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A comprehensive methodology for developing block-level land resource inventory using geospatial techniques: A case study of Jhagadia Taluka, Bharuch district, Gujarat

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ABSTRACT

Land Resource Inventory (LRI) at large scale provides a scientific basis for site-specific land use planning and sustainable agricultural development. The present study was undertaken in Jhagadia taluka of Bharuch district, Gujarat, to generate a detailed LRI at 1:10,000 scale using geospatial techniques. High-resolution satellite data (IRS-P6 LISS-IV and Cartosat-1 DEM) were integrated with terrain analysis to delineate landforms, slope classes, land use/land cover, and Landscape Ecological Units (LEUs). A total of 30 LEUs were identified and used as base units for soil survey. Detailed field investigations involving 100 soil profiles were carried out for soil characterization and classification as per Soil Taxonomy.

The soils of the study area exhibited significant variability across landforms, ranging from very deep, fine-textured, high water-holding capacity soils in alluvial plains to shallow, erosion-prone soils in pediments. Major soil series identified include Jarsad, Motipura, Haripara, Moretalab, Shir, Amalzar, Tavdi, and Kadwali. Land capability classification revealed that a major portion of the area falls under Class II (53.5%), followed by Class III (11.7%) and Class IV (8.7%). Irrigability classification indicated that about 43.6% of the area has moderate limitations, while 30.1% has severe limitations for sustained irrigation.

Crop suitability evaluation showed that 43.9% of the area is highly suitable for sugarcane, whereas cotton is predominantly moderately (31.2%) to marginally suitable (28.2%). The study highlights that integration of geospatial tools with soil survey significantly enhances the precision of soil mapping and provides a robust framework for land capability assessment and crop suitability evaluation. The generated LRI database can serve as a valuable input for site-specific land use planning, resource optimization, and sustainable agricultural management.

Keywords: Land resource inventory, Geospatial techniques, Landscape ecological units, Land capability classification, Land irrigability

INTRODUCTION

Land resources form the foundation of agricultural production, ecosystem sustainability, and livelihood security. However, increasing population pressure, land degradation, and competing land uses necessitate scientific assessment and sustainable management of land resources. In this context, Land Resource Inventory (LRI) plays a crucial role in generating spatially explicit information on soils, terrain, and land resources for sustainable land management (FAO, 1976; FAO, 2007).

Land resource inventory involves systematic collection, analysis, and interpretation of soil and land-related data to delineate land units and evaluate their suitability for different uses. It integrates soil survey, terrain analysis, hydrology, and land use information to support land evaluation and planning. FAO guidelines emphasize that LRI combines field observations with spatial datasets to develop a comprehensive understanding of land characteristics and their variability (FAO, 1976; FAO, 1990). Soil survey, as a fundamental component of LRI, provides essential information on soil morphology, classification, and behavior, which are critical for predicting land performance under various management practices (Soil Survey Staff, 2000).

Conventional soil survey methods, although reliable, are often labor-intensive and time-consuming. The integration of geospatial technologies, including Remote Sensing (RS), Geographic Information Systems (GIS), and Global Positioning Systems (GPS), has significantly enhanced the efficiency, accuracy, and spatial coverage of land resource assessment (Obi Reddy and Singh, 2018). High-resolution satellite data, combined with cadastral maps and field validation, have enabled large-scale soil mapping and detailed LRI at micro-level planning scales.

Recent advances in digital soil mapping and geospatial modelling have further improved the precision and applicability of LRI. These approaches integrate terrain attributes, remote sensing data, and legacy soil information to produce high-resolution spatial databases for sustainable land management (Hengl and MacMillan, 2019). Furthermore, recent studies highlight the importance of geospatial tools and modelling approaches in improving soil quality assessment and supporting climate-resilient agriculture (Singh *et al.,* 2022; Sharma *et al.,* 2025).

In India, ICAR-NBSS&LUP has implemented LRI at 1:10,000 scale, which is highly suitable for block- and watershed-level planning. Detailed LRI provides critical inputs for land capability classification, crop suitability evaluation, and site-specific management practices (Choudhury *et al.,* 2018). A pioneering study by Sharma *et al.,* (2018) on Pata Meghpar village in Jamnagar district, Gujarat, demonstrated the effectiveness of integrating high-resolution satellite data (IRS LISS-IV), cadastral maps, and field observations for developing village-level LRI. The study successfully delineated landscape ecological units (LEUs) and soil mapping units, highlighting the utility of geospatial techniques for precise soil resource characterization and land use planning. Such studies promoted the LRI as a foundational database for micro-level agricultural planning and sustainable resource management.

Jhagadia Taluka of Bharuch district in Gujarat is characterized by diverse geomorphology, alluvial landscapes, and intensive agricultural practices. Despite its agricultural importance, detailed block-level land resource information is limited, which constrains scientific land use planning and resource optimization. Therefore, the present study aims to develop a block-level Land Resource Inventory using geospatial technique to generate high-resolution spatial information on soil and land characteristics. The findings of this study are expected to support sustainable land use planning, crop suitability assessment, and efficient natural resource management in the region.

MATERIALS AND METHODS

Location and Extent of study area

Jhagadia taluka, the focus of the present study, is an agriculturally and industrially important region known for banana cultivation as well as mineral resources such as lignite, bauxite, and silica sand. Geographically, it is situated between 21°34′44″ to 21°46′07″ N latitude and 73°03′49″ to 73°23′46″ E longitude in Bharuch district, Gujarat (Fig.1). The elevation of the area ranges up to 414 m above mean sea level (MSL). The taluka covers an area of 61,003 ha, representing about 9.37% of the total geographical area of Bharuch district. It comprises 167 villages with a total population of approximately 1.85 lakh as per the 2011 Census.

Geology

The geology of Jhagadia taluka is characterized by the Jhagadia Formation, consisting predominantly of light-coloured sandstone, marl, limestone, and conglomerate. The region is mainly underlain by Quaternary alluvium, forming part of the extensive Gujarat alluvial plains. This basin developed due to differential basement topography associated with the reactivation of Tertiary faults, bounded by the Satpura highlands in the east and the Aravalli ranges in the north (Merh, 1995).

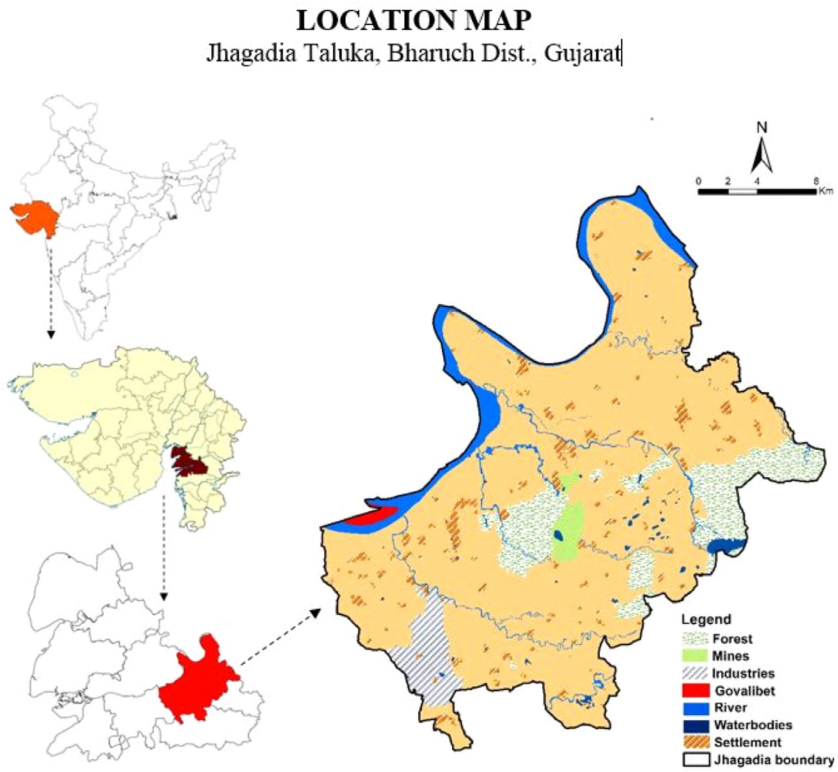

Fig. 1. Location map of Jhagadia block

The alluvial deposits of the study area are primarily derived from basaltic parent material originating from the Amarkantak plateau (Anuppur district, Madhya Pradesh) and transported by the Narmada river system. These deposits consist of a thick sequence of unconsolidated sediments laid down through fluvial and aeolian processes during the Quaternary period. Mineralogical studies indicate the dominance of smectitic clay minerals along with illite, kaolinite, and mixed-layer minerals, reflecting the strong influence of Deccan basalt and contributions from diverse lithological sources, which in turn control soil genesis, shrink–swell behaviour, cation exchange capacity, and nutrient dynamics (Sharma *et al.,* 2022). Variations in sediment thickness suggest the presence of structural features such as horsts and grabens, while the surface topography ranges from nearly level alluvial plains to undulating and hilly terrains with a general slope from northeast to southwest, significantly influencing soil formation, drainage, and land use suitability in Jhagadia taluka.

Climate

The climate of the study area is semi-arid, characterized by hot and humid summers and mild, dry winters. The mean annual temperature is 27.9 °C, with average summer and winter temperatures of 31.1 °C and 23.3 °C, respectively. April and May are the hottest months, recording mean daily maximum temperatures of 39–40 °C, while January is the coldest month with a mean daily minimum temperature of 12.7 °C. The area receives an average annual rainfall of about 873 mm, predominantly from the southwest (SW) monsoon. The length of growing period (LGP) ranges from 90 to 120 days. Agro-ecologically, the region falls under AESR 5.2, classified as a hot semi-arid ecoregion with medium and deep black soils, characterized by ustic soil moisture and hyperthermic soil temperature regimes (Velayutham *et al.,* 1999).

Soil Survey Methodology and Interpretations

A detailed soil survey of the study area was conducted using a base map at 1:10,000 scale, prepared from Indian Remote Sensing (IRS-P6 LISS IV and Cartosat-1) satellite data along with Digital Elevation Model (DEM) data. Landform analysis was carried out using elevation information, and thematic layers such as landform, slope, and land use/land cover were integrated in a GIS environment (ArcGIS) to delineate Landscape Ecological Units

(LEUs) (Sharma *et al.,* 2020). These LEUs, being relatively homogeneous in terms of soil-forming factors and predictive of soil characteristics, served as the base for field verification.

A total of 100 soil profiles were exposed across the study area to capture spatial variability and were examined for morphological characteristics following standard procedures (Soil Survey Division Staff, 2000). The soils were classified according to Soil Taxonomy (Soil Survey Staff, 2014). Based on field correlation and variability in soil phases, 22 representative master profiles were selected and described in detail for site and soil characteristics such as slope, erosion, colour, texture, and structure, following standard soil survey protocols.

The soil legend codes were developed to represent the soil series along with surface texture, slope, erosion, and stoniness following standard procedures (IARI, 1971). Soil samples collected from representative pedons were analyzed for various physical and chemical properties using standard analytical methods (Black, 1965; Jackson, 1973). Based on their characteristics, the soils were classified into different land capability sub-classes (Klingebiel and Montgomery, 1961) and land irrigability sub-classes (IARI, 1971). Soil-site suitability for major crops was evaluated using the FAO framework for land evaluation (FAO, 1976), as modified by Sys *et al.,* (1991). The crop-specific soil-site requirements suggested by Naidu *et al.,* (2006) were used to assess the suitability of different soil mapping units.

RESULTS AND DISCUSSION

Land Use/Land Cover

Based on IRS-P6 LISS-IV satellite data (November 2015 and May 2016), nine land use/ land cover classes were delineated in the study area. The analysis (Fig. 2) reveals that agriculture is the dominant land use, occupying about 65.9% of the total geographical area (TGA), of which 36.7% is under single cropping and 29.2% under double cropping. Forests cover 10.1% of the area, followed by wastelands (6.6%) and industrial land (3.5%). Other land use categories include pastureland (1.4%), mining areas (1.3%), and *Govali bet* (0.4%), while miscellaneous uses such as habitation, water bodies, and river channels account for 10.8% of the area. Overall, single-cropped areas constitute the largest share, indicating scope for agricultural intensification and improved land management practices in Jhagadia block.

Landform Delineation

Visual interpretation of IRS-P6 LISS-IV satellite data enabled the delineation of major landforms in the study area, namely lower alluvial plain, middle alluvial plain, upper alluvial plain, lower pediment, and upper pediment. These landforms were further sub-divided based on slope, land use, and other terrain characteristics. Based on slope, three categories were identified: very gently sloping plains, gently sloping plains, and moderately sloping plains.

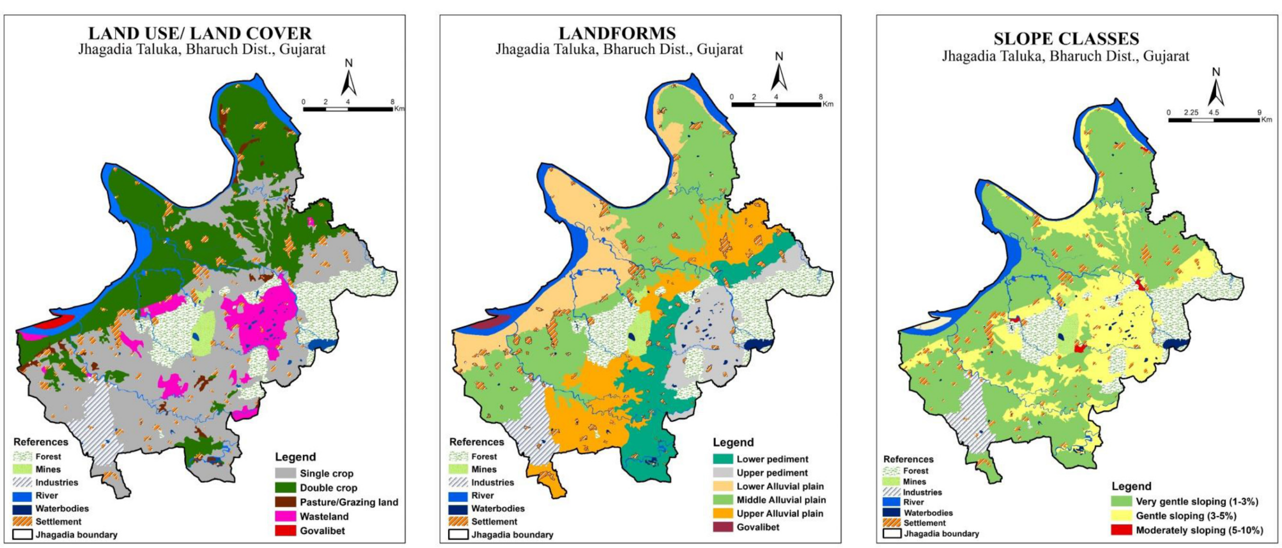

Fig. 2. Present land use/land cover map, Landform map and Slope map of Jhagadia block

The middle alluvial plain occupies the largest area (26.1%), followed by upper alluvial plain (15.5%), lower alluvial plain (13.4%), lower pediment (10.9%), and upper pediment (8.1%). The remaining 26.1% of the area is under miscellaneous land uses, including *Govali bet* (0.4%) (Fig.2).

The dominance of alluvial plains indicates a favorable geomorphic setting for agriculture, as these areas are generally associated with deep, well-developed soils having better moisture retention and fertility status. In contrast, pediment regions, particularly upper pediments, are characterized by shallow soils, higher slopes, and erosion susceptibility, thereby imposing limitations on intensive cultivation. The variation in slope and landform significantly influences soil formation, drainage conditions, and land capability, ultimately governing land use patterns and crop suitability across Jhagadia block.

Slope

Slope is a key terrain attribute influencing soil formation, erosion, surface runoff, and moisture availability, thereby governing land use and management practices. In the study area, three slope classes were identified and mapped (Fig. 2), namely very gently sloping (1–3%), gently sloping (3–5%), and moderately sloping (5–10%) lands.

The very gently sloping class (1–3%) occupies the largest area of 29,869 ha, accounting for 49.0% of the total geographical area (TGA) of the block. This is followed by gently sloping lands (3–5%), covering 15,019 ha (24.6%), while moderately sloping lands occupy only 167 ha (0.3%) of the TGA.

The predominance of very gently sloping terrain indicates favorable conditions for agriculture due to reduced runoff, minimal erosion risk, and better moisture retention, supporting higher land capability and crop suitability. In contrast, gently to moderately sloping areas are more prone to runoff and soil erosion, which may limit soil depth and fertility, thereby restricting their suitability for intensive cultivation and necessitating appropriate soil and water conservation measures.

Landscape Ecological Units (LEU)

The landform, slope, and land use/land cover maps were integrated in a GIS environment (ArcGIS) to generate the Landscape Ecological Unit (LEU) map. Based on this integration, a total of 30 LEUs were delineated in the study area (Fig. 3). These LEUs represent relatively homogeneous units in terms of terrain, land use, and soil-forming factors, and thus serve as a reliable basis for soil mapping and land evaluation.

On the lower alluvial plain, five LEUs were identified based on two slope classes (1–3% and 3–5%) and four land use/land cover classes (single crop, double crop, wasteland, and grazing land). The middle alluvial plain exhibited the highest diversity with eight LEUs, reflecting variations in similar slope and land use categories. In the upper alluvial plain, five LEUs were delineated, while the lower pediment showed the maximum heterogeneity

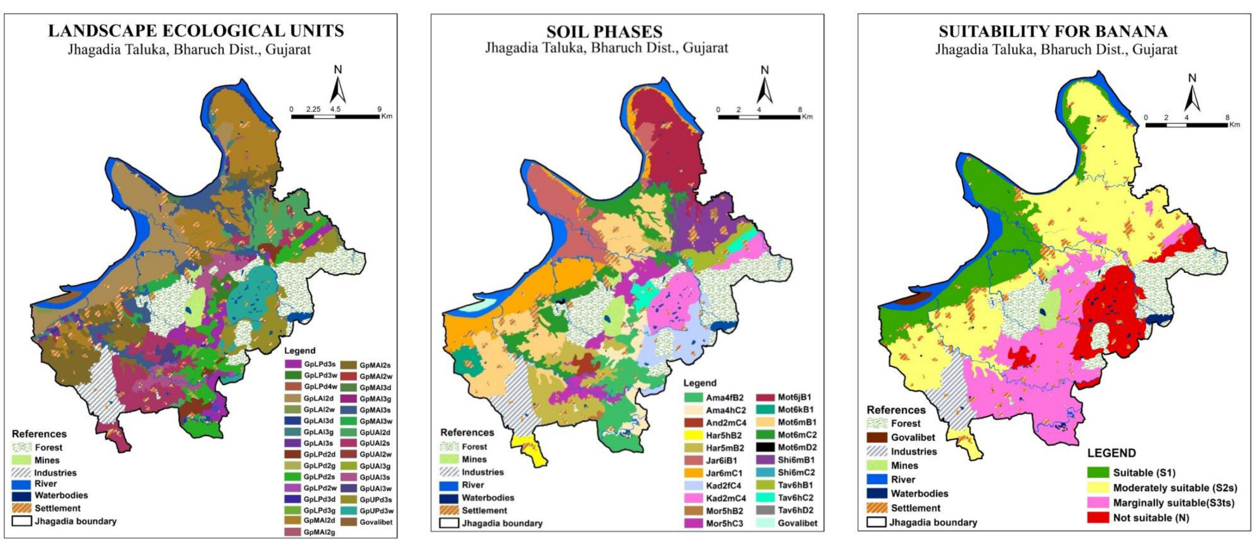

Fig. 3. LEU map, Soil phase map and Soil-site suitability map for banana of Jhagadia block

with nine LEUs due to the inclusion of an additional slope class (5–10%) along with variations in land use. In contrast, only three LEUs were identified in the upper pediment, indicating relatively uniform conditions dominated by limited land use options and moderate slopes.

The higher number of LEUs in alluvial plains and lower pediments reflects greater variability in land use and slope, which in turn influences soil variability and land capability. Conversely, fewer LEUs in upper pediments indicate constrained conditions with limited agricultural suitability. Overall, the LEU-based approach effectively captures spatial heterogeneity and provides a robust framework for detailed soil resource mapping, land capability classification, and crop suitability assessment in Jhagadia block.

Soils of Different Landforms

The study area; Jhagadia block was delineated in five landforms and the soils are classified in nine series with 21 mapping units. Brief description presented in Table 1 and depicted in Figure 3. Soil landform relationship is showed in Figure 4.

Table 1. Brief description of soil series and phases of Jhagadia block

Landform	Soil series	Soil map unit	Mapping legend	Brief description of soil series	Area (ha)	TGA (%)
Lower alluvial plain	Jarsad	6	Jar6kB1	Very deep, imperfectly drained, brown to very dark grayish brown soils on very gentle slope in lower alluvial plain with silty clay surface texture and slight erosion (Fine, mixed, hyperthermic, Typic Haplustepts).	3727.8	6.1
	Jarsad	7	Jar6mC1	Very deep, imperfectly drained, brown to very dark grayish brown soils on gentle slope in lower alluvial plain with clayey surface texture and slight erosion (Fine, mixed, hyperthermic, Typic Haplustepts).	4417.0	7.2
Middle alluvial plain	Motipura	12	Mot6jB1	Very deep, moderately well to well drained, dark grayish brown to very dark grayish brown soils on very gentle slope in middle alluvial plain with silty surface texture and slight erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	4452.5	7.3
	Motipura	13	Mot6kB1	Very deep, moderately well to well drained, dark grayish brown to very dark grayish brown soils on very gentle slope in middle alluvial plain with silty clay surface texture and slight erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	673.1	1.1
	Motipura	14	Mot6mB1	Very deep, moderately well to well drained, dark grayish brown to very dark grayish brown soils on very gentle slope in middle alluvial plain with clayey surface texture and slight erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	6688.7	11.0
	Motipura	15	Mot6mC2	Very deep, moderately well to well drained, dark grayish brown to very dark grayish brown soils on gentle slope in middle alluvial plain with clayey surface texture and moderate erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	4070.2	6.7
	Motipura	16	Mot6mD2	Very deep, moderately well to well drained, dark grayish brown to very dark grayish brown soils on moderate slope in middle alluvial plain with clayey surface texture and moderate erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	29.9	0.1

Contd...

Landform	Soil series	Soil map unit	Mapping legend	Brief description of soil series	Area (ha)	TGA (%)
Upper alluvial plain	Andhar-kachhala	3	And2mC4	Shallow, somewhat excessively drained, dark grayish brown to very dark grayish brown soils on gentle slope in upper alluvial plain with clayey surface texture and very severe erosion (Clayey skeletal, mixed, hyperthermic, Lithic Haplustepts).	366.0	0.6
	Haripara	4	Har5hB2	Deep, well drained, dark brown to very dark grayish brown soils on very gentle slope in upper alluvial plain with sandy clay loam surface texture and moderate erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	493.6	0.8
	Haripara	5	Har5mB2	Deep, well drained, dark brown to very dark grayish brown soils on very gentle slope in upper alluvial plain with clayey surface texture and moderate erosion (Fine, smectitic, hyperthermic, Typic Haplusterts).	3618.9	5.9
	Moretalab	10	Mor5hB2	Deep, moderately well to well drained, dark reddish brown soils on very gentle slope in upper alluvial plain with sandy clay loam surface texture and moderate erosion (Clayey skeletal, mixed, hyperthermic, Vertic Hapludalfs).	152.5	0.2
	Moretalab	11	Mor5hC3	Deep, moderately well to well drained, dark reddish brown soils on gentle slope in upper alluvial plain with sandy clay loam surface texture and severe erosion (Clayey skeletal, mixed, hyperthermic, Vertic Hapludalfs).	2130.0	3.5
	Shir	17	Shi6mB1	Very deep, moderately well drained, very dark grayish brown soils on very gentle slope in upper alluvial plain with clayey surface texture and slight erosion (Fine, mixed, hyperthermic, Vertic Haplustepts).	2649.9	4.3
	Shir	18	Shi6mC2	Very deep, moderately well drained, very dark grayish brown soils on gentle slope in upper alluvial plain with clayey surface texture and moderate erosion (Fine, mixed, hyperthermic, Vertic Haplustepts).	16.4	0.1
Lower pediments	Amalzar	1	Ama4fB2	Moderately deep, moderately well drained, very dark grayish brown soils on very gentle slope in lower pediment with clay loam surface texture and moderate erosion (Fine, mixed, hyperthermic, Vertic Haplustepts).	3217.0	5.3
	Amalzar	2	Ama4hC2	Moderately deep, moderately well drained, very dark grayish brown soils on gentle slope in lower pediment with sandy clay loam surface texture and moderate erosion (Fine, mixed, hyperthermic, Vertic Haplustepts).	1620.7	2.7
	Tavadi	19	Tav6hB1	Very deep, well to somewhat excessively drained, very dark grayish brown soils on very gentle slope in lower pediment with sandy clay loam surface texture and slight erosion (Fine, mixed, hyper-thermic, Typic Haplustepts).	919.0	1.5
	Tavadi	20	Tav6hC2	Very deep, well to somewhat excessively drained, very dark grayish brown soils on gentle slope in lower pediment with sandy clay loam surface texture and moderate erosion (Fine, mixed, hyperthermic, Typic Haplustepts).	820.7	1.3

Contd...

Landform	Soil series	Soil map unit	Mapping legend	Brief description of soil series	Area (ha)	TGA (%)
	Tavadi	21	Tav6hD2	Very deep, well to somewhat excessively drained, very dark grayish brown soils on moderate slope in lower pediment with sandy clay loam surface texture and moderate erosion (Fine, mixed, hyperthermic, Typic Haplustepts).	49.8	0.1
Upper pediments	Kadwali	8	Kad2fC4	Very shallow to shallow, somewhat excessively to excessively drained, dark brown soils on gentle slope in upper pediment with clay loam surface texture and very severe erosion (Loamy, mixed, hyperthermic, Lithic Haplustepts).	2225.1	3.6
	Kadwali	9	Kad2mC4	Very shallow to shallow, somewhat excessively to excessively drained, dark brown soils on gentle slope in upper pediment with clay surface texture and very severe erosion (Loamy, mixed, hyper-thermic, Lithic Haplustepts).	2715.6	4.5
				Total cultivated area	**45054.7**	**73.9**
				Miscellaneous	15948.2	26.1
				Total area	**61003**	**100**

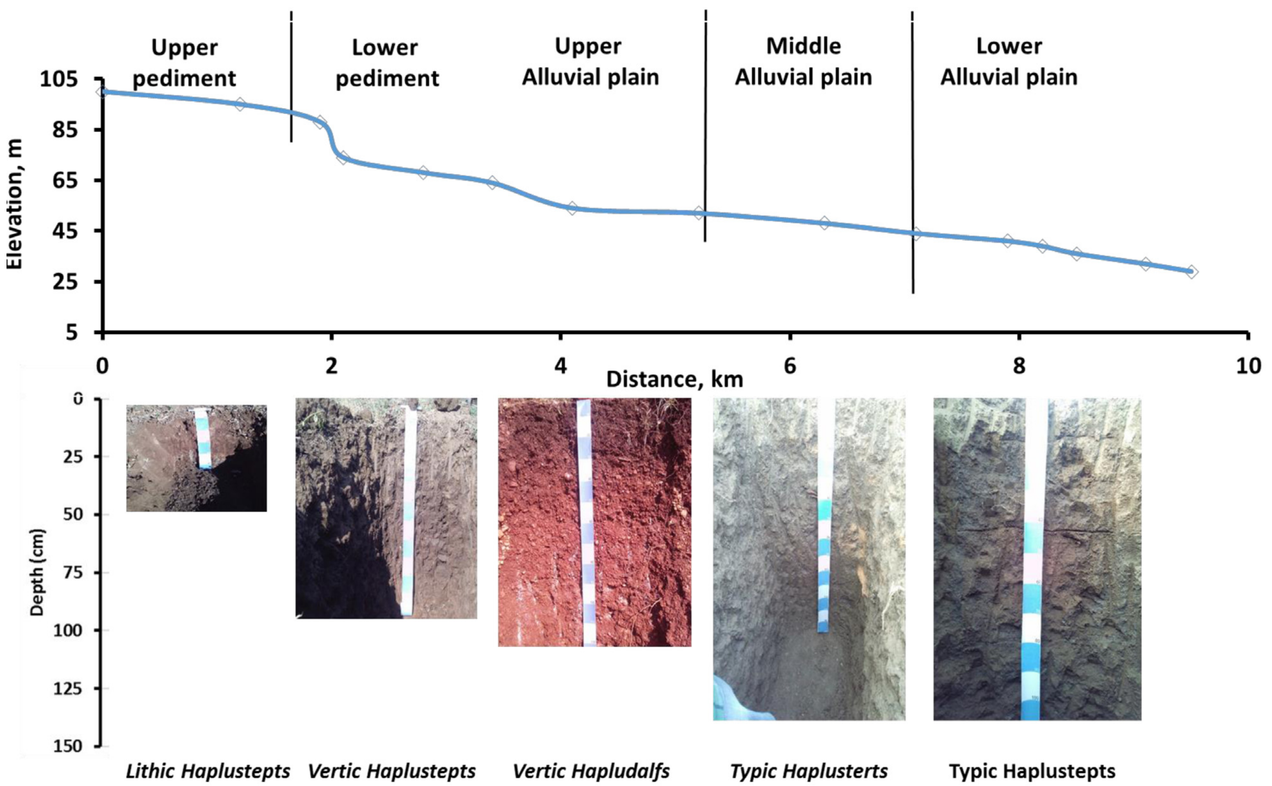

Fig. 4. Soil –landform relationship diagram of Jhagadia block (AESR 5.2)

Soils of Lower Alluvial Plain

The soils of the lower alluvial plain are represented by the Jarsad series, which are very deep, imperfectly drained, brown to very dark grayish brown soils occurring on very gentle to gentle slopes with sandy clay to clay surface texture and slight erosion. These soils are classified as *Fine, mixed, hyperthermic, Typic Haplustepts*. They are moderately alkaline with high base status, moderately slow permeability, and very high water holding capacity

(>200 mm/m), resulting in high nutrient reserves. These favorable properties support intensive agriculture, and the soils are predominantly under double cropping systems such as banana, sugarcane, and maize. The lower alluvial plain exhibits high productivity potential and is represented by soil mapping units 6 and 7, covering 8,145 ha (13.4% TGA).

Soils of Middle Alluvial Plain

The middle alluvial plain is dominated by the Motipura series, characterized by very deep, moderately well to well-drained, dark grayish brown to very dark grayish brown soils with silty to clayey surface textures and slight to moderate erosion. These soils belong to *Fine, smectitic, hyperthermic, Typic Haplusterts*. They are moderately alkaline with high base status, moderately slow permeability, and high water holding capacity (150–200 mm/m). The dominance of smectitic clay imparts shrink–swell properties, enhancing moisture retention and nutrient availability. These soils support double cropping systems such as banana, sugarcane, cotton, and pigeon pea, indicating high productivity potential. Soil mapping units 12–16 represent this landform, covering 15,915 ha (26.1% TGA).

Soils of Upper Alluvial Plain

The upper alluvial plain exhibits considerable soil variability and is represented by Andharkachhala, Haripara, Moretalab, and Shir series due to variations in slope, erosion, parent material, and depositional history.

Andharkachhala soils are shallow, somewhat excessively drained, and severely eroded with clayey skeletal texture, classified as *Lithic Haplustepts*, having low water holding capacity (50–100 mm/m) and low productivity potential, mostly under grazing or single cropping.

Haripara soils are deep, well-drained *Typic Haplusterts* with moderate water holding capacity (100–150 mm/m) and high base saturation, supporting crops such as pigeon pea, sorghum, cotton, and maize, indicating high productivity potential.

Moretalab soils are deep, moderately well-drained *Vertic Hapludalfs* with sandy clay loam texture and moderate to severe erosion. These soils are slightly acidic to neutral with moderate water holding capacity (100–150 mm/m), supporting single cropping and grassland, reflecting moderate productivity.

Shir soils are very deep, moderately well-drained *Vertic Haplustepts* with clayey texture, high water holding capacity (150–200 mm/m), and high base status, supporting double cropping systems such as sugarcane, banana, and maize, indicating high productivity.

The variability in soils of this landform is attributed to pedogenic processes such as translocation, transformation, addition, and losses of soil constituents. Soil mapping units 3, 4, 5, 10, 11, 17, and 18 represent this landform, covering 9,427 ha (15.5% TGA).

Soils of Lower Pediments

The soils of lower pediments are represented by Amalzar and Tavdi series. Amalzar soils are moderately to slightly deep, moderately well-drained *Vertic Haplustepts* with clay loam to sandy clay loam texture and moderate erosion. These soils are neutral to moderately alkaline, with high water holding capacity (150–200 mm/m) and moderate productivity, supporting crops like pigeon pea, cotton, and sorghum.

Tavdi soils are very deep, well to somewhat excessively drained *Typic Haplustepts* with sandy clay loam texture, moderate permeability, and medium water holding capacity (100–150 mm/m). These soils have high base status and support similar cropping systems under single cropping, with relatively higher productivity potential compared to Amalzar soils.

Soil mapping units 1, 2, 19, 20, and 21 represent this landform, covering 6,627 ha (10.9% TGA).

Soils of Upper Pediments

The upper pediments are characterized by Kadwali series, comprising very shallow to shallow, excessively drained soils with clay to clay loam texture and severe erosion. These soils are classified as *Loamy, mixed, hyperthermic, Lithic Haplustepts*. They are slightly acidic with moderate base saturation, low water holding capacity (<50 mm/m), and poor nutrient reserves, resulting in low productivity potential. These soils are mainly used for single cropping (sorghum, bajra fodder) or remain under marginal use. Soil mapping units 8 and 9 represent this landform, covering 4,941 ha (8.1% TGA).

Land Capability Classification

Land capability classification (LCC) is an interpretative system that groups soils based on their suitability for sustained agricultural use and highlights inherent limitations and management requirements. The system classifies land into eight classes (I–VIII), where Classes I to IV are suitable for cultivation with varying degrees of limitations, while Classes V to VIII are generally unsuitable for arable farming and are recommended for alternate uses such as pasture, forestry, and conservation (Klingebiel and Montgomery, 1961). Subclasses indicate the type of limitations, including erosion (e), wetness (w), soil constraints (s), and climate (c).

In Jhagadia block, soils were grouped into three capability classes—II, III, and IV—reflecting varying degrees of limitations related to soil properties, erosion, and drainage. Class II is the dominant class, covering 53.5% of the total geographical area (TGA), with slight limitations and suitable for a wide range of crops under proper management. Class III occupies 11.7% of the area and is characterized by moderate limitations requiring careful soil and water management. Class IV covers 8.7% of the area, with severe limitations such as shallow depth, erosion, and low available water capacity, restricting its use to limited or occasional cultivation.

Overall, the LCC results indicate that a major portion of the study area is suitable for agriculture with appropriate management practices, while areas with higher limitations require conservation measures and alternative land use planning. The classification reflects the combined influence of soil characteristics, terrain, and climate on land use suitability.

Land Irrigability Classification

Land irrigability classification evaluates the suitability of soils for sustained irrigation based on limitations such as topography, soil characteristics, and drainage. In the study area, irrigability subclasses 2 to 4 were identified, indicating moderate to very severe limitations.

Class 2 lands, covering the largest area (43.6% TGA), have moderate limitations due to topography and drainage (subclasses 2t and 2td) and are suitable for irrigation with proper management practices such as land leveling and drainage improvement. Class 3 lands occupy 30.1% of the area and are characterized by severe limitations related to topography, soil, and drainage (subclasses 3t, 3st, and 3td), requiring careful water management and soil conservation measures for sustainable irrigation. Class 4 lands constitute a negligible area (0.2% TGA) and are marginal for irrigation due to very severe soil and topographic limitations.

Overall, the irrigability classification indicates that a substantial portion of the cultivated area can be brought under irrigation with appropriate management interventions, while areas with severe limitations require cautious use or alternative land use practices to prevent land degradation.

Suitability for Crops

Soil Suitability for Sugarcane (Saccharum officinarum L.)

Sugarcane is an important cash crop requiring deep, well-drained soils with good moisture retention, moderate texture, and near-neutral pH for optimum growth. It performs best under warm climatic conditions with adequate moisture availability and is sensitive to constraints such as shallow depth, poor drainage, salinity, and adverse topography (FAO, 1976, Sys *et al.,* 1991).

The suitability evaluation of soils in Jhagadia block indicates that they range from highly suitable to not suitable for sugarcane cultivation. A major portion of the area (43.9% of TGA; 26,800 ha) falls under the highly suitable (S1) class, mainly comprising deep, fine-textured soils with good water holding capacity and favorable drainage conditions. Moderately suitable (S2) soils occupy 8.2% (4,977 ha) and are constrained by moderate limitations such as soil properties and topography. Marginally suitable (S3) soils account for 13.1% (7,971 ha), where limitations such as erosion, slope, and moderate soil constraints reduce productivity. About 8.7% (5,307 ha) of the area is not suitable (N) due to severe limitations of shallow soil depth, stoniness, and unfavorable topography.

The spatial distribution of suitability classes indicates that lower and middle alluvial plains are highly favorable for sugarcane cultivation, whereas pediment regions with shallow and eroded soils are unsuitable. The current prevalence of sugarcane cultivation in the area aligns well with the suitability assessment, suggesting that soil-site conditions are conducive for its expansion in suitable zones with appropriate management practices.

Table 2. Soil suitability for major crops

Phase no.	Soil_phase	Banana	Sugarcane	Cotton	Pigeon pea	Wheat
1	Ama4fB2	S3ts	S3ts	S1	S3ws	S2ws
2	Ama4hC2	S3ts	S3ts	S2wst	S3ws	S2ws
3	And2mC4	N	N	S3ws	N	N
4	Har5hB2	S2s	S2s	S3ws	S2ws	S2ws
5	Har5mB2	S3ts	S1	S2wst	S2ws	S2ws
6	Jar6iB1	S1	S1	S3ws	S3ws	S2ws
7	Jar6mC1	S1	S2s	S2wst	S2ws	S2ws
8	Kad2fC4	N	N	N	N	N
9	Kad2mC4	N	N	N	N	N
10	Mor5hB2	S3ts	S3ts	S3ws	S2ws	S2ws
11	Mor5hC3	S3ts	S3ts	S3ws	S2ws	S2ws
12	Mot6jB1	S2s	S1	S3ws	S2ws	S1
13	Mot6kB1	S2s	S1	S1	S2ws	S2ws
14	Mot6mB1	S2s	S1	S2wst	S2ws	S2ws
15	Mot6mC2	S2s	S1	S3ws	S2ws	S2ws
16	Mot6mD2	S2s	S3ts	S3ws	S2ws	S2ws
17	Shi6mB1	S2s	S1	S2wst	S2ws	S2ws
18	Shi6mC2	S2s	S2s	S2wst	S2ws	S2ws
19	Tav6hB1	S2s	S1	S3ws	S2ws	S1
20	Tav6hC2	S3ts	S3ts	S3ws	S1	S2ws
21	Tav6hD2	S2s	S2s	S3ws	S2ws	S1

Soil Suitability for Cotton (Gossypium sp.)

Cotton is an important commercial fibre crop that thrives well under warm climatic conditions and performs best in deep, well-drained soils with good structure and moderate to high water holding capacity. Fine-textured soils such as loam to clay loam with adequate drainage are considered ideal, whereas limitations such as poor drainage, unfavorable topography, and shallow soil depth adversely affect its productivity (Sys *et al.,* 1991).

The suitability assessment of soils in Jhagadia block indicates considerable variability in cotton suitability. About 6.4% of the total geographical area (TGA) falls under suitable (S1) class, while a significant portion is moderately suitable (S2) covering 31.2% of TGA, constrained by moderate limitations of soil properties, drainage, and topography. Marginally suitable (S3) soils account for 28.2% of the area, where limitations such as erosion, slope, and wetness reduce crop performance. Approximately 8.1% of the area is not suitable (N) due to moderate to severe limitations related to wetness, unfavorable topography, and soil constraints.

The results indicate that cotton cultivation is best suited to moderately well-drained, fine-textured soils of the alluvial plains, whereas pediment regions with shallow depth and higher erosion risk are less suitable. The current limited adoption of cotton in the block reflects these soil constraints, suggesting that its expansion should be restricted to moderately suitable and suitable areas with appropriate soil and water management practices.

Similarly, the soils were evaluated and mapped for suitability for banana, cotton, pigeon pea and wheat crops also. The mapping unit wise suitability is given in Table 2.

CONCLUSIONS

The study demonstrates that large-scale Land Resource Inventory (LRI) using geospatial techniques is an effective approach for capturing soil variability and supporting scientific land use planning. The integration of remote sensing data, terrain analysis, and detailed soil survey enabled precise delineation of Landscape Ecological Units (LEUs), which served as reliable units for soil mapping and interpretation.

The results revealed considerable spatial variability in soils across different landforms, significantly influencing land capability, irrigability, and crop suitability. The dominance of Class II lands indicates good potential for agricultural intensification, whereas areas under Classes III and IV require careful soil and water management practices. Crop suitability analysis showed that crops like sugarcane and banana are well suited to deep alluvial soils, while cotton and other crops exhibit moderate to marginal suitability depending on soil and site constraints.

The study highlights the importance of matching land use with soil capability to enhance productivity and sustainability. The LRI outputs provide a strong scientific basis for developing site-specific land use plans, improving input use efficiency, and minimizing land degradation. Such high-resolution soil resource information is crucial for promoting climate-resilient agriculture and informed decision-making at the block level.

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