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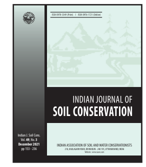

Soil quality evaluation for management of soil resources using geospatial technique of Shegaon watershed, Chandrapur district, Maharashtra

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ABSTRACT

The assessment and mapping soil quality for management of resources of Shegaon watershed, Chandrapur district of Maharashtra were carried out. IRS-LISS-IV and LISS-III data and GIS coupled with ground truth verification were used to delineate present land use/land cover (LU/LC), slope and the watershed's physiography. The characterization and classification of soils through profile study, identified and mapped seven different soil series and complex with phases on 1:12500 scale based on physiography-soil relationship. Soils occurring on moderately sloping (8-15%) isolated mound are shallow, well drained, and non-calcareous (*Typic Ustorthents*) whereas soils on subdued plateau are shallow *Lithic* to *Typic Haplustepts* in complexes. *Typic* and *Vertic Haplusterts* in complex are identified on gently sloping (1-3%) upper pediment. Soils of lower pediments are shrink-swell *Typic Haplusterts*. Upper plain lands of the watershed show very deep, calcareous; shrink-swell soils (*Typic Haplusterts*) whereas soils of lower plains are *Sodic Haplusterts*. Soil quality assessed by measuring soil attributes or properties that serve as soil quality indicators. The used dataset was the weighted mean of different variables from the pedons representing a particular soil series of the watershed for evaluating the soil quality index (SQI). The SQI has been calculated by goal finalization, found the minimum data set (MDS) through PCA or expert opinion, assign the score to MDS by an appropriate method. The soils under different soil series compared considering SQI by taking in to account hydraulic conductivity, exchangeable sodium percentage, soil respiration (CO_2), clay, organic carbon and DTPA extractable Fe as parameters for the MDS, and the SQI varied from 0.50 to 0.81. The Pohe-3 soils (*Typic Haplustepts*) showed highest SQI (0.81) whereas the Shegaon-3 soils (*Sodic Haplusterts*) showed the least SQI (0.50). The soil quality of the Shegaon watershed was mainly governed by hydraulic conductivity, soil pH, ESP and organic carbon, which were identified as soil quality indicators. Suitable conservation measures and interventions have been suggested to improve the productivity of these soils.

1. INTRODUCTION

Sustainable management of land resources is essential for food security, maintenance of environment and betterment of the society. Soils are considered as integral part of the landscape, and their characteristics are governed mainly by landform on which they are developed. (Sawhney *et al.,* 1992; Sharma *et al.,* 1999). The systematic study of morphology and taxonomy of soils, provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for various uses. (Sehgal, 1996). Precise scientific information on characteristics, potential, limitations and management needs of different soil is indispensable for planned development of land resources to maintain the soil productivity and meet the demands of the future. Rational utilization of land resources can be achieved by optimizing its use, ensuring its sustainable use.

Remote sensing (RS) data provide multi-spectral, multi-temporal and multi-sensor information of the earth's surface and offers greater accuracy, economy and is more efficient in data collection and mapping of land resources than the conventional method (Venkatratnam 1981; Kasturirangan *et al.,* 1996; Nasare *et al.,* 2013). Several studies have initiated to characterize, evaluate, and manage land resources at large scale using advanced tools (Srivastava and Saxena, 2004; Shukla *et al.,* 2009; Nagaraju *et al.,* 2015; Das *et al.,* 2019). An attempt has been made to characterize, evaluate and map the land resources of Shegaon watershed in Warora tahsil, district Chandrapur, Maharashtra using IRS-P6 (Resource sat-1) LISS-IV and LISS-III data in GIS alongwith Survey of India (SoI) topographical sheet on 1:50000 scale (55P/3) to collect topographical information.

Soil variability is the outcome of many processes acting and interacting across a continuum of spatial and temporal scales and is inherently scale-dependent (Trangmar *et al.,* 1985). Spatial variability is an inherent and dynamic feature of soil. It may be both vertical (within a pedon) and horizontal (across the landscape).

Shegaon watershed near Warora tehsil of Chandrapur district, Maharashtra has varied soils faces several constraints related to erratic and uneven distribution of rainfall, thin soil cover, crusting, gravellines in some soils and reduction in productivity. The system of farming has changed considerably during the last few years due to peri-urban pressure. Rapid urbanization, deforestation, wastelands and unwise utilization of natural resources causing human induced environmental degradation and ecological imbalances that warrant sustainable development and optimum management of land resources. The study focused on assessing the fertility status of soils of Shegaon watershed for better utilization of available soil resources for achieving the sustainable output.

Soil quality assessed by measuring soil attributes that serve as soil quality indicators by selecting the appropriate soil quality indicators to efficiently and effectively monitor critical soil functions as determined by the specific management goals for which an evaluation is being made. These indicators together form a minimum data set (MDS) that can be used to determine the performance of the critical soil function associated with each management goal (Pable *et al.,* 2016; Sonune *et al.,* 2021).

2. MATERIALS AND METHODS

Shegaon watershed is located between 20°18' to 20°22'N latitudes and 79°05' to 79°10'E longitudes. The total area of watershed is 2249.88 ha. The study area falls in the SoI toposheet No. 55P/3. The general elevation of area varies from 220 to 280 m above mean sea level. The area's climate is subtropical; dry sub-humid with ustic soil moisture regime and hyperthermic soil temperature regime. The average rainfall is 1100 mm which is received mostly from the southern monsoon. The mean annual temperature of the area is 27.8°C. The maximum temperature ranges from 27°C to 43°C and minimum from 12°C to 28°C. The relative humidity varies from high 77.97% during monsoon to a low of 37.3% during pre-monsoon summer.

Based on the soil variability, 22 typifying pedons were studied for their morphological, physical and chemical properties. Horizon wise soil samples were collected for laboratory analysis. Standard methods were used for laboratory analysis (Piper, 1966; Jackson, 1973). Digital data of IRS-P6 LISS-IV of Feb, 2010 alongwith LISS-III data of Oct, 2010 obtained from NRSC, Hyderabad was used to generate land use/land cover (LU/LC) and other thematic maps of the watershed. Satellite data of *kharif* and *rabi* seasons were visually interpreted for delineating various LU/LC categories by assessing the image characteristics of different land utilization types.

To quantify soil quality, a MDS comprised of a small number of carefully chosen soil physical, chemical, and biological indicators is needed (Doran and Parkin, 1996). SQI of identified soil series of Shegaon watershed has been calculated for suggesting better land-use plan. For estimation of SQI, the weighted mean of different physical, chemical properties has been taken along with the depth of soil series. Biological properties *viz.,* soil microbial biomass carbon (SMBC), dehydrogenase activity (DHA) and soil respiration (CO_2 evolution) of surface samples were analyzed (Jenkinson and Powlson, 1976; Klein *et al.,* 1971; Anderson, 1982) for SQI calculation.

The method used for arriving at MDS was by principal component analysis (PCA) alongwith experts' opinion (EO), with the use of a multivariate data reduction technique. The PCA was done using SPSS software (*ver.* 16.0 for Windows).

In the present study, Arc-GIS *ver.* 10.2 software was used for spatial and attribute database generation, GIS analysis and generation of various thematic maps.

3. RESULTS AND DISCUSSIONS

Present Land Use/Land Cover (LU/LC)

Based on image characteristics, the primary LU/LC visually identified are cultivated land, wasteland with and without scrub, habitation and waterbodies (Fig.1a). Cultivated land is again delineated into single and double-crop based on temporal data. The extent of area under different land utilization types indicates that cultivated land occupies 83.85% of the total geographical area (TGA) of which 55.44% is under single crop. Double crop occupies 28.41% of the cultivated area where assured/protective irrigation is available. Wasteland occupies 11.16% of the TGA, out which 7.88% wasteland without scrub while 3.28% wasteland with scrub. Waterbodies and habitation occupy 3.38 and 1.61% area, respectively.

Landform-Soil Relationship

Six major physiographic units *viz.,* isolated mound, subdued plateau, upper pediment, lower pediment, upper plain and lower plain were identified and delineated

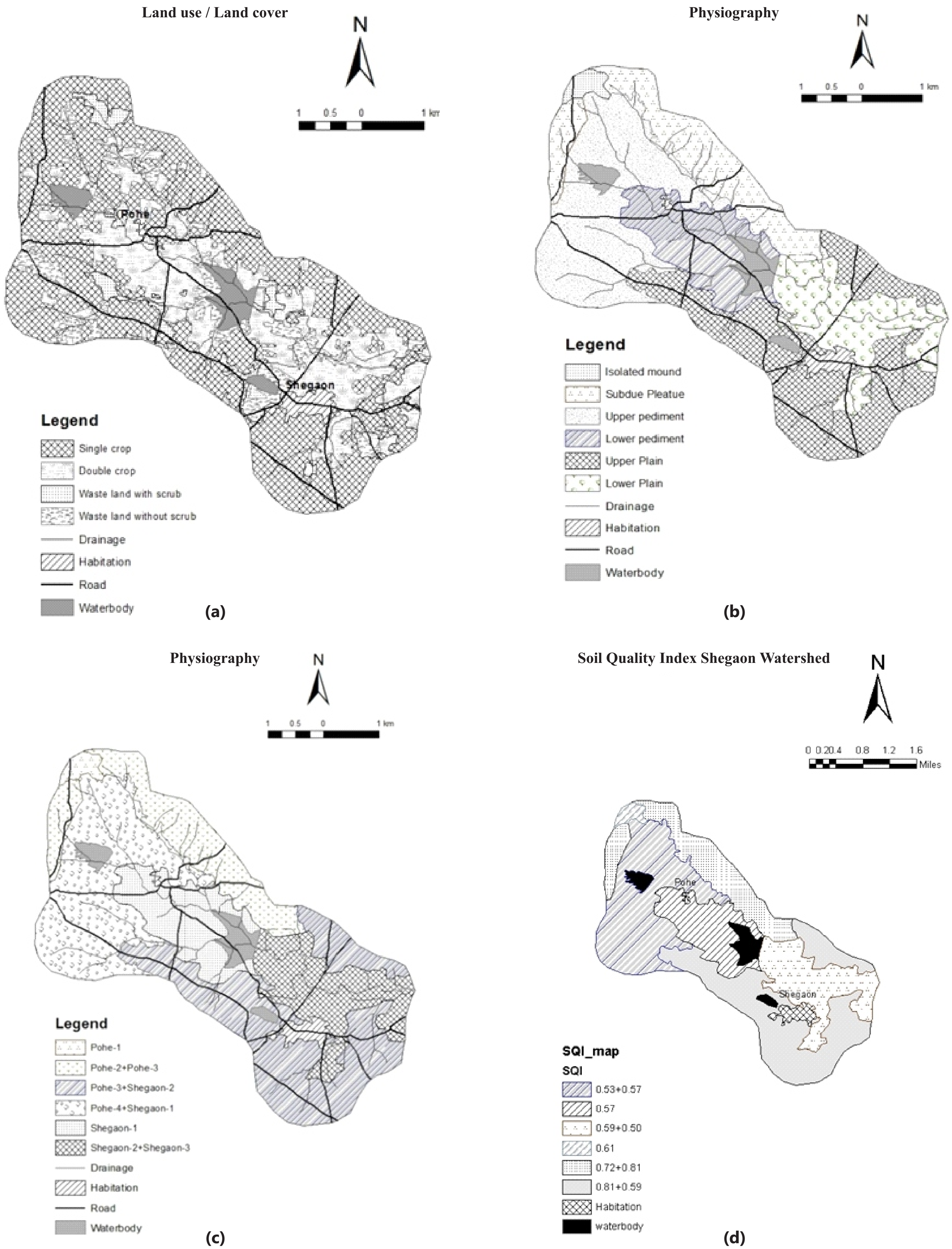

Fig. 1. (a) Land use/land cover (b) physiography (c) soils (d) Soil quality index maps of Shegaon waterhsed

(Fig.1b). Moderately sloping (8-15%) isolated mound occur at an elevation of 274 to 272 m above mean sea level (AMSL) and support mostly single cropland. The gently sloping (3-8%) subdued plateau occurs at an elevation 274 to 256 m AMSL also supported by single cropland. The very gently sloping (1-3%) pediments according to their elevation subdivided into upper pediment occurs at an elevation 269 to 252 m AMSL lower pediment occur at an elevation 245 to 239 m AMSL, and upper plain land occur at an elevation 260 to 245 m AMSL mainly supports both single and double crop with a small area under wasteland with scrub. Similarly level to nearly level (0-1%) lower plain lands occur at an elevation 235 to 225 m AMSL supports mostly double crop with few scattered orchards.

Seven soil series (Pohe-1, Pohe-2, Pohe-3, Pohe-4, Shegaon-1, Shegaon-2 and Shegaon-3) are tentatively identified and mapped as soil series and complex (Fig.1c) with phases at 1:12500 scale after the establishment of landform-soil relationship (Table 1).

Physical and Chemical Properties of Soils

The clay content of soil varied from 38.00 to 59.98%. Higher clay content is noticed in soils of Shegaon-3 developed on lower plains associated with higher bulk density due to subsurface sodicity and compactness (Table 2). The amount of water retained at -33 kPa suction varied from 27.81% in soils of Pohe-3 to 47.84% in Shegaon-1 soil series. The water retention at -1500 kPa suction varies from 12.1% in soils of Shegaon-3 to 29.9% in Shegaon-1 soils. The available water content of soils varied from 10.51% in soils of Pohe-3 to 20.02% in soils of Shegaon-3 soil series. The saturated hydraulic conductivity of the soils of watershed varied from 0.27 to 2.52 cm hr^{-1} was less in the subsurface horizons than that in the surface. The Shegaon-3 soils have least hydraulic conductivity due to more compactness caused by dispersion of soil aggregates.

The chemical properties indicated that the soils of the isolated mound (Pohe-1) and lower pediment (Shegaon-1) are neutral in reaction whereas the soils subdued plateau (Pohe-3) upper pediment (Pohe-4) are slightly alkaline. In contrast, soils of the upper plain (Shegaon-2) and lower plain (Shegaon-3) were strongly alkaline. The organic carbon in surface soils of the study area ranged from 4.32 g kg^{-1} in soils (Pohe-1) of the isolated mound to 8.46 g kg^{-1} in soils of the subdued plateau (Pohe-2). The Shegaon-2 soils are calcareous in nature, whereas other soils are non-calcareous. In general, all these soils are highly base saturated soils. The exchangeable sodium content ranged from 0.8 to 7.54 cmol (p+) kg^{-1} in sub-surface horizons of Shegaon-3 soils which is indicative of the development of subsoil sodicity, which is also reflected in the increased pH and ESP and decrease in saturated hydraulic conductivity of these soils. The cation exchange capacity of soils of watershed varied from 32.29 cmol(p+) kg^{-1} in soils of Pohe-1 to 51.65 cmol (p+) kg^{-1} in

Table: 1
Soil map legend

S.No.	Landform	Soil series and its complex	Soil characteristic	Soil taxonomy
1.	Isolated mound	Pohe-1	Very shallow, well-drained, non-calcareous, very dark greyish brown, (10 yr 3/2), clayey soils with moderate erosion.	Fine, smectitic, hyperthermic *Typic Ustorthents*
2.	Subdued plateau	Pohe-2 + Pohe-3	Shallow, well-drained, non-calcareous, very dark greyish brown, (10 yr 3/2), clayey-skeletal soils with moderate erosion in complex with, well-drained, non-calcareous, very dark greyish brown (10 yr 3/2) and clay-loam to clayey soils with moderate erosion.	Clayey-skeletal, smectitic, hyperthermic *Lithic Haplustepts* Clayey, smectitic, hyperthermic *Typic Haplustepts*
3.	Upper pediment	Pohe-4 + Shegaon-1	Deep, moderately well-drained, non-calcareous, dark brown (10 yr 3/3) clayey soils with slight erosion in complex with; Deep to very deep, moderately well-drained, non-calcareous, dark greyish brown (10 yr 4/3) clayey soils with slight erosion	Fine, smectitic, hyperthermic, Vertic Haplustepts Fine, smectitic, hyperthermic *Typic Haplusterts*
4.	Lower pediment	Shegaon-1	Deep to very deep, moderately well-drained, non-calcareous, dark greyish brown (10 yr 4/3) clayey soils with slight erosion	Fine, smectitic, hyperthermic *Typic Haplusterts*
5.	Upper plain	Pohe-3 + Shegaon-2	Well-drained, non-calcareous, very dark greyish brown (10 yr 3/2) and clay-loam to clayey soils with moderate erosion in complex with; Deep, moderately well-drained, calcareous, very dark greyish brown (10 yr 3/2), fine soils with slight erosion	Clayey, smectitic, hyperthermic *Typic Haplustepts* Fine, smectitic, (Calcareous) hyperthermic *Typic Haplusterts*
6.	Lower plain	Shegaon-2 +	Deep, moderately well-drained, calcareous, very dark greyish brown (10 yr 3/2), fine soils with slight erosion, in complex with Very Deep, imperviously drained, very dark greyish brown (10 yr 3/2), fine soil	Fine, smectitic, (Calcareous) hyperthermic, *Typic Haplusterts* with slight erosion Fine, smectitic, hyperthermic *Sodic Haplusterts*

Table: 2
Physical properties of soils

Horizon	Depth (cm)	Sand	Silt %	Clay	BD (Mg m^{-3})	HC (cm hr^{-1})	MWD (mm)	Water retention (%) 33 kPa	1500 kPa	AWC
Pedon - 1 (Isolated mound) Pohe-1: Fine, smectitic, hyperthermic *Typic Ustothents*										
Ap	0-20	24.67	34.58	40.75	1.58	2.52	0.78	32.49	20.25	12.24
Pedon - 2 (Subdued plateau) Pohe-2: Clayey-skeletal, smectitic, hyperthermic *Lithic Haplustepts*										
Ap	0-18	17.50	39.03	43.47	1.56	2.31	0.68	29.28	15.10	14.18
Bw	18-32	14.83	36.27	48.90	1.50	2.66	0.68	33.74	18.93	14.80
Pedon - 3 (Subdued plateau) Pohe-3: Clayey, smectitic hyperthermic *Typic Haplustepts*										
Ap	0-20	31.03	30.97	38.00	1.54	2.23	0.76	36.54	27.04	9.49
Bw1	20-60	26.57	34.10	39.33	1.58	2.49	0.78	35.25	23.65	11.60
Bw2	60-83	21.83	36.18	41.99	1.62	2.07	0.79	37.69	24.86	12.83
Pedon - 4 (Upper pediment) Pohe-4: Fine, smectitic, hyperthermic *Vertic Haplustepts*										
Ap	0-20	19.47	31.63	48.90	1.45	2.51	0.75	33.18	21.37	11.81
Bw1	20-52	14.20	34.18	51.62	1.52	2.15	0.76	32.59	20.36	12.23
Bw2	52-89	10.33	32.62	57.05	1.54	1.97	0.79	39.85	26.96	12.89
Bw3	89-122	10.67	29.57	59.77	1.57	1.91	0.75	34.69	21.20	13.49
Pedon - 5 (Lower pediment) Shegaon-1: Fine, smectitic, hyperthermic *Typic Haplusterts*										
Ap	0-18	31.00	26.89	42.11	1.44	2.43	0.81	34.11	22.18	11.93
Bw	18-42	27.00	28.18	44.83	1.48	2.08	0.83	34.58	20.37	14.21
Bss1	42-81	25.00	27.46	47.54	1.51	2.03	0.84	36.40	21.16	15.24
Bss2	81-118	21.67	29.43	48.90	1.55	1.67	0.81	41.57	24.79	16.78
Bss3	118-150	19.67	30.08	50.26	1.59	1.25	0.76	47.94	29.91	18.03
Pedon - 6 (Upper plain) Shegaon-2: Fine (Calcareous), smectitic, hyperthermic *Typic Haplusterts*										
Ap	0-19	28.13	33.83	38.03	1.55	2.22	0.79	28.87	17.65	11.22
Bw	19-42	25.53	31.00	43.47	1.57	2.19	1.80	31.07	17.72	13.36
Bss1	42-82	25.07	28.75	46.18	1.65	1.47	0.80	33.11	19.16	13.95
Bss2	82-125	23.17	27.93	48.90	1.67	1.41	0.86	38.84	22.00	14.83
Pedon - 7 (Lower plain) Shegaon-3: Fine, smectitic hyperthermic *Sodic Haplusterts*										
Ap	0-17	21.78	32.58	45.64	1.68	2.46	0.77	28.06	14.78	13.29
Bw	17-54	19.48	31.62	48.90	1.70	2.38	0.74	30.98	17.38	13.60
Bss1	54-85	19.00	34.06	46.94	1.82	1.64	0.72	30.56	12.09	18.47
Bss2	85-120	8.88	32.44	58.68	1.76	0.66	0.73	32.81	13.45	19.36
Bss3	12-150	8.16	31.86	59.98	1.82	0.27	0.71	36.28	16.26	20.02

soils of Shegaon-3 soil series. Relatively higher CEC values have been observed in the soils of the lower plain region could be attributed to high clay content with smectitic mineralogy (Pal and Deshpande, 1987).

Soil Fertility

In general, the soils of Shegaon watershed are deficient to medium in available nitrogen. The nitrogen content in soils ranged from 57.58 (Shegaon-3) to 287.88 kg ha^{-1} (Pohe-3). The available nitrogen content decreased with depth in all soils. Phosphorus content varied between 3.33 (Pohe-2) to 16.35 kg ha^{-1} (Pohe-3) and decreased with depth in all soils. Available potassium content in the soils of watershed varied from 250.88 kg ha^{-1} to 605.25 kg ha^{-1} the potassium content also increased with the clay content. This may be attributed to the K-rich minerals occurring in the soil (Pal, 1987).

The DTPA extractable micro-nutrient cations (Fe, Mn, Cu and Zn) of the soils (Table 3) indicated that the DTPA-extractable Fe ranged from 0.84 to 10.24 mg kg^{-1} the critical value of DTPA-Fe is 4.5 mg kg^{-1} (Lindsay and Norvell, 1978). The soil developed on the isolated mound, subdued plateau, upper pediment and lower plains are deficient. In contrast, soils on lower pediment (Shegaon-1) and upper plain region (Shegaon-2) were sufficient in DTPA-Fe. The DTPA-Mn ranged from 5.2 to 24.72 mg kg^{-1} above the critical limit of 3.0 mg kg^{-1} (Takkar *et al.,* 1989). DTPA-Cu varied from 0.7 to 2.35 mg kg^{-1} was higher than the critical value of 0.2 mg kg^{-1} (Katyal and Randhawa, 1983). The DTPA–Zn ranged from 0.18 to 0.48 mg kg^{-1}and was found deficient below the critical level of 0.6 mg kg^{-1} as suggested by Katyal and Randhawa (1983). The micro-nutrient contents, in general decreased with depth. Deficient Fe and Zn may hamper crop productivity and needs further investigation.

Soil Quality Assessment

Total 31 variables were selected for PCA analysis. PCA analysis in Table 5 showed that six PCs had eigen value >1 and can explain 100% variance in the data. With each principal component, only highly weighted loading factor

Table: 3
Chemical and nutrient properties of soils

Horizon	Depth (cm)	pH (1:2.5)	EC (1:2.5)	OC (g kg^{-1})	$CaCO_3$ (%)	CEC cmol(p+) kg^{-1}	BS (%)	Available micro-nutrients (mg kg^{-1})			
								Cu	Fe	Zn	Mn
Pedon - 1 (Isolated mound) Pohe-1: Fine, smectitic, hyperthermic *Typic Ustrothents*											
Ap	0-20	7.61	0.46	4.32	1.35	32.29	99.19	0.70	4.64	0.33	16.41
Pedon - 2 (Subdued plateau) Pohe-2: Clayey-skeletal, smectitic, hyperthermic *Lithic Haplustepts*											
Ap	0-18	7.54	0.37	8.46	7.17	33.73	96.78	2.35	5.12	0.48	20.41
Bw	18-32	7.64	0.6	6.49	3.88	33.92	97.52	1.66	4.71	0.42	16.588
Pedon - 3 (Subdued plateau) Pohe-3: Clayey, smectitic, hyperthermic *Typic Haplustepts*											
Ap	0-20	8.03	0.15	7.94	0.82	32.93	95.66	0.86	6.12	0.48	10.03
Bw1	20-60	8.10	0.13	5.21	1.29	35.23	93.97	0.84	5.77	0.37	7.59
Bw2	60-83	8.10	0.16	3.62	2.23	37.88	92.80	0.83	5.07	0.33	5.26
Pedon - 4 (Upper pediment) Pohe-4: Fine, smectitic, hyperthermic *Vertic Haplustepts*											
Ap	0-12	8.09	0.11	5.31	0.82	36.82	95.58	1.02	6.13	0.34	14.19
Bw1	12-42	8.12	0.13	4.14	2.23	36.06	96.59	0.88	5.38	0.24	11.35
Bw2	42-88	8.19	0.2	2.76	4.11	37.87	94.82	0.80	5.04	0.22	10.45
Bw3	88-122	8.27	0.23	2.94	1.53	38.92	92.94	0.68	4.92	0.18	8.95
Pedon - 5 (Lower pediment) Shegaon-1: Fine, smectitic, hyperthermic *Typic Haplusterts*											
Ap	0-18	7.02	0.17	5.76	2.53	37.78	95.65	1.80	7.12	0.46	24.73
Bw1	18-42	7.28	0.16	3.84	3.35	38.37	93.94	1.15	6.45	0.42	22.86
Bw2	42-81	7.57	0.13	3.10	2.18	39.15	93.03	1.01	5.53	0.38	13.73
Bss1	81-118	7.42	0.15	2.57	3.82	39.69	92.32	0.96	5.04	0.37	15.11
Bss2	118-150	7.51	0.2	3.11	4.53	40.25	90.94	1.39	4.85	0.36	16.32
Pedon - 6 (Upper plain) Shegaon-2: Fine (Calcareous), smectitic, hyperthermic *Typic Haplusterts*											
Ap	0-19	7.89	0.33	6.87	4.55	35.65	91.06	1.55	10.25	0.37	21.30
Bw1	19-42	8.22	0.31	2.62	5.82	38.04	88.03	1.09	8.25	0.36	12.76
Bss1	42-82	8.38	0.22	2.18	9.46	41.26	89.41	1.15	6.24	0.33	11.59
Bss2	82-125	8.54	0.30	1.01	15.72	44.68	87.46	0.96	6.12	0.32	13.29
Pedon - 7 (Lower plain) Shegaon-3: Fine, smectitic, hyperthermic *Sodic Haplusterts*											
Ap	0-17	8.05	0.16	5.77	6.12	32.37	95.59	1.07	4.44	0.42	11.66
Bw	17-54	8.37	0.14	5.37	5.78	35.31	93.91	1.04	4.32	0.39	9.57
Bss1	54-85	8.8	0.18	4.98	7.82	37.46	93.55	1.02	3.85	0.44	8.40
Bss2	85-120	8.94	0.3	4.58	11.26	39.63	93.02	0.97	3.66	0.40	7.06
Bss3	120-150	9.01	0.7	4.45	14.84	42.47	89.99	0.92	3.08	0.45	6.49

(indicated in bold numbers in Table 4) were retained for the MDS.

The soil quality index (SQI) map of identified soil series in complexes is depicted in Fig. 1(d). The different soil series of Shegaon watershed were compared by calculating the SQI by taking into variables from different principal components as the MDS, it is found that the Pohe-3 soil series showed higher SQI (0.81) while Shegaon-3 soil series having least SQI (0.50) due to subsurface sodicity.

Suggested Interventions

Thematic data of present LU/LC, slope, physiography and soils were evaluated for their fertility, erosion, land capability, irrigability and suitability classes for the crops grown in the area and integrated with GIS environment. The gently sloping lower pediment, level to nearly level lower plain under double-crop includes soil series Pohe-4, Shegaon-1, Shegaon-2, Shegaon-3, Shegaon-4 are the most potential zones in the study area. Under intensive cultivation practices, judicious soil and water conservation practices such as crop rotation including legumes mixed cropping, adopting alternate beds and furrows for irrigation, proper application of manures and fertilizers and pesticides for pest control, etc. should be implemented to maintain productivity on a sustainable basis. The gently sloping subdued plateau to very gently sloping upper pediment and upper plain comprising soil series Pohe-2, Pohe-3 and Shegaon-2 under single crop, with soil and water conservation measures and agronomic measures like crop rotation, raising of short duration crops like green gram, sesamum, sunflower this area can be turned up into double-crop. The moderately sloping isolated mound and gently sloping subdued plateau having shallow soils, are under single crop and wasteland needs to be protected through proper field bunding and mulching to reduce run-off and conserve moisture. Agroforestry and agri-horticultural interventions with suitable species may be needed. Trees of locally adaptable species useful to farmers can be planted along the bunds. The land between the bunds can be used for growing drought-resistant crop species. Silvipasture systems

Table: 4
Factor loading / eigenvectors of PCA of different soil series

	Rotated component matrix					
	1	2	3	4	5	6
Depth	-0.733	0.242	0.338	-0.178	0.312	-0.045
pH	-0.699	0.358	-0.526	0.063	-0.137	-0.288
OC	0.418	0.1	-0.288	-0.068	**0.831**	-0.192
$CaCO_3$	-0.582	-0.04	-0.284	0.056	0.338	0.679
Ex_Ca	-0.211	**-0.945**	-0.036	0.19	-0.159	0.01
Ex_Mg	-0.413	0.473	0.57	0.518	0.061	0.098
Ex_Na	-0.273	**0.825**	-0.172	0.422	-0.06	-0.185
Ex_K	0.694	-0.533	-0.459	-0.017	-0.092	0.122
CEC	-0.704	-0.367	0.058	0.58	-0.169	0.024
BS	**0.935**	0.222	-0.034	-0.248	0.047	-0.111
ESP	-0.247	**0.850**	-0.137	0.408	-0.053	-0.171
EMP	0.125	0.792	0.546	0.114	0.204	0.066
Sand	0.109	0.072	0.336	-0.463	-0.251	0.77
Silt	0.411	-0.11	-0.336	-0.418	0.477	-0.551
Clay	-0.428	0.009	-0.096	**0.805**	-0.1	-0.387
BD	-0.379	**0.834**	-0.386	-0.048	-0.068	-0.073
HC	**0.935**	-0.137	0.023	-0.228	0.228	-0.039
kpa33	-0.009	0.117	0.956	-0.07	-0.058	0.254
kpa1500	0.12	-0.03	0.755	-0.6	-0.031	0.229
AWC	-0.223	0.22	0.046	0.948	-0.031	-0.036
MWD	0.154	-0.061	0.792	0.14	-0.539	-0.186
Av_N	**0.805**	-0.113	-0.348	-0.481	0.292	0.15
Av_P	-0.419	0.636	0.143	-0.546	-0.075	-0.311
Av_K	**0.854**	-0.376	-0.283	0.125	-0.05	-0.177
Zn	0.11	0.554	0.12	-0.242	0.757	0.189
Cu	0.205	-0.09	0.008	0.283	**0.885**	0.295
Fe	-0.181	-0.226	0.002	-0.248	-0.144	0.913
Mn	0.525	-0.207	0.194	0.135	0.215	0.761
SMBC	-0.057	-0.019	0.038	-0.133	**0.910**	-0.387
DHA	0.698	-0.494	0.324	-0.234	0.317	0.088
Co_2	-0.209	-0.241	**0.944**	0.008	0.052	-0.067

with restricted grazing designed for dryland condition. It provides pastoral activity for fodder and growing trees for timber and fuel. The practice also allows rearing of cattle for developing dairy as a side business, supporting agriculture.

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Table: 5
Results of (PCA) of soil quality indicators of statistically significant variable for different soil series

Parameters	PC-1	PC-2	PC-3	PC-4	PC-5	PC-6
Total eigen value	9.90	5.85	5.38	3.30	3.19	2.35
% Total variance	33.02	19.52	17.95	11.02	10.63	7.84
% Cumulative variance	33.02	52.54	70.50	81.52	92.15	100
Weightage (W)	0.33	0.20	0.18	0.11	0.11	0.08

Table: 6
Calculation of SQI using the weight factor from the eigenvalues of PCA for the different soil series of Shegaon watershed

Soil series	PC-1 HC	PC-2 ESP	PC-3 CO_2	PC-4 Clay	PC-5 OC	PC-6 Fe	SQI	RSQI
Weightage (Wi)	0.33	0.20	0.18	0.11	0.11	0.08		
Pohe-1	1.00	0.55	0.28	0.73	0.57	0.56	0.61	76.39
Pohe-2	0.97	0.77	0.40	0.82	1.00	0.40	0.72	89.28
Pohe-3	0.77	1.00	0.68	0.80	0.69	0.15	0.81	100
Pohe-4	0.62	0.35	0.50	1.00	0.44	0.2	0.53	65.49
Shegaon-1	0.72	0.28	1.00	0.85	0.44	0.54	0.57	70.63
Shegaon-2	0.49	0.55	0.46	0.81	0.44	1.00	0.59	73.74
Shegaon-3	0.56	0.06	0.32	0.95	0.65	0.15	0.50	61.78

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