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Soil mapping and land evaluation of Khandala village in Nagpur district using high-resolution satellite data and GIS

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ABSTRACT

The present investigation was carried out to characterize and evaluate the land resources using Cartosat-1-sharpened-LISS-IV satellite data (2.5 m spatial resolution) in Khandala village of Nagpur district, Maharashtra. Five major landforms *viz.,* plateau, escarpment, pediment, alluvial plain and valley were identified and delineated. Based on image characteristics, seven land use / land cover (LU/LC) classes, namely, single crop, double crop, degraded forest, wasteland, river, water body and habitation were identified. Five classes of slopes *viz.,* nearly level to level (0-1%), very gently sloping (1-3%), gently sloping (3-8%), moderately sloping (8-15%) and moderately steeply sloping (15-30%) lands were identified. Five soil series (Khandala-1, Khandala-2, Khandala-3, Khandala-4, and Khandala-5) were identified and mapped on 1:5000 scale. Very shallow soils (Lithic Ustorthents / Typic Ustorthents) were associated with plateau, escarpment and pediments. Alluvial plain has shallow soils (Typic Haplustepts), while, valley portion of village possessed deep Vertisols. The soils were grouped under land capability sub classes of IId, IIIs, IVs, VIs and VIes, and land irrigability sub-classes of 2sd, 2s, 3 and 4s. The productivity of Khandala-1 soil was poor due to severe limitation of soil moisture and effective depth. The soils of Khandala-2 series were extremely poor in productivity owing to very severe limitation of soil depth, soil moisture and organic matter and soils of Khandala-3 and Khandala-4 had average productivity, while, soils of Khandala-5 series were grouped under good productivity. Various land use options and soil and water conservation measures have been suggested in different land units.

1. INTRODUCTION

Sustainable management of land resources is essential for food security, maintenance of environment and general well-being of the people. Indiscriminate use of resources coupled with lack of management has, however, led to land degradation echoing the concern of planners, researchers and farmers alike (Sharma, 2006). It is essential to enhance the soil productivity to meet the future demand. Detailed soil spatial and attribute information is required for many environmental modelling and land management applications (Nagaraju *et al*., 2014). The resource information so generated is, generally, interpreted for grouping of soils for land capability, land irritability, soil productivity and suitability for crops through evaluation procedures which helps the administrators and managers for agriculture and related developmental activities on sustainable basis. Remote sensing data provides a wealth of information of large areas and permit lithological discrimination, identification of different landforms and land use / land cover (LU/LC) patterns which will help in land resource characterization (Sagar-Ingle *et al*., 2019). The advancements in sensor technology with enhanced spatial, spectral and radiometric resolution over a period of time has helped to map the soils at large scale for detailed characterization of land resources at village or watershed level. Geographic information system (GIS) helps in building of spatial database and generation of various thematic maps. Precise scientific information on characteristics, potential, limitations and management needs of different soils is indispensable for planned development of these resources to maintain the present level of soil productivity and to meet the demands of the future. Therefore, increased emphasis is being laid on characterization of soils, their evaluation and precise mapping using remote sensing and GIS.

The Katol tehsil of Nagpur district in Vidarbha region of Maharashtra is predominantly under rainfed farming with erratic rainfall distribution associated with low crop productivity. The site-specific information is required in terms of soil characteristics, productivity potentials and limitations for land resources development and management. Keeping this in view, the present investigation was planned to characterize and evaluate the land resources of Khandala village in Nagpur district for land resource management.

2. MATERIALS AND METHODS

Study Area

The Khandala village (21°14' to 21°16'N; 78°32' to 78° 35'E) covers an area of 568.5 ha in Katol tehsil, Nagpur district, Maharashtra (Fig. 1). Five major landform units *viz.,* plateau, escarpments, pediment, alluvial plain and valley were identified in the village. The elevation of the area, derived from Survey of India (SoI) toposheet, ranges from 420 to 520 m above mean sea level. The area is associated with level to nearly level sloping (0-1%) to moderately steep sloping (15-30%) lands. The climate is mainly subtropical, dry sub-humid with mean annual temperature of 26.9°C and mean annual rainfall of 920 mm. The area qualifies for ustic soil moisture regime and hyperthermic soil temperature regime. The natural vegetation comprises of teak (*Tectona grandis*), acacia (*Acacia* spp.), palash (*Butea frondosa*), charoli (*Bachanania latifolia*), jujube (*Ziziphus jujuba*) etc. The major crops grown in the area are cotton (*Gossypium* spp.), soybean (*Glycine max*), sorghum (*Sorghum bicolor*) and pigeonpea (*Cajanus cajan*) in *kharif* and gram (*Cicer arietinum*) and wheat (*Triticum aestivum*) in *rabi* under irrigation or on stored moisture. Nagpur mandarin (*Citrus reticulata* Blanco) is the main fruit crop of the area.

Methodology

The processed digital data of Cartosat-1 sharpened IRS-P6 LISS-IV of January 2010 with a spatial resolution of 2.5 m was used in the present study (Fig. 1). The standard false colour composite (FCC) was generated with the combination of band 2 (green), band 3 (red) and band 4 (near infrared). SoI toposheet No. 55K/11 (1:50000 scale) was used to collect topographic and location information. The landforms, slope and land use / land cover (LU/LC) were considered for depicting the soil variability and generating the soil map (Srivastava and Saxena, 2004). Using the interpreted maps (landform and LU/LC maps prepared from toposheet and satellite data), the area was traversed to verify different landform units and present LU/LC classes. To understand the soil variability in the watershed, twenty-eight soil profiles representing different landform units were studied. Site and soil characteristics like slope, stoniness, erosion, colour, texture, structure etc. were recorded as per Soil Survey Division Staff (2000) and soils were classified as per keys to soil taxonomy (Soil Survey Division Staff, 2003). Nearly 2 kg of horizon-wise soil samples were collected from representative pedons of soil series. Clods were also collected from each horizon for estimation of bulk density (BD). The physical properties *viz.,* sand, silt, clay and BD, chemical properties *viz.,* pH, electrical conductivity (EC), organic carbon (OC), calcium carbonate ($CaCO_3$), exchangeable cations, cation exchange capacity (CEC) and base saturation (BS) and nutrient status *viz.,* available N, P, K, Fe, Mn, Cu and Zn of soil samples were carried out using

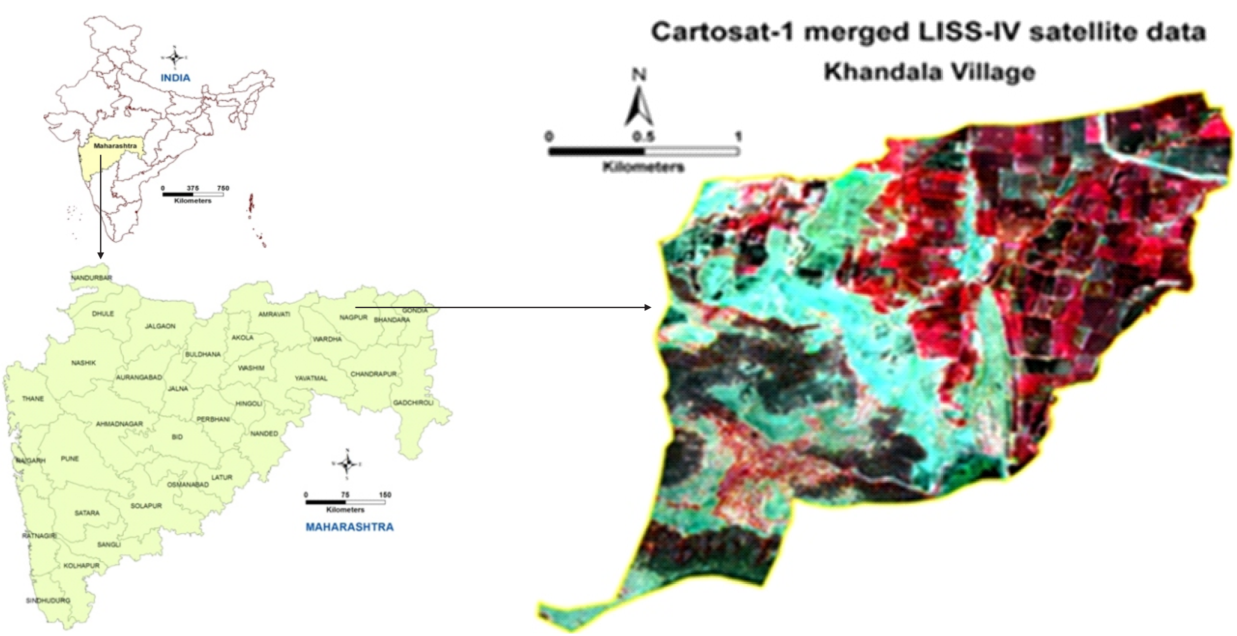


Fig. 1. Location of study area

standard procedures (Black, 1965; Jackson, 1967; Lindsay and Norvell, 1978). The soil productivity index was computed and grouped under different soil productivity classes (Riquier *et al.,* 1970). The soils were grouped under different land capability sub-classes (Klingebiel and Montgomery, 1961), land irrigability sub-classes (AIS &LUS, 1971). The soil-site suitability analysis (NBSS&LUP, 1994) was carried out for assigning the suitability of different mapping units for cotton, pigeonpea, soybean and gram. ArcGIS software was used to generate various spatial thematic maps. The flow chart of the methodology for soil characterization and evaluation is presented in Fig. 2.

3. RESULTS AND DISCUSSIONS

Present Land Use/Land Cover (LU/LC)

Based on image characteristics (Fig. 3a), the major LU/LC identified were cultivated land, wasteland, forest, habitation and water bodies. Cultivated land was again delineated into single and double crop based on temporal satellite data. The extent of area under different land utilization types indicated that cultivated land occupies 54.4% of the total geographical area (TGA) of which 11.5% was under single crop. The area under double crop was 42.9% of the cultivated area, where, assured / protective irrigation was available. Forest land was again delineated into moderately dense forest (11.4%) and degraded forest (31.1%). Wasteland covered 5.8%, while, waterbodies and habitation occupy 6.5 and 5.6% area, respectively.

Slope

Five slope classes *viz.,* nearly level to level (0-1%), very gently sloping (1-3%), gently sloping (3-8%) and moderately sloping (8-15%), moderately steeply sloping (15-30%) lands were identified (Fig. 3b). The perusal of slope class data indicated that nearly 25.4% area was under level to nearly level (0-1%), 27.9% area under very gently slope (1-3%), 21.4% under gently sloping (3-8%), 11.3% area under moderately sloping (8-15%) and 11.8% area under moderately steeply sloping (15-30%) class (Fig. 3b).

Landform-Soils

Based on visual interpretation of digital data of Cartosat-1 sharpened IRS-P6 LISS-IV of January 2010 with a spatial resolution of 2.5 m along with SoI toposheet No. 55K/11, five major landform units *viz.,* plateau, escarpments, pediments, alluvial plains and valleys were identified. These landform units were further sub-divided based on slope LU/LC (Fig. 3c). Five soil series (Khandala-1, Khandala-2, Khandala-3 Khandala-4 and Khandala-5) were identified on different landform units and mapped as soil series at 1:5000 scale (Fig. 3d) as per landform-soil relationship (Table 1). Soils of Khandala-1 are very shallow, somewhat excessively drained, dark reddish brown (5 yr 3/2 m), clayey- skeletal

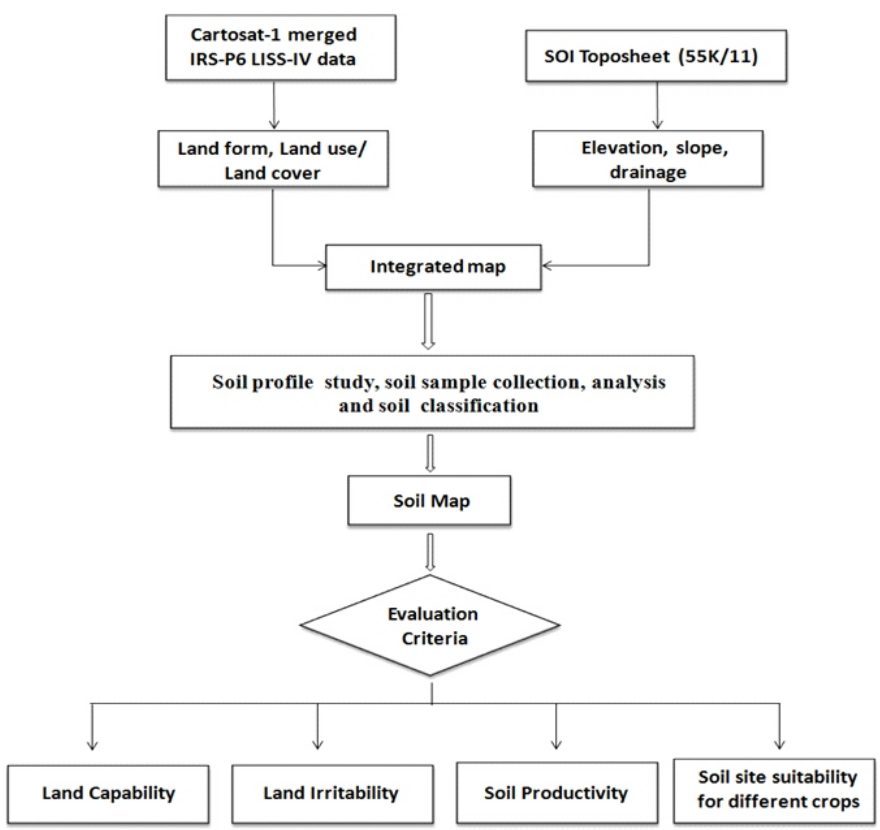


Fig. 2. Flow chart of the methodology for soil characterization and evaluation

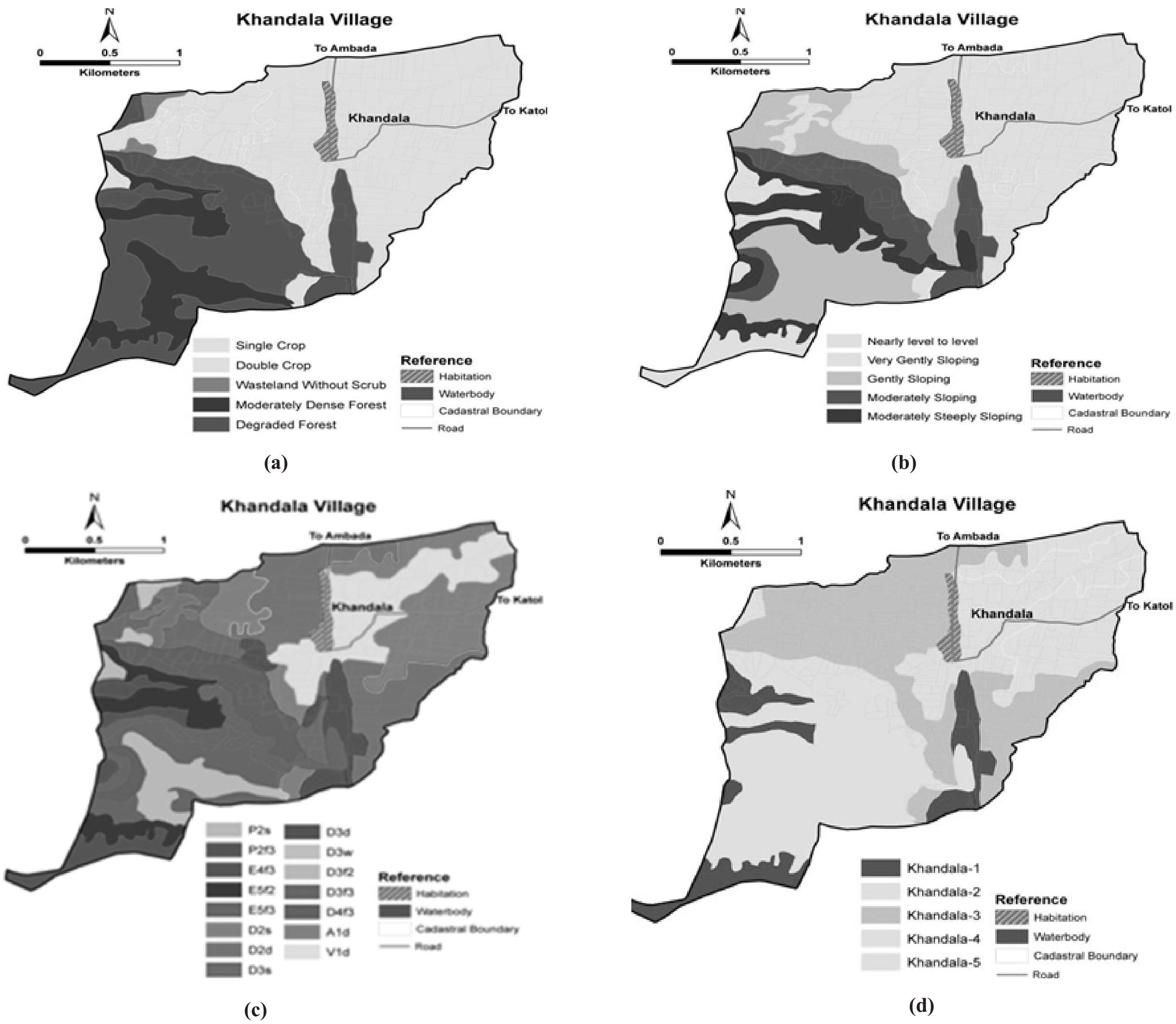


Fig. 3. Maps of a) land use/land cover, b) slope, c) landforms and d) soils

soils with very severe erosion, soils of Khandala- 2 are very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion, soils of very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion, soils of Khandala-4 are shallow, moderately well drained, dark yellowish brown (10 yr 3/2 m) clay soils with moderate erosion, whereas, soils of Khandala-5 are deep, moderately well drained, very dark gray (10 yr 3/1 m) very-fine soils with moderate erosion.

Physical and Chemical Properties of Soils

Data (Table 2) indicates that the soils of area had higher proportion of clay compared to sand and silt in plateau, alluvial plain and valley soils but it was low in escarpment and pediment. The sand, silt and clay in soils ranged from 26.5 to 50.1%, 12.7 to 34.0% and 15.9 to 40.6%, respectively, in erosional surface (plateau, escarpment, pediment), whereas, the sand, silt and clay in soils ranged from 4.4 to 11.0%, 27.2 to 39.4% and 49.6 to 67.2% in depositional surface (alluvial plain and valley). The BD of soils ranged from 1.44 to 1.93 Mg m^{-3}.

The soils of the village were acidic to alkaline (6.1 to 8.5 pH). The EC of the soils ranged from 0.05 to 0.48 dS m^{-1}, while, OC content ranged from 5.6 to 17.7 g kg^{-1} in different horizons. Soils of Khandala-1 had higher OC content as these soils are under forests and some patches are brought under cultivation. In general, the OC content decreased with depth. The calcium carbonate content varied from 4.5 to 13.8%. The exchangeable calcium content of the soils ranged from 4.8 to 49.6 cmol(p^+)kg^{-1} and it was higher in soils of Khandala-4 (alluvial plain) and Khandala-5 (valley).

Table: 1
Relationship between landforms and soils in Khandala village, Nagpur

S.No.	Map symbol	Landform cum photomorphic unit			Soil series	Soil characteristics	Soil taxonomy
		Landform	Slope (%)	Image characteristics			
1	P2s	Plateau	1-3	Greenish blue tone, diffuse checker board	Khandala-1	Very shallow, somewhat excessively drained, dark reddish brown (5 yr 3/2 m), clayey-skeletal soils with very severe erosion	Clayey-skeletal, smectitic, hyperthermic Lthic Ustorthents
2	P2f3	Plateau	1-3	Bluish green tone some pink patches, medium texture	Khandala-1	Very shallow, somewhat excessively drained, dark reddish brown (5 yr 3/2 m), clayey-skeletal soils with very severe erosion	Clayey-skeletal, smectitic, hyperthermic Lithic Ustorthents
3	E4f3	Escarpment	8-15	Bluish green tone some pink patches, medium texture	Khandala-2	Very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents
4	E5f2	Escarpment	15-30	Red and brown tone, medium texture	Khandala-2	Very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents
5	E5f3	Escarpment	15-30	Bluish green tone some pink patches, medium texture	Khandala-2	Very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents
6	D2s	Pediment	1-3	Greenish blue tone, diffuse checker board	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
7	D2d	Pediment	1-3	Dark red and brown, bold checker board pattern	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
8	D3s	Pediment	3-8	Greenish blue, diffuse checker board pattern	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
9	D3d	Pediment	3-8	Dark red and brown, bold checker board pattern	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
10	D3w	Pediment	3-8	Bluish green tone and pink patches, medium texture	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
11	D3f2	Pediment	3-8	Red and brown tone, medium texture	Khandala-3	Very shallow, well drained, dark yellowish brown (10 yr 3/4 m) sandy clay loam soils with severe erosion	Loamy, mixed, hyperthermic Lithic Ustorthents
12	D3f3	Pediment	3-8	Bluish green tone some pink patches, medium texture	Khandala-2	Very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents
13	D4f3	Pediment	8-15	Bluish green tone some pink patches, medium texture	Khandala-2	Very shallow, excessively drained, dark yellowish brown (10 yr 3/4 m) loamy-skeletal soils with very severe erosion	Loamy-skeletal, mixed, hyperthermic Lithic Ustorthents
14	A1d	Alluvial plain	0-1	Dark red and brown, bold checker board pattern	Khandala-4	Shallow, moderately well drained, dark yellowish brown (10 yr 3/4 m) clay soils with moderate erosion	Clayey, smectitic, hyperthermic Typic Haplustepts
15	V1d	Valley	0-1	Dark red and brown, bold checker board pattern	Khandala-5	Deep, moderately well drained, very dark gray (10 yr 3/4 m) very-fine soils with moderate erosion	Very-fine, smectitic, hyperthermic (calcareous) Typic Haplusterts

Table: 2
Physical properties of soils of Khandala village, Nagpur

Horizon	Depth (cm) (mm) (%)	Sand 2-0.05 (mm) (%)	Silt 0.05-0.002 (mm) (%)	Clay <0.002 (Mgm-3)	BD
Khandala-1					
A	0-7	26.5	32.9	40.6	1.71
Khandala-2					
A	0-9	50.1	34.0	15.9	1.44
Khandala-3					
Ap	0-20	50.1	12.7	37.2	1.64
Khandala-4					
Ap	0-15	11.0	39.4	49.6	1.74
Bw	15-39	4.8	33.0	62.2	1.69
Khandala-5					
Ap	0-18	5.9	27.2	60.9	1.80
Bw	18-46	4.4	28.4	62.7	1.82
Bss1	46-74	5.7	27.4	66.9	1.93
Bss2	74-111	6.8	30.5	66.9	1.86
Bss3	111-150	5.9	30.2	67.2	1.84

Exchangeable magnesium of the surface soils ranged from 2.9 to 19.7 cmol(p$^+$)kg^{-1}. Exchangeable sodium ranged from 0.02 to 0.41 cmol(p+)kg^{-1}, while, exchangeable potassium varied from 0.01 to 0.03 cmol(p$^+$)kg^{-1}. CEC of surface soils ranged from 8.9 to 59.5 cmol(p$^+$)kg^{-1} and it was higher in soils of Khandala-4 (alluvial plain) followed by Khandala-5 (valley), Khandala-1 (plateau), Khandala-2 (escarpment) and Khandala-3 (pediment) (Table 3).

Soil Fertility

The available nitrogen content in surface soils ranged from 197.1 to 250.8 kg ha^{-1}. The available phosphorus content of the surface soils varied from 1.01 (Khandala-1 series) to 12.4 kg ha^{-1} (Khandala-5 series). Available potassium content in the surface soils varied from 74.0 kg ha^{-1} to 392.7 kg ha^{-1} (Table 3). Similar results were also reported by Ardak *et al.* (2010) in soil of basaltic terrain of Nagpur district.

The DTPA- extractable Fe, Mn, Cu and Zn of the soils (Table 3) indicated that the DTPA- Fe ranged from 5.9 to 46.3 mg kg^{-1} a gains the critical value of 4.5 mg kg^{-1} (Lindsay and Norvell, 1978). The DTPA-Mn ranged from 1.8 to 24.8 mg kg^{-1} against the critical limit 3.0 mg kg^{-1} (Takkar *et al.*, 1989). DTPA-Cu varied from 3.0 to 10.8 mg kg^{-1}and it was higher than the critical limit of 0.2 mg kg^{-1} (Katyal and Randhawa, 1983). The DTPA-Zn ranged from 0.2 to 0.8 mg kg^{-1} and was deficient as per the critical level of 0.6 mg kg^{-1} (Katyal and Randhava, 1983) barring soils of Khandala-1 and Khandala-5 series.

Soil Productivity

Different soil series evaluated for soil productivity (Table 4) indicated that Khandala-5 series are good in productivity with moderate limitations of soil drainage. The productivity of Khandala-1 soil is poor due to severe limitation of soil moisture and effective depth. The soils of Khandala-2 series are extremely poor in productivity with very severe limitation of soil depth, soil moisture and organic matter, while, soils of Khandala-3 and Khandala-4 are average in productivity.

Land Capability, Land Irrigability, and Soil Suitability for Crops

The soils were grouped under five land capability subclasses (Table 5; Fig. 4a). Land type IId are good cultivable lands with minor problem of drainage (12.9% of TGA), IIIs are moderately good cultivable lands with moderate limitation of soil depth (12.5% of TGA), IVs are moderately good cultivable lands with moderate problem of depth (29.4% of TGA), VIes are non-arable lands as these lands occur on moderately to strongly sloping lands with shallow soils and well suited for grazing and forestry(33.8% of TGA) and VIs are non-arable lands due to extremely shallow depth (9.2% of TGA). The lands rated under 2sd land irritability subclass possessed moderate limitation of soil texture and drainage for sustainable use under irrigation (12.5% of TGA), while, 2s type lands are associated with moderate limitation of soil depth (12.8% of TGA). Land grouped as 3t had severe limitation of topography (29.4% of TGA), while, 4s land were marginally suitable owing to very severe limitation of soil depth (0.5% of TGA) (Table 5; Fig. 4b).

The suitability evaluation for major crops *viz*., cotton, pigeonpea, soybean and gram of the village (Table 5; Fig. 5) indicated that the soils of Khandala-1 and Khandala-2 are not suitable for growing cotton, pigeonpea, gram and soybean. The soils of Khandala-3 are marginally suitable for cotton, pigeonpea and gram but not suitable for growing soybean. The soils of Khandala-4 are marginally suitable for cotton, pigeonpea, soybean and gram. The soils Khandala-5 are highly suitable for growing cotton, pigeonpea, soybean and gram.

Land Resources Management

The integration of landforms, soil, present land use and

Table: 3
Chemical properties and fertility of soils of Khandala village, Nagpur

Horizon	Depth (cm)	pH (1:2)	EC (dS m^{-1})	OC (g kg^{-1})	$CaCO_3$ (%)	Exchangeable cations Ca^{++}	Mg^{++}	Na^{+}	K^{+} cmol (p^{+}) kg^{-1}	Sum of cations	CEC	BS (%)	Available nutrients N	P (kg ha^{-1})	K	Fe	Mn	Zn (mg kg^{-1})	Cu
Khandala-1																			
A	0-7	6.1	0.08	17.7	8.9	25.5	19.7	0.14	0.01	45.4	42.7	106.2	232.9	1.01	89.6	46.3	1.8	0.8	10.8
Khandala-2																			
A	0-9	6.7	0.06	8.0	5.7	4.8	2.9	0.19	0.03	8.0	8.9	88.8	197.1	2.57	6.2	30.2	12.3	0.5	4.4
Khandala-3																			
Ap	0-20	6.7	0.05	6.2	6.7	23.6	7.9	0.16	0.01	31.6	32.4	97.5	215.0	2.57	22.4	20.0	24.8	0.4	3.0
Khandala-4																			
Ap	0-15	7.8	0.12	9.0	6.9	47.3	8.8	0.21	0.02	56.3	55.1	102.2	232.9	3.02	89.6	5.9	9.7	0.3	1.7
Bw	15-39	7.9	0.12	8.5	4.7	38.9	18.3	0.17	0.01	57.4	59.5	96.5	197.1	1.01	89.6	7.5	8.5	0.2	2.4
Khandala-5																			
Ap	0-18	7.5	0.15	11.1	4.5	49.6	9.6	0.02	0.01	59.2	58.6	101.0	250.8	12.4	179.2	9.3	13.7	0.6	5.3
Bw	18-46	7.7	0.12	7.5	6.4	44.7	11.9	0.02	0.01	56.6	57.3	98.8	250.8	5.3	100.8	11.8	12.2	0.7	5.4
Bss1	46-74	8.0	0.14	5.6	9.1	42.1	12.7	0.10	0.01	54.9	54.2	101.3	197.1	5.6	134.4	14.5	11.5	0.5	6.6
Bss2	74-111	8.2	0.27	9.6	13.8	46.5	13.6	0.41	0.01	60.6	58.9	102.8	161.2	3.2	89.6	12.8	10.0	0.5	6.2
Bss3	111-136	8.5	0.48	8.8	13.8	45.1	5.6	0.28	0.01	51.7	53.1	97.4	125.4	4.6	67.2	9.0	7.5	0.4	6.1

slope maps under GIS environment has brought out the fifteen composite land units which lead to identify the areas for resource development and conservation. Suitable interventions, namely, agri-horticulture, agro-forestry, silvipasture and intensive cultivation have been suggested in different composite land units. The plateau representing 6.8% of area with very shallow soils supporting single crop soybean and moderately dense and degraded forest (Khandala-1) without any soil and water conservation measures. To improve the productivity of 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 (Preeti-Solanke *et al.*, 2005). Afforestation needs to be undertaken in forest areas with suitable tree species and moderately sloping and moderately steeply sloping escarpments representing 14.3% of the area with very shallow soils (Khandala-2) with severe soil erosion may be brought under agroforestry and silvipasture systems (Sagar-Ingle *et al.,* 2019). To reduce the run-off and to conserve soil and water, contour vegetative bunds and continuous contour trenches are recommended (Rashmi-Bante *et al*., 2012). Pediments constitute 51.4% of the village mainly under single crop, wasteland and double crop. The shallow to very shallow soils under rainfed cultivation (Khandala-3) are suggested for agri-horticulture systems. Proper field bunding, gully plugging and contour bunding is needed to conserve soil and water (Swapnil-Pachpor *et al*., 2012). Silvipasture systems may be adopted to improve the productivity in wastelands. Controlled grazing is required in these land units. In alluvial plain (Khandala-4) constituting 12.6% of TGA, the soils are moderately shallow, clayey with average soil productivity. The productivity of these soils may be improved with suitable agro-interventions such as crop rotation including legumes, mixed cropping and vegetable cultivation (Swapnil-Pachpor *et al*., 2012). The deep, clay soils of valley (Khandala-5) covering 12.9% with good productivity may be put under intensive cultivation involving rotation with legumes, mixed cropping, vegetable cultivation and adoption of broad bed and furrow for irrigation.

4. CONCLUSIONS

The terrain information in terms of landforms, LU/LC and slope of the study area has been generated and used for characterization and evaluation of soils. Five soil series (Khandala-1, Khandala-2, Khandala-3, Khandala-4, and Khandala-5) were identified, characterized in terms of their morphological, physical and chemical properties and evaluated. The study area has fairly good to good cultivable lands and moderate to very severe limitations for sustained use under irrigation. The soil-site suitability evaluation indicated that soils of plateau, escarpments and pediments are marginally suitable to not suitable with severe soil limitations; soils of valley are marginally suitable, whereas,

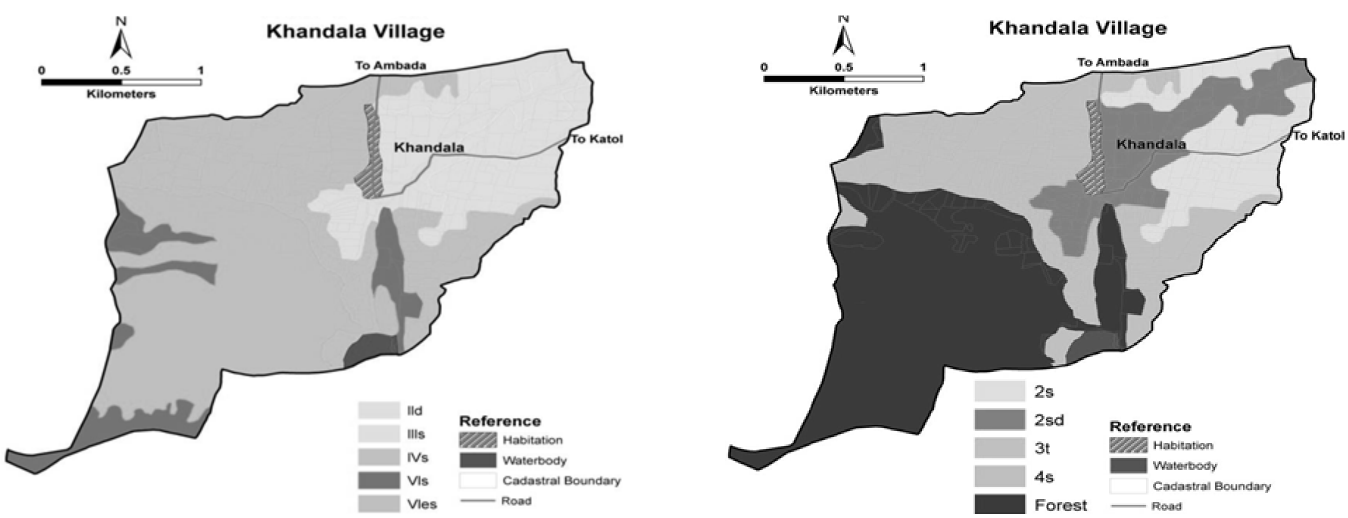
Table: 4
Productivity index and productivity class of soils of Khandala village, Nagpur

Soil series	Soil moisture	Drainage	Effective soil depth	Texture/ Structure	Soluble salts	Organic matter	Nature of clay	Mineral reserve	Productivity index	Productivity classes
	H	D	P	T	S	O	A	M		
Khandala-1	H2c (40)	P2 (20)	D3a (90)	T5b (100)	S1 (100)	O3 (100)	A3 (100)	M3c (100)	7.2	Poor
Khandala-2	H2c (40)	P2 (20)	D3a (90)	T6b (90)	S1 (100)	O2 (90)	A1 (90)	M3c (100)	5.2	Extremely poor
Khandala-3	H3b (60)	P3 (50)	D3a (90)	T6b (90)	S1 (100)	O2 (90)	A2 (95)	M3c (100)	24.3	Average
Khandala-4	H3b (60)	P3 (50)	D3a (90)	T6b (90)	S1 (100)	O2 (90)	A3 (100)	M3c (100)	21.8	Average
Khandala-5	H3c (70)	P6 (100)	D4 (100)	T5b (80)	S1 (100)	O2 (90)	A3 (100)	M3c (100)	50.4	Good

Table: 5
Land capability, land irrigability and soil suitability for different crops in Khandala village, Nagpur

Soils	Land capability	Land irrigability	Cotton	Pigeonpea	Soybean	Gram	Wheat
Khandala - 1	VIs	4s	N1	N1	N1	N1	N1
Khandala - 2	VIes	4s	N1	N1	N1	N1	N1
Khandala - 3	IVs	3t	S3	S3	N1	S3	S3
Khandala - 4	IIIs	2s	S2	S3	S3	S3	S1
Khandala - 5	IId	2sd	S1	S1	S1	S1	S1

Note:- s: soil, e: erosion, d: drainage, t: topography; S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable, N1: Temporarily not suitable



(a) **(b)**

Fig. 4. Maps of a) land capability and b) land irrigability

soils of valley with deep fine clayey soils are highly suitable for growing cotton, pigeonpea, soybean and gram. Various interventions and soil and water conservation measures have been suggested for better management of land resources in Khandala village of Nagpur district of Maharashtra.

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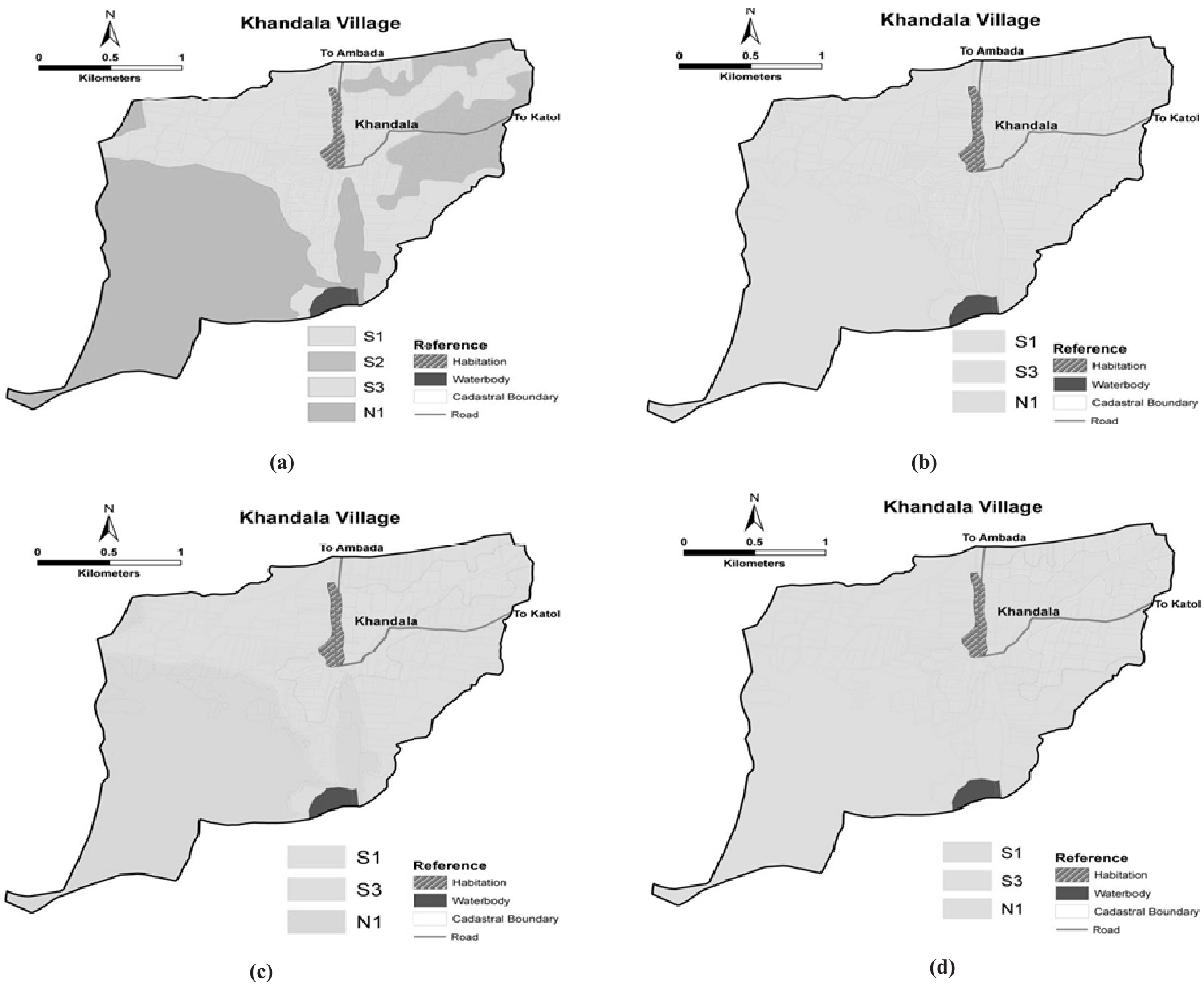

Fig. 5. Suitability of soils for a) cotton, b) pigeonpea, c) gram and d) soybean

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