope and physiography for characterization and mapping of soils in Savli micro-watershed. Field survey supported by laboratory data has been used to assess the soil fertility and soil-site suitability for growing cotton, pigeonpea and soybean. The land use/land cover classes identified are single crop, double crop, wasteland, waterbody and habitation. Five major physiographic units *viz.* plateau, escarpment, pediments, alluvial plain and narrow valley were identified. Ten soil series (Savli-1 to Savli-10) were tentatively identified, characterized and mapped in to seven soil series associations. The soils are extremely poor to poor (Savli-1, Savli-3, Savli-5, Savli-6, Savli-7 and Savli-10), average (Savli-2, Savli-4) and good (Savli-8 and Savli-9) in soil productivity. The surface soils of these series had 208.8 to 348.1 kg ha^{-1} available N, 1.9 to 20.8 kg P ha^{-1} and 66.1 to 901.8 kg ha^{-1} K and seventy per cent of soils are deficient in Zn. The soils of Savli-8 and Savli-9 series are moderately to highly suitable for growing cotton, pigeonpea and soybean, whereas, other soils are marginally suitable. An alternate land uses have been suggested with suitable soil and water conservation measures for land resources management.

Additional key words : *Soil fertility, soil productivity, suitability for crops, land use, soil conservation*

Introduction

Precise scientific information on characteristics, potentials, limitations and management needs of different soils is indispensable for planned development of land resources to maintain the soil productivity and to meet the demands of the future. Soil resource inventory provides an insight into the potentialities and limitations of soils for its optimum utilization. It also provides adequate information in terms of landform, terrain, vegetation as well as characteristics of soils which can be utilized for land resources management and development (Manchanda *et al.* 2002). Rational utilization of land resources can be achieved by optimizing its use, which demands evaluation of land for alternative land use, ensuring its sustainable use. Therefore, increased emphasis is being laid on characterization of soils, their evaluation and precise mapping using remote sensing and GIS.

Satellite remote sensing has emerged as a powerful and efficient technology for mapping and

monitoring of natural resources of earth surface environment. The synoptic coverage, multispectral and multi-temporal sensing capabilities offered by space borne sensors are well suited to inventorying natural resources. Several workers have utilized this technique for soil mapping on different terrain conditions at different scales (Srivastava and Saxena 2004; Velmurugan and Carlos 2009) and on watershed basis (Shukla *et al.* 2009; Patil *et al.* 2010; Patil *et al.* 2010).

The Karanja tehsil of Wardha district in Vidarbha region of Maharashtra is pre-dominantly under rainfed farming with erratic rainfall distribution associated with low crop productivity and needs site-specific information in terms of soil characteristics, their productivity potentials and limitations for land resources development and management. Through present study, an attempt has been made to characterize and evaluate the land resources of Savli micro-watershed in Karanja tehsil of Wardha district for land resource management using remote sensing and GIS.

Materials and Methods

Geographically, the Savli micro-watershed is located between 78°30' to 78°32' E longitudes and 21° 07' to 21° 09' N latitudes (55K/12 SOI toposheet) in Karanja tehsil of Wardha district, Maharashtra with an area of 998.6 ha. The general elevation of the area ranges from 460 to 520 m above mean sea level (MSL). The drainage is, essentially, dendritic in nature. The climate of the area is sub-tropical dry sub-humid with well expressed summer (March to May), rainy season (June to October) and winter (November to February). The mean annual temperature is 33.5°C and mean annual precipitation is about 903 mm of which nearly 90 per cent is received during monsoon. The relative humidity is high during monsoon period (75 to 88%) and low during other period (30 to 40%). The area qualifies for '*Ustic*' and '*Hyperthermic*' soil moisture and soil temperature regimes, respectively. The natural vegetation comprises of teak (*Tectona grandis*), babul (*Acacia spp.*), palas (*Butea frondosa*), charoli (*Buchanania latifolia*), ber (*Ziziphus jujuba*) *etc.* The major crops grown in the area are soybean (*Glycine max*), cotton (*Gossypium spp.*), pigeonpea (*Cajanus cajan*) and sorghum (*Sorghum bicolor*) in *kharif* and wheat (*Triticum aestivum*) and gram (*Cicer arietinum*) in *rabi* under irrigation or stored moisture. Nagpur mandarin (*Citrus reticulata* Blanco) is the main fruit crop of the area.

Digital data of IRS-P6 LISS-IV (5.8 m resolution) of February, 2004 was used. The satellite data was georeferenced to SOI toposheet using Geomatica image processing software. Standard visual interpretation technique was used to prepare land use/land cover map of the area. Landforms and slope maps of the area were derived using contour information available on SOI toposheet. The landforms, slope and land use/land cover maps were integrated to prepare the physiographic unit map. Profiles were exposed in each physiographic unit and studied for morphological properties (Soil Survey Division Staff 2000) and classified as per Soil Taxonomy (Soil Survey Staff 1998). Soil map was prepared based on physiography-soil relationship. Soil samples were collected from representative pedons and analyzed for different physical and chemical properties following standard procedures (Black 1965; Jackson 1967). The soils were grouped under different productivity classes (Riquier *et al.* 1970). The soil-site suitability for cotton, pigeonpea and soybean was worked out as per the methodology given in the FAO frame work on land evaluation (FAO 1976) as modified by Sys *et al.* (1991). The soil-site requirements as suggested by NBSS&LUP (1994) have been used for evaluating the suitability of different mapping units for cotton, pigeonpea and soybean. ArcGIS software (Ver. 10.1) has been used for digitization, generation of spatial and attribute database and preparation of various thematic maps.

Results and Discussion

Present land use/land cover

Based on image characteristics, the major land use/ land cover identified are cultivated land, wasteland and habitation (Fig. 1a). Cultivated land is again delineated into single and double crop with orange orchards based on temporal data. The study indicates that 71.3 per cent area of the watershed is under cultivation. The wasteland, waterbody and habitation constitute 27.1, 0.9 and 0.7 per cent of the total area, respectively.

Slope

Two slope classes *viz.* very gentle slopes (1-3%) and moderate slopes (8-15%) were identified (Fig. 1b). Nearly 91.7 per cent area of the watershed is under very gently sloping class and 6.7 per cent area is under moderately sloping class.

Physiography and soils

Based on visual interpretation of IRS-P6 LISS-IV data along with SOI toposheet and subsequent ground truth verification, five major physiographic units *viz.* plateau, escarpment, pediments, alluvial plain and narrow valley were identified (Fig. 1c). These physiographic units were further sub-divided based on slope, land use/land cover and image characteristics. Physiography, elevation slope, land use, area, image characteristics and soil composition has been shown in Table 1.

After systematic study of soils in different physiographic units, the physiography-soil relationship was established (Table 1). The physiography-soil relationship indicated the changes in important soil properties *viz.* profile development (morphological), physical and chemical properties with the variation in physiographic unit. In all, ten soil series were

Table 1. Physiography-soil relationship in Savli micro-watershed

Physiography	Physiography-cum-photomorphic unit				Map Unit	Area (ha)	Soil Series Association
	Elevation (m)	Slope (%)	Land Use	Image characteristics			
Plateau	520-500	1-3	Single crop	Greenish blue with diffuse checker board pattern	P2s1	377.6 (37.8)*	Savli-1-Savli-2
			Wasteland	Very light blue, medium texture	P2w2	163.4 (16.4)*	Savli-2-Savli-1
Escarpment	500-480	8-15	Wasteland	Dark brown with medium texture	E4w3	67.2 (6.7)*	Savli-3-Rockout crop
Pediment		1-3	Single crop	Greenish blue with diffuse checker board pattern	D2s1	114.6 (11.5)*	Savli-4-Savli-5
		1-3	Wasteland	Very light blue, medium texture	D2w2	24.1 (2.4)*	Savli-6-Savli-7
		1-3	Wasteland	Very light blue with pink tone, medium texture	D2w5	15.9 (1.6)*	Savli-6-Savli-7
Alluvial plain	480-460	1-3	Double crop	Dark red and brown, bold checker board pattern	A2d4	168.1 (16.8)*	Savli-8-Savli-9
Narrow valley	460	1-3	Single crop	Greenish blue with diffuse checker board pattern	V2s1	51.9 (5.2)*	Savli-9-Savli-10

* *indicate per cent area*

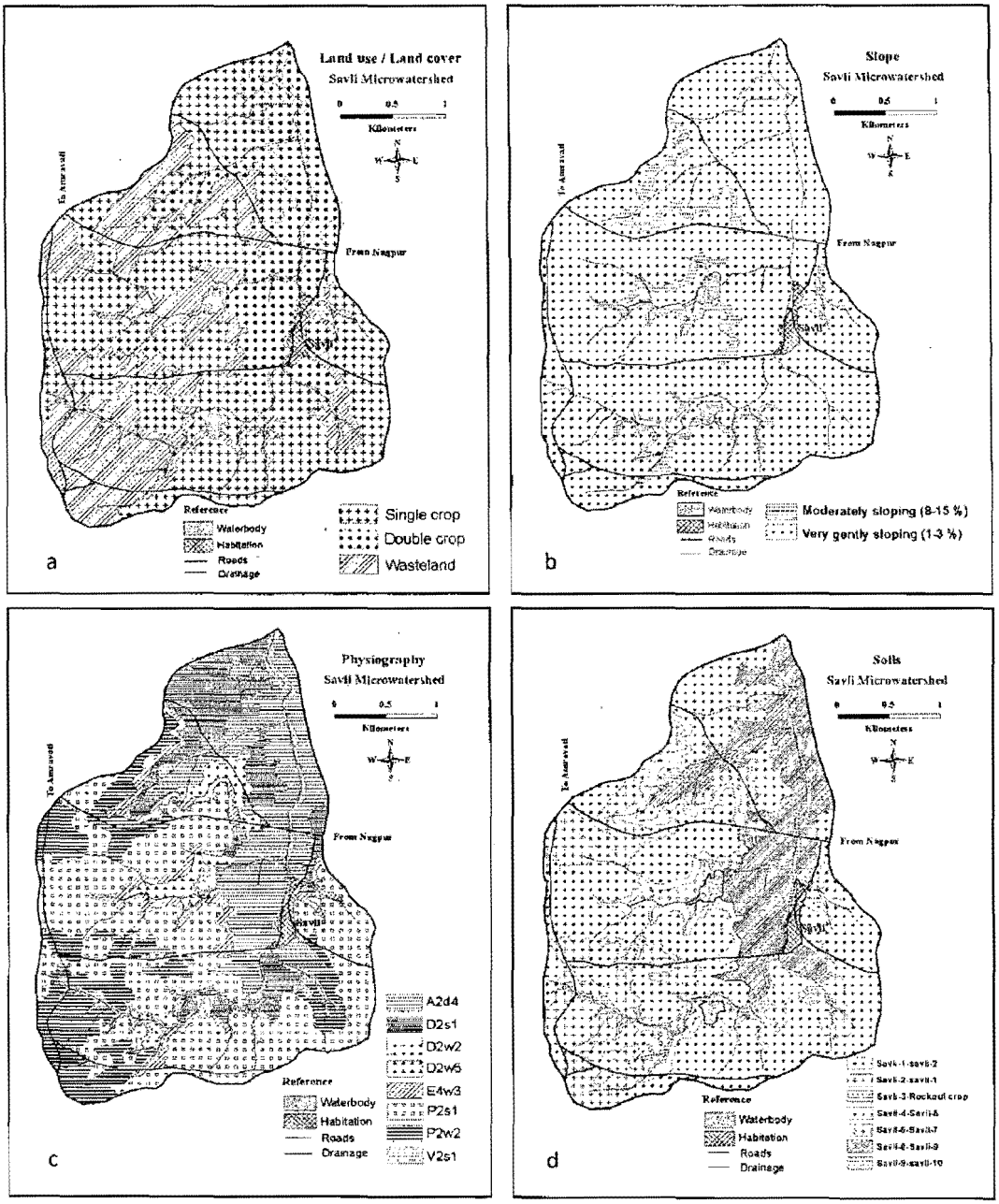

Fig. 1 Characterization and mapping of a) Land use/land cover b) Slope c) Physiography and d) Soils in Savli micro-watershed

tentatively identified in the area and mapped in eight mapping units as association of soil series (Fig. 1d).

The soils of Savli-1 are very shallow, well drained, very dark greyish brown (10YR 3/2M), loam (surface horizon) with moderate erosion. The soils of Savli-2 are shallow, moderately well drained, very dark grey (10YR 3/1M), clayey with moderate erosion. Soils of Savli-3 are very shallow, excessively drained, brown (7.5YR 4/3M), loam (surface), severely eroded. The soils of Savli-4 are shallow, moderately well drained, very dark greyish brown (10YR 3/2M), clayey with moderate erosion. These soils are cultivated to

Table 2. Physical properties of soils of Savli micro-watershed

Horizon	Depth	Sand	Silt	Clay	B.D.	Water retention (%)		
	(cm)	(%)	(%)	(%)	(Mg m^{-3})	-33 kPa	-1500 kPa	AWC
Savli-1 : Loamy-skeletal, smectitic, hyperthermic Lithic Ustorthents								
Ap	0-12	38.4	35.4	26.2	1.69	26.9	16.9	10.0
Savli-2 : Clayey, smectitic, hyperthermic (calcareous) Vertic Haplustepts								
A	0-15	5.9	22.7	71.4	1.68	40.2	25.5	14.7
Bw	15-40	6.7	23.6	69.7	1.74	38.1	25.1	13.0
Savli-3 : Loamy- skeletal, smectitic, hyperthermic Lithic Ustorthents								
A	0-10	50.4	33.4	16.2	1.77	22.0	11.7	10.3
Savli-4 : Clayey, smectitic, hyperthermic Vertic Haplustepts								
Ap	0-13	10.4	32.6	57.0	1.84	39.7	27.0	12.7
Bw	13-36	10.3	30.9	58.8	1.85	40.6	27.4	13.2
Savli-5 : Loamy- skeletal, smectitic, hyperthermic Lithic Ustorthents								
Ap	0-10	39.1	43.8	17.1	1.77	23.6	15.3	8.3
Savli-6 : Loamy, smectitic, hyperthermic Lithic Ustorthents								
A	0-11	25.2	47.2	27.6	1.82	29.1	19.2	9.9
Savli-7 : Clayey- skeletal, smectitic, hyperthermic (calcareous) Lithic Ustorthents								
A	0-7	25.8	34	40.2	1.75	32.5	23.2	9.3
Savli-8 : Very-fine, smectitic, hyperthermic (calcareous) Typic Haplusterts								
Ap	0-20	12.9	29.5	57.6	1.71	47.4	31.3	16.1
Bw	20-49	9.0	24.5	66.5	1.74	45.8	29.0	16.8
Bss1	49-82	8.1	20.8	71.1	1.77	46.9	29.6	17.3
Bss2	82-116	6.3	22.4	71.3	1.76	51.3	30.8	20.5
Bss3	116-150	7.1	21.1	71.8	1.78	52.6	32.0	20.6
Savli-9 : Fine, smectitic, hyperthermic Vertic Haplustepts								
Ap	0-22	56.1	15.2	28.7	1.73	18.1	11.8	6.3
Bw1	22-55	18.5	27.5	54.0	1.75	43.0	29.1	13.9
Bw2	55-86	21.0	31.9	47.1	1.63	47.0	31.4	15.6
Savli-10 : Loamy, smectitic, hyperthermic Lithic Ustorthents								
Ap	0-16	38.3	34.0	27.7	1.77	28.2	16.8	11.4

Table 3. Chemical properties of soils of Savli micro-watershed

Soil series	Horizon	pH (1:2.5)	EC (dS m^{-1})	O.C. (%)	$CaCO_3$ (%)	CEC [cmol(p+)kg^{-1}]	B.S. (%)
Savli-1	Ap	7.1	0.08	0.71	1.1	30.6	104.5
Savli-2	A	8.1	0.15	0.9	3.2	63.9	114.2
	Bw	8.0	0.18	0.85	5.3	64.3	117.4
Savli-3	A	6.6	0.12	1.86	1.6	21.3	113.6
Savli-4	Ap	7.9	0.19	0.82	0.6	64.3	85.3
	Bw	7.9	0.11	0.63	0.5	64.3	78.8
Savli-5	Ap	7.0	0.13	0.41	1.7	22.1	119.2
Savli-6	A	7.5	0.11	0.71	0.9	31.9	107.9
Savli-7	A	8.0	0.22	0.64	15.1	58.3	106.3
Savli-8	Ap	8.0	0.14	1.02	9.0	63.6	107.2
	Bw	8.0	0.25	0.85	7.8	63.9	110.8
	Bss1	8.0	0.14	0.72	7.1	65.1	114.1
	Bss2	7.9	0.31	0.68	5.9	64.1	117.3
	Bss3	7.9	0.29	0.67	17.0	64.8	114.8
Savli-9	Ap	7.5	0.14	0.45	0.5	32.9	85.1
	Bw1	7.5	0.10	0.85	1.3	66.7	100.9
	Bw2	7.6	0.18	0.75	3.1	67.2	116.4
Savli-10	Ap	7.7	0.15	0.90	0.9	49.6	93.5

soybean during *kharif*. The soils of Savli-5 are very shallow, somewhat excessively drained, dark brown (10YR 3/3M), loam with moderate erosion and cultivated to soybean and pigeonpea during *kharif*. The soils of Savli-6 are very shallow, somewhat excessively drained, dark brown (10YR 3/3M), clay loam (surface texture) with moderate erosion whereas, soils of Savli-7 are extremely shallow, somewhat excessively drained, brown (10YR 4/3M), calcareous, clay with moderate erosion. The soils of Savli-8 are very deep, moderately well drained, very dark greyish brown (10YR 3/2M), clayey, calcareous, moderate to strongly alkaline with moderate erosion. The soils of Savli-9 are moderately deep, moderately well drained, very dark greyish brown (10YR 3/2M), sandy clay loam (surface), with moderate erosion. These soils are cultivated to soybean and pigeonpea during *kharif* and gram during *rabi*. The soils of Savli-10 are very shallow, well drained, very dark greyish brown (10YR 3/2M), clay loam (surface) with moderate erosion and cultivated to soybean during *kharif*.

Physical properties

The particle size-distribution data (Table 2) indicated that sand, silt and clay contents in different soil series ranged from 5.9 to 38.4 per cent, 22.7 to 35.4 per cent and 26.2 to 71.4 per cent, respectively. Higher clay content was observed in soils of Savli-2 followed by Savli-8 and Savli-4 and the lowest clay content in soils of Savli-3. Clay content significantly and positively correlated with moisture retention at -33 kPa ($r = 0.88^{**}$), -1500 kPa ($r = 0.87^{**}$) and available water capacity ($r = 0.82^{**}$). The highest bulk density was noticed in soils of Savli-4 and the lowest one in soils of Savli-2. The bulk density, in general, increased with depth.

Chemical properties

The pH of the soils (Table 3) is neutral to moderately alkaline with pH ranging from 6.6 to 8.1. The electrical conductivity varies from 0.08 to 0.31 dSm^{-1} which is well below the permissible limit. Organic carbon content ranged from 0.41 to 1.86 per cent in different horizons of pedons and in general,

Table 4. Nutrient status of soils of Savli micro-watershed

Soil Series	Horizon	Available						
		N	P	K	Fe	Mn	Cu	Zn
Savli-1	Ap	313.2	6.2	66.1	26.7	48.0	6.1	0.7
Savli-2	A	232.1	2.3	223.6	9.3	9.1	3.4	0.1
	Bw	116.0	1.2	156.6	9.0	10.3	3.7	0.2
Savli-3	A	347.9	2.6	154.6	42.3	40.2	7.8	0.9
Savli-4	Ap	255.2	20.8	901.8	18.8	23.5	6.5	0.2
	Bw	197.2	9.2	319.6	15.2	17.1	5.6	0.1
Savli-5	Ap	255.1	13.1	221.9	30.2	30.8	3.5	0.3
Savli-6	A	255.1	1.9	143.2	41.5	30.7	9.2	tr
Savli-7	A	220.3	2.4	178.9	10.8	11.1	3.3	0.1
Savli-8	Ap	348.1	10.3	897.6	12.3	14.1	9.3	0.8
	Bw	185.6	8.9	220.1	8.9	8.6	5.2	0.2
	Bss1	174.0	4.5	231.2	10.4	12.1	5.9	0.2
	Bss2	162.4	3.3	256.4	11.2	12.2	6.6	0.1
	Bss3	139.2	2.6	257.4	11.8	9.3	7.5	0.2
Savli-9	Ap	208.8	8.1	66.5	15.8	18.9	4.2	tr
	Bw1	243.6	1.6	122.1	18.1	25.5	6.7	0.2
	Bw2	197.2	1.2	143.2	17.8	15.7	6.2	0.1
Savli-10	Ap	290	9.4	67.7	36.3	29.3	1.3	0.4

decreased with depth. The soils of Savli-2, Savli-7 and Savli-8 are calcareous with $CaCO_3$ varied from 3.2 to 17.0 per cent. Cation exchange capacity (CEC) of soils ranged from 21.3 to 67.2 cmol(p+)kg^{-1} soil and the highest CEC was observed in soils of Savli-9 developed on alluvial plain. The base saturation ranged from 78.8 to 119.2 per cent.

Available NPK

The available soil nitrogen was rated as very low (<140 kg ha^{-1}), low (141-280 kg ha^{-1}), medium (281-420 kg ha^{-1}), moderately high (421-560 kg ha^{-1}), high (561-700 kg ha^{-1}) and very high (>700 kg ha^{-1}). Soils of Savli-2, Savli-4, Savli-5, Savli-6, Savli-7 and Savli-9 are low (208.8-255.2 kg ha^{-1}) and soils of other series are medium (290.0-348.1kg ha^{-1}) in available nitrogen (Table 4). The available phosphorus content of the surface soils (Table 4) indicated that soils of Savli-1, Savli-2, Savli-3, Savli-6 and Savli-7 are very low (1.9 to 6.2 kg P ha^{-1}); soils of Savli-5, Savli-8, Savli-9 and Savli-10 are low (8.1 to 13.1 kg P ha^{-1}) and soils of Savli-4 are medium (20.8 kg P ha^{-1}) in available phosphorus. The data (Table 4) indicated that soils of Savli-1, Savli-9 and savli-10 are very low (66.1 to 67.7 kg K ha^{-1}); soils of Savli-6 are low (143.2 kg K ha^{-1}); soils of Savli-3 and Savli-7 are medium (154.6 to 178.9 kg K ha^{-1}); soils of Savli-2 and Savli-5 are moderately high (221.9 to 223.6 kg K ha^{-1}) and soils of Savli-4 and Savli-8 are very high in available potassium (897.6 to 901.8 kg K ha^{-1}).

Available micronutrients

The DTPA-Fe ranged from 8.9 to 42.3 mg kg^{-1} (Table 4) and found to be much higher than the critical level of 4.5 mg kg^{-1} (Lindsey and Norvell 1978) in all the soils. DTPA-Mn varied from 8.6 to 48.0 mg kg^{-1} (Table 4) and found to be much higher than the critical level of 3.0 mg kg^{-1} (Takkar *et al.* 1989) in all the soils. DTPA-Cu of the soils ranged from 1.3 to 9.3 mg kg^{-1} (Table 4) and decreased with depth but higher than the critical value of 0.2 mg kg^{-1} (Katyal and Randhawa 1983) in all the soils. Zn content of the soils varied from 0.0 to 0.9 mg kg^{-1} (Table 4) and the soils of Savli-2, Savli-4, Savli-5, Savli-6, Savli-7, Savli-9 and Savli-

Table 5. Soil productivity and suitability for major crops in Savli micro-watershed

Soil series	Productivity	Soil suitability		
		Cotton	Pigeonpea	Soybean
Savli-1	Poor	N	N	N
Savli-2	Average	S3	S3	S3
Savli-3	Poor	N	N	N
Savli-4	Average	S3	S3	S3
Savli-5	Poor	N	N	N
Savli-6	Poor	N	N	N
Savli-7	Extremely poor	N	N	N
Savli-8	Good	S2	S1	S2
Savli-9	Good	S2	S2	S2
Savli-10	Poor	N	N	N

10 are deficient in Zn as per critical level of 0.6 mg kg^{-1} (Katyal and Randhawa 1983; Sharma *et al.* 1996). Soil pH is the most important factor regulating Zn supply in calcareous soils. At alkaline pH, very low levels of soluble Zn are found, and only a negligible amount can be in the form of exchangeable Zn^{2+}, which is available to plants and need to be supplemented (Patricia 2000).

Soil productivity and suitability for crops

The data on soil productivity and suitability evaluation is presented in table 5. Based on productivity index, the soils were found to be extremely poor (Savli-7), poor (Savli-1, Savli-3, Savli-5, Savli-6 and Savli-10), average (Savli-2 and Savli-4) and good (Savli-8 and Savli-9). As per soil-site criteria for cotton crop, soils of Savli-8 and Savli-9 had moderate limitation of soil texture and organic carbon and hence are moderately suitable (S2) whereas, the soils of Savli-2 and Savli-4 are marginally suitable (S3) as these soils have marginal limitations of soil depth and texture. The soils of Savli-1, Savli-3, Savli-5, Savli-6, Savli-7 and Savli-10 are not suitable (N) for growing cotton due to very severe limitations of soil depth. The soils of Savli-8 are highly suitable (S1) with slight limitations. The soils of Savli-9 are moderately suitable (S2) with moderate limitations of soil depth. The soils of Savli-2 and Savli-4 are marginally suitable (S3) with severe limitations of soil depth whereas, soils of Savli-1, Savli-3, Savli-5, Savli-6, Savli-7 and Savli-10 are not suitable (N) for pigeonpea due to very severe limitations of soil depth. The suitability of soils for soybean indicates that soils of Savli-8 and Savli-9 are moderately suitable (S2) for growing soybean with moderate limitations of soil texture and soil pH. The soils of Savli-2 and Savli-4 are marginally suitable (S3) with marginal limitations of soil depth, soil texture and soil pH whereas, soils of Savli-1, Savli-3, Savli-5, Savli-6, Savli-7 and Savli-10 are not suitable (N1) due to very severe limitations of soil depth.

Socio-economics

The data on farm holdings in Savli village (Table 6) indicate that 38.6 per cent of farm holdings are small, 27.5 per cent are medium, 23.2 per cent are

Table 6. Farm holdings in Savli micro-watershed

Farm Holdings	Farm size (ha)	Total	Per cent
Marginal	0.50-0.99	92	23.2
Small	1.00-1.99	153	38.6
Medium	2.00-3.99	109	27.5
Large	>4	42	10.7
		396	100.0

marginal and 10.6 per cent are large. The yield data collected from the farmer's field indicate that the productivity of soybean (12 to 15 q ha^{-1}), cotton (10 to 15 q ha^{-1}), wheat (20 to 25 q ha^{-1}) and gram (8 to 12 q ha^{-1}) is very low. Low productivity of the crops is affecting the socio-economics of the farmers.

Land resources management

The integration of physiography, soil, present land use and slope maps under GIS environment has brought out the eight composite land units which lead to identify the areas for alternate land use, resource development and conservation. The plateau representing 54.2 per cent of area with shallow to very shallow soils under single crop (Savli-1) mainly cultivated to soybean and wasteland (Savli-2) without any soil and water conservation measures. To improve the productivity in cultivated land units, agri-horticulture with gooseberry, guava, custard apple and drum stick may be adopted with suitable soil and water conservation measures like contour bunding, gully plugging and water harvesting structures. The soils under wasteland may be brought under silvipasture. Moderately sloping escarpments representing 6.7 per cent of the area presently under wasteland with shallow soils (Savli-3) may be also brought under silvipasture systems. To reduce the runoff and conserve soil and water, contour vegetative bunds and continuous contour trenches are recommended. The shallow to very shallow soils (Savli-4, Savli-5) of pediment supporting rainfed crop in *kharif* are suggested for agri-horticulture systems. Proper field bunding, gully plugging and contour bunding is needed to conserve soil and water. Silvipasture systems may be adopted to improve the productivity in wastelands (Savli-6, Savli-7). Controlled grazing is required in these land units. In alluvial plain, the soils (Savli-8, Savli-9) are moderately deep to very deep, shrink-swell soils under double crop may be suggested for intensive cultivation with agronomic measures such as crop rotation that includes legumes, mixed cropping, vegetable cultivation and adoption of broad bed and furrows for irrigation. Mandarin is the main fruit crop in these land units and the productivity can be improved by adopting site-specific nutrient management. The soils representing Savli-10 series may be put under crop rotation with legumes and mixed cropping.

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