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Landscape Analysis for Pedo-Geomorphological Characterization in Part of Basaltic Terrain, Central India Using Remote Sensing and GIS

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ABSTRACT

In the present study, an attempt has been made to analyse IRS-ID LISS-III satellite data in conjunction with field observations for geomorphological mapping and pedo-geomorphological characterisation in Mohgaon area of Nagpur district, Maharashtra. Analysis of satellite data reveals distint geomorphological units viz., plateau top, isolated mounds, linear ridges, escarpments, plateau spurs, subdued plateau, rolling plains, pediments, narrow valleys and main valley floor. Soil profiles, studied on different identified landforms, showed variation in site and morphological charactaristics. Moderate soil erosion occurs on plateau top, isolated mounds, plateau spurs, rolling plains and pediments. Severe erosion was identifed on escarpments and subdued plateau and narrow valleys suffer very slight erosional hazards. Moderately well drained soils were found on rolling plains, pediments, narrow valleys and main valley floor. Well drained soils were noticed on plateau top and plateau spurs. Very shallow soils were found on the plateau top and isolated mounds. Shallow soils are found in linear ridges, escarpments, plateau spurs and rolling plains. Moderately deep and deep soils are found on subdued plateau, pediments and main valley floor. The landform-soil relatioinship reveals that the soils on the plateau top and isolated mounds are very shallow, well drained, clay textured. The soils on the narrow valleys and main valley floor are deep, moderatly well drained, and clayey in texture. It also indicates that landform-soil processes are governed by physiographic position, drainage, slope and erosion conditions of the area. The present study reveals that the analysis of remotely sensed data in conjunction with field observations in GIS will be of immense help in geomorphology mapping, analysis of landform-soil relationships and generation of their geo-spatial database.

Introduction

Reliable information on geomorphology and soil resources of an area with respect to their nature, extent, spatial distribution, potential and limitations is very useful for evaluation and optimal utilization of natural resources on

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sustainable basis. Geomorphological features are manifestations of under laying parent material and the nature and duration of geomorphic processes (Wright, 1993). Geomorphological analysis and mapping allows understaning of the landscape-soil relationship for better land use planning, watershed management and landscape ecological planning (Fairbridge, 1968). Gaikawad *et al.*, (1986) reported that landforms and elevation affect the soil depth, colour, slope, erosion and physico-chemical properties. Soils from different parent materials show variation in depth, colour, texture, structure, consistency, development of diagnostic sub-surface horizons and morphological properties of the soils (Tamgadge and Ghosh, 1991). Landscape configuration features follow a fairly definite soil pattern, which influences soil morphology and physico-chemical properties on the basaltic terrain (Pofali *et al.*, 1979). Dent and Young (1981) explained that development of soils in a toposequence is influenced by given landform, slope, and their processes. Inter-relationship between landform and soils in a defined toposequence is generally studied by establishing pedo-geomorphological relationship (Birkeland, 1990). The analysis of landform-soil relationship, in association with drainage and elevation properties, can be effcetive to understand spatial patterns of soil attributes in similar geological and climatic terrain conditions (Bell *et al.*, 1994; Gessler *et al.*, 1995). Reddy *et al.*, (1999) analysed the landscape-soil relationship in part of the Bazargaon plateau, Maharashtra and showed that the soil-physiography realationship plays a vital role in understanding genesis of the soil and assessment of their potential for various kinds of uses.

The synoptic coverage and high precision of remotely sensed data is an extremely effective tool in geomorphological analysis and soil mapping. An integrated element of generating map information involves data derived from different sources such as a remotely sensed imagery, ground surveys and collateral data (Chagarlamudi and Plunkett, 1993). Innumerable studies have been reported on soil mapping with visual interpretation of remotely sensed data (Venkataratnam, 1984; Prasad *et al.*, 1990) and particularly, 1:50,000 scale have been found very useful for soil mapping at different levels (Ahuja *et al.*, 1992). Launch of IRS-1C/1D satellites carrying multi-spectral sensors (LISS-III) made a quantum difference in detail geomorphological studies and soil mapping. With the increasing demand for mapping, evaluation, monitoring and management of the vast natural resources, GIS has become an efficient and inevitable platform for landform-soil mapping, analysis and generation of their spatial database (Burrough, 1986 and Maji *et al.*, 1998). In the present study, an attempt has been made to demonstrate the use of satellite data and GIS in landscape analysis, geomorphological mapping and characterization and classification of pedo-geomorphic site parameters and analysis of their inter-relationships.

Study Area

The study area is covering part of Hingna Tehsil, Nagpur district, Maharashtra. It extends between 21°00' to 21°05' N latitudes and 78°50' to 78°55' E longitudes with an area of 80 km^2 (Fig. 1). The elevation of the area is ranging from 280 to 440 m above mean sea level (MSL). The mean annual temperature is 26.6°C and total annual precipitation is 1099 mm. Geologically, the study area is covered by different basaltic lava flows of lower Eocene to upper Cretaceous popularly known as "Traps".

Materials and Methods

The Survey of India toposheet of 55K/16 on 1:50,000 scale was used in the study for the generation of base map of the study area. The IRS-1D LISS-III digital data (Path 99 and Row 57) acquired on March 7, 2000 was used for delinetation of distinct geomorphological units (Fig. 2). Ground control points (GCPs) common to the map and image were identified to register the satellite image in EASI/PACE image analysis

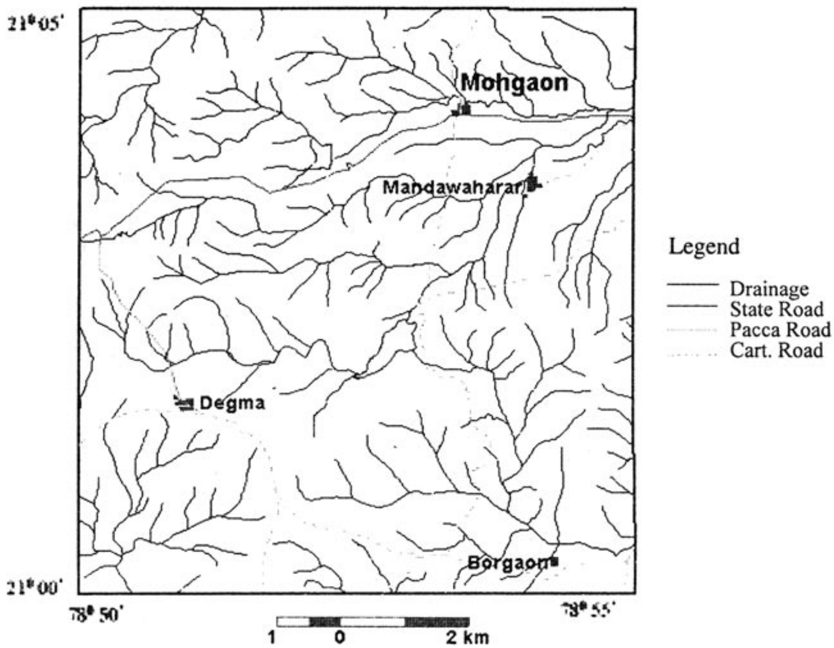

Fig. 1. Location map of study area.

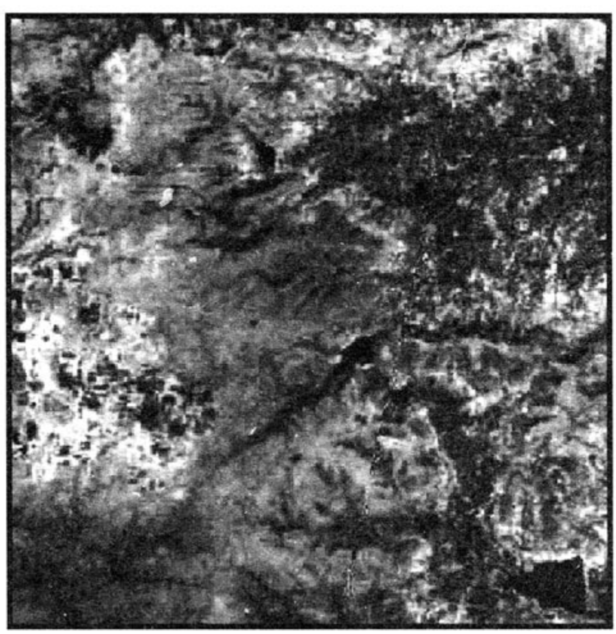

Fig. 2. IRS-ID-LISS-III Satellite imagery of the study area.

system (PCI, 2000) at sub-pixel accuracy using a second polynomial transformation with root mean square error of 0.96. The false color composite (FCC) was generated from green, red and infrared (NIR) spectral bands (bands 2, 3 and 4). Visual interpretation techniques have been followed in delineation of geomorphic units based on the tone, texture, shape, drainage pattern, colour and characteristics of satellite imagery. Image enhancement techniques like linear, root, adptive and equalization were followed while onscreen digitation was carried out to clearly identify and distinguish different geomorphological units. Besides the image characteristics, the changes in the topographic slopes, relief patterns, crest type and drainage pattern were also considered in delineation of boundaries of different geomorphological units. Detail field checks have been conducted before finalisation of geomorphology map of the study area.

Based on the existing relief amplitude, position in toposequence, contour crenullation in association with drainage, the characteristics of different landforms were analysed. Based on the characteristics of the each landfrom, the representative site was selected for the study of soil profiles. Soil profiles were dug up to the partially weathered bedrock or up to 150 cm of depth. The site and morphological properties were analysed for studied pedons (Soil Survey Staff, 1995) and the soil map has been prepared. The digitized vector layers of drainage, contours, geomorphology and soils were imported into AGROMA ver 7.0 (PCI, 1999) GIS environment. The errors were rectified in line layers and area layer was generated for geomorphology using line to areas transformation option in GIS. Topology was built and attributions were assigned for the base layer of geomorphology. The database on soil site and physical parameters at geomorphic unit-wise was genertaed in MS-Access and linked to the polygon attribute table (PAT). From the attribute database, thematic maps were generated from the geomorphology coverage. The geomorphological units layer was overlaid individually on slope, soils, soil depth, texture, draiange and erosion thematic maps to extract the associated information for analysis of landform-soil relationship and their processes.

Results and Discussion

Geomorphology

The geomorphological analysis involves delineation of distinct units from satellite data and classification of these units based on their nature of genesis, extent and their processes (Reddy *et al.*, 2002). Many of these features are well represented on the high resolution satellite data and help to provide reliable information to generate geomorphology map in conjuction with slope and drainage parameters. The analysis of IRS-1D-LISS-III data reveals that ten distinct geomorphological units are existing in the study area (Fig. 3). These have been devided into denudational and depositional landforms based on their origin and genesis.

The denudational landforms have been identified based on the image characteristics of light tone and coarse texture in conjunction with relief and drainage parameters. Plateau tops are existing at an elevation ranging from 400 to 420 m above MSL with gentle slopes (1-3%) and are progruding towards the mainland and with sharp slopes. Sheetwash flow is predominant in this unit and occupying top most portion of the landscape. Isolated mounds are found at an elevation ranges from 420 to 460 m above MSL with slopes ranging from 3-8%. These units are mostly isolated and circular in nature and influenced by circum denudational geomorphic processes. They are relict in nature and are rements of erosion due to retreat of the slopes from all directions. Linear ridges occur at elevation ranging from 360 to 400 m above MSL with steep slopes (30-50%) and formed due to detachment of various fluvial processes. These units may be resultant of lateral intrutions of basaltic lava flows and are hard in nature and as a result, these units are exposed by differenet weathering processes. Escarpments

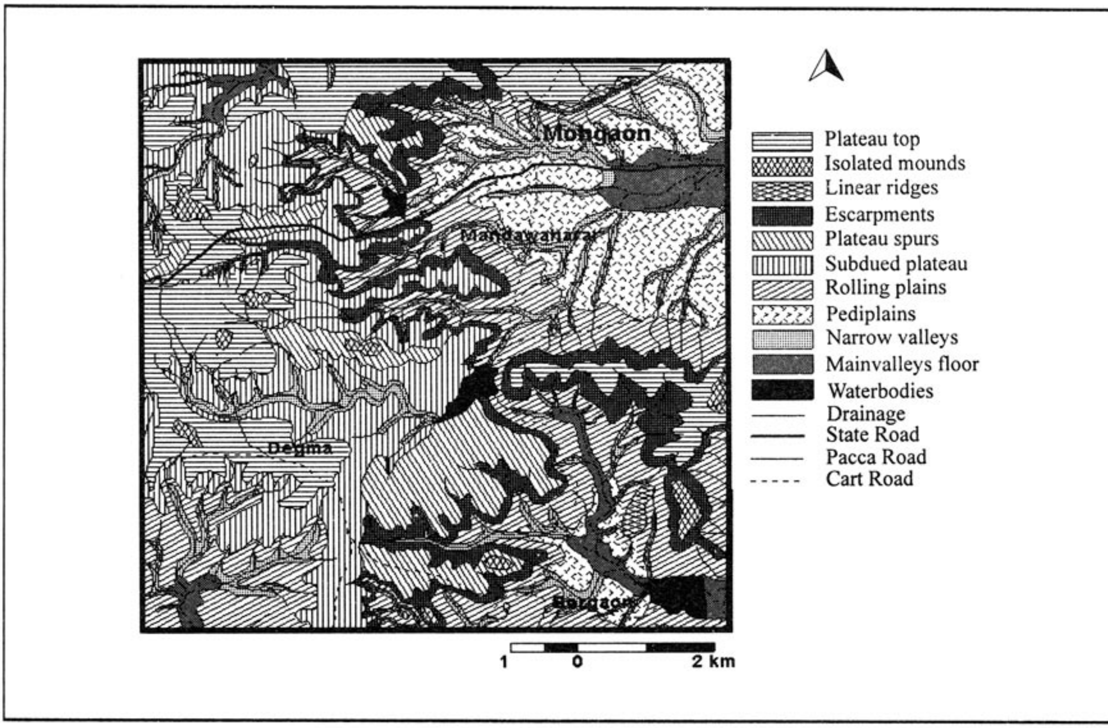

Fig. 3. Geomorphology map of the study area

are narrow and elongated in nature and elevation is ranging from 360 to 400 m above MSL with very steep slopes (30-50%). Slope brakes in the form of bench, interrupt the valley side-slopes of these units. Slope wash is dominent of geomorphic processes followed by rill and protogully formation. Plateau spurs are linear in nature and protruding towards rolling plains. The elevation of these units ranges from 400 to 420 m above MSL. The units are having gentle to moderate slopes (1-3%) and they are under the influence of differential weathering and erosional processes. Subdued plateau formed in between plateau top and escarpments zones at the elevation ranges from 400 to 420 m above MSL with moderate to steep slopes (8-15%). The active physical and chemical weathering followed by sheet wash the main causative factors for the genesis of this unit.

The fluvio-depositional landforms are formed under the influence of erosion dynamics and slope retreat processes. The deposition of sediments transported from upland area is responsible for the development of various depositional landforms. Rolling plains are wide and elongated in nature and are occuring at an elevation ranging from 340 to 360 m above MSL. These units are associated with moderate gently slope (1-3%) and moderate to moderately severe erosion conditions. Pediments are moderately deep, buried and overlaying with basaltic alluvium transported from upland areas. These deposited sediments are admixed with sandy loam to clay fragments. The elevation of this unit is ranging from 300 to 320 m above MSL with slope ranging from gentle (3-8%) to very gentle slopes (1-3%). Narrow valleys are elongated and narrow in nature and are found at an elevation ranges from 320 to

400 m above MSL in association with 3rd and 4th order streams. Slope of these units vary from gentle (3-8%) to very gentle (1-3%). These units are scooped out by the tributaries and subsequently filled up by the final sediments transported from the uplands. Main valley floor is predominantely depositional in nature and occupies lowest portion of the study area. The elevation of this unit is ranging from 300 to 310 m above MSL.' These units are mostly associated with high order streams and thick stratified sediments. These sediments are mainly consisting of fine to very fine clay particles at places with few pebbles and cobbles.

Soil Site Characteristics

Landform and their processes at different elevations affect the soil site and morphological properties more significantly (Gaikawad *et al.,* 1986). The site charactersitics of soils observed during the field investigation at different geomorphic units reveals that the nearly level to level slopes (0-1%) are associated with narrow valleys, main valley floors and plateau tops of the study area (Fig. 4). Very gentle sloping areas (1-3%) are associated with pediments, rolling plains, subdued plateau and plateau top. The gentle slopes (3-8%) are mainly confined to rolling plains and subdued plateau. The moderate slopes (8-15%) are mainly in association with rolling plains and plateau spurs, the moderately steep slopes (15-30%) are mainly confined to escarpments and subdued plateau. The steep (30-50%) and very steep slopes (>50%) are mainly confined to escarpments, linear ridges and isolated mounds. Very slight and slight erosion occurs in main valley floor and narrow valleys with an area of 4.27% and 9.11% of total geographical area (TGA) respectively. The moderate erosion occurs in plateau top, isolated mounds, plateau spurs, rolling plains and pediments with an area of 56.0%. Severe erosion is active in escarpments and subdued plateau with an area of 28.0% of TGA. Very severe erosion occurs in linear ridges and occupies around 0.5% of TGA.

Moderately well drained soils found on rolling plains, pediments and narrow valleys occuping an area of 46.1% of TGA (Fig. 5). Well-drained soils are noticed on plateau top and plateau spurs and covers an area of 23.3% of TGA. Somewhat excessively drained soils are found on isolated mounds and subdued plateau, which occupies an area of 18.85% of TGA. The excessive drained soils are found on linear ridges and escarpments, which cover 0.58% of TGA. The soils on the subdued plateau are associated with strong stoniness of more than 40% surface coverage and covering nearly 17.70% of TGA. Stoniness on isolated mounds, linear ridges and escarpments covers (15-40%) of TGA with an area of 19.82%. Slight stoniness in the soils on plateau top and narrow valleys covering 24.37% of TGA, whereas the soils on pediments, rolling plain and mainvalley floor have very slight surface stoniness of less than 3% and covering nearly 36.98% of TGA.

Soil Morphological Characteristics

Ten soils types have been identified as typifying pedons for representing the soils of the area based on soil profiles studied at different geomorphic units. The morphological characteristics of these typifying soils on a toposequence and developed on basalt, basaltic colluvial and alluvial fills were studied. Soil color is one of the most important morphological characteristics used for soil identification and appraisal. Basalt being a basic igneous rock is rich in ferromagnesium minerals and show intrinsic properties to weathering into dark coloured soils. The soils occurring on plateau top, isolated mounds, plateau spurs, subdued plateau with color 5YR shown light to light brown and light grey colour on the satellite imagery. The soils on escarpments shows dark brown (7.5YR) colour, which may be due to the release of oxidized form of iron resulting from "weathering limited" and well drained condition. The soils on linear ridges, rolling plain, pediments, narrow valleys and main valley floor are dark brown to very dark greyish

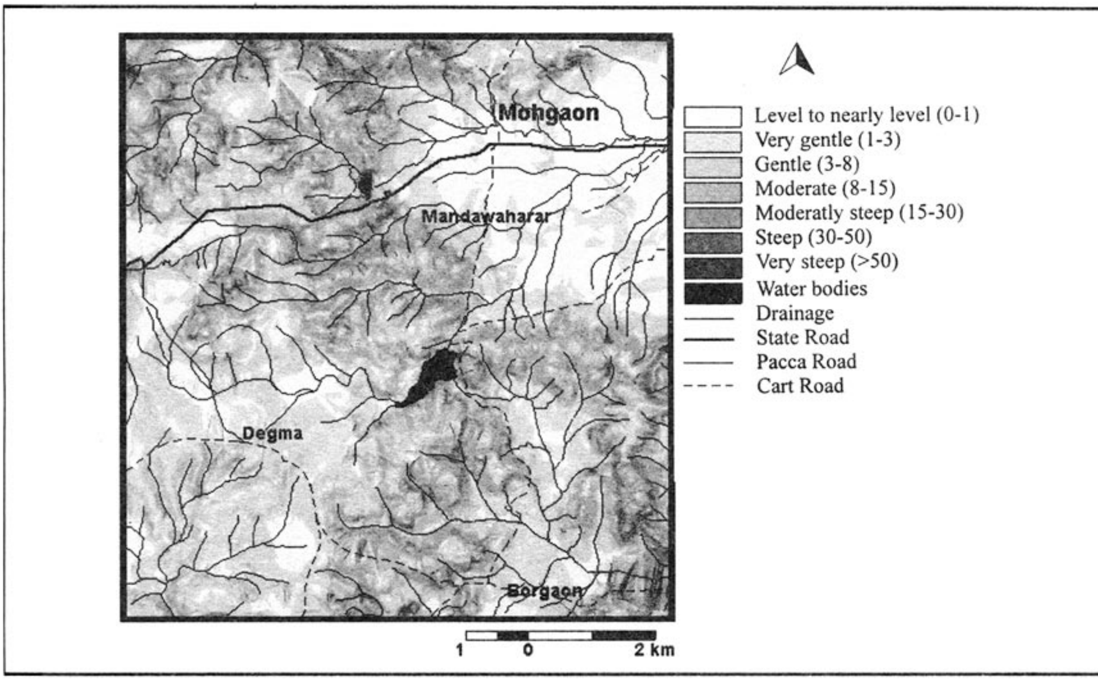

Fig. 4. Slope map of the study area.

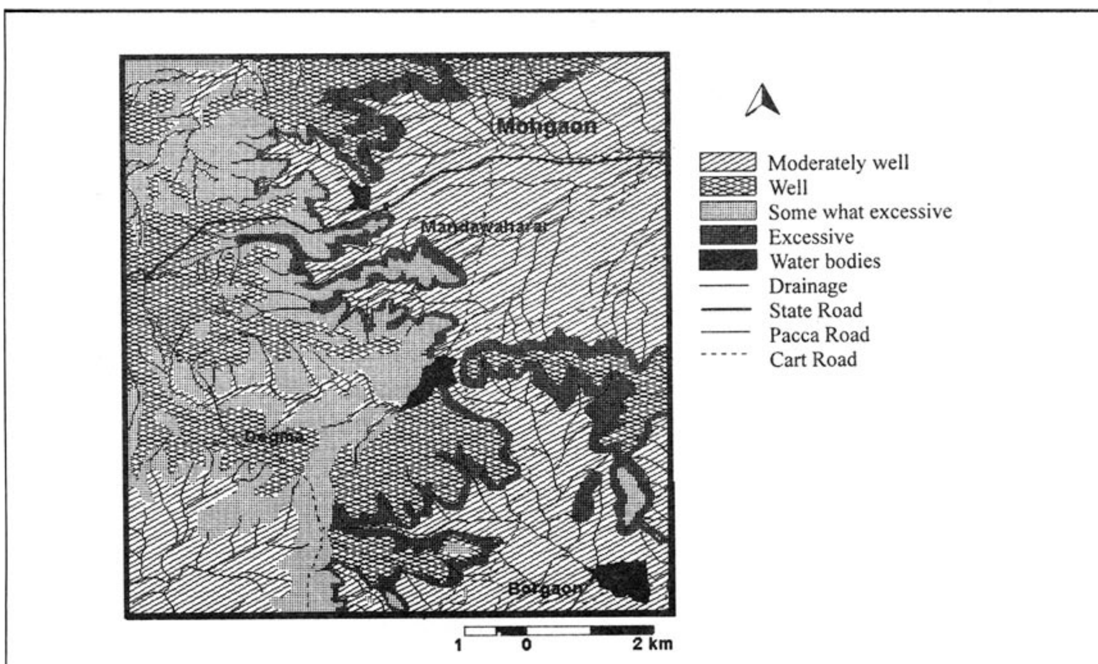

Fig. 5. Soil drainage map of the study area.

brown (10YR) as the condition remains moist for longer period, favouring reduction of iron, under the influence of relatively impeded drainage conditions. These soils can be identified with light red to dark red and light brown colour on satellite imagery. The textural variability shows that clayey texture is found in majority of the soils and clay loam texture is noticed only in the middle horizens of some of soil pofiles.

Medium, week, subangular blocky structures were found in plateau top, isolated mounds, linear ridges, escarpments, plateau spurs, subdued plateau, narrow valleys and main valley floor. The structure of soils found in pediments and rolling plains are medium, moderate, subangular blocky and medium, strong angular blocky. Coarse, strong, angular blocky structure occurs at lower horizen of the soils in pediments. Very shallow soils were found on the plateau top, isolated mounds with an area of 16.40% of TGA (Fig. 6). Shallow soils are found in linear ridges, escarpments, plateau spurs and rolling plains with an area of 38.54% of TGA. Moderately deep soils are found on subdued plateau and narrow valleys, which cover nearly 26.81% of TGA. Deep soils are found on pediments and main valley floor, which cover nearly 17.10% of TGA. Variations observed in the depth of the soils on different geomorphic locations are due to the manifastation of the geomorphic processes, climate and surficial features (Sarkar, 1987).

Soils

The soils of the area namely as Mohgaon-1 to Mohgaon-6 have been formed on the plateau top, isolated mounds, linear ridges, escarpments, plateau spurs and subdued plateau are classified as *Lithic Usthorthents* (Fig. 7). Mohgaon-7 soils are classified under sub-group *Lithic Haplustepts*. Mohgaon-9 soils are classified under sub group *Typic Haplustepts*. The Mohgaon-10 soils are clasified under sub-group *Vertic Haplustepts*. Vertisosl are deep, moderatly well drained, 10 YR4/2, 3/2 and clay textured with cracks from 2 to 60 cm depth in the profile. Mohogaon-8 soils developed in the pediments from weatherd basalt underlain by numerous corestones. These soils qualify for sub-order Usterts and great group Haplusterts and further divided into sub-group *Typic Haplusterts*. The geomorphic units delinetaed based on satellite data show distinct variation in soil site and morpholiogical characteristics.

Landform-Soil Relationship

The study reveals that geomorphological mapping and analysis based on the IRS-ID LISS-III data in conjunction with drainage and elevation information will be of immense help in conducting soil survey and better understanding the relationship between landforms–soils. Very shallow, well drained, 5YR3/3 and clay textured Mohgaon-1 soils are developed on moderately eroded plateau top with very gentle slopes. Very shallow, somewhat excessive drained, 5YR3/3 and clayey textured Mohgaon-2 soils are developed on moderately eroded isolated mounds with steep to very steep slopes. Shallow, excessive drained, 10YR4/4, 4/3 and clay textured Mohgaon-3 soils are developed on very severely eroded linear ridges with steep to very steep slopes. Shallow, excessive drained, 7.5YR4/4, 4/3 and clayey textured Mohgaon-4 soils are developed on very severely eroded escarpments with very steep slopes. Shallow, well-drained, 5YR3/2 and clayey textured Mohgaon-5 soils are developed on moderately eroded plateau spurs with moderate slopes. Moderatly deep, somewhat excessively drained, 5YR3/3 and clayey textured Mohgaon-6 soils are developed on severely eroded subdued plateau with steep slopes. Shallow, well drained, 10YR4/2 and clay textured Mohgaon-7 soils are developed on moderately eroded rolling plains with gentle slopes. Deep, moderatly well drained, 10 YR4/2, 3/2 and clayey textured Mohgaon-8 soils are developed on moderately eroded pediments with gentle to very gentle slopes.

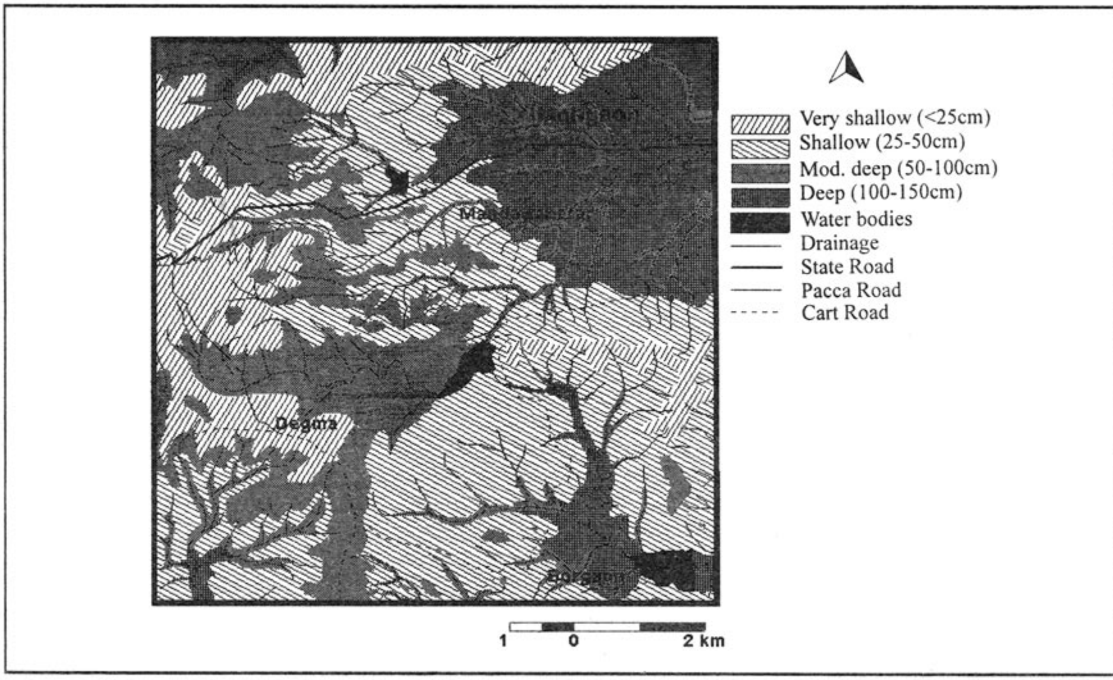

Fig. 6. Soil depth map of the study area.

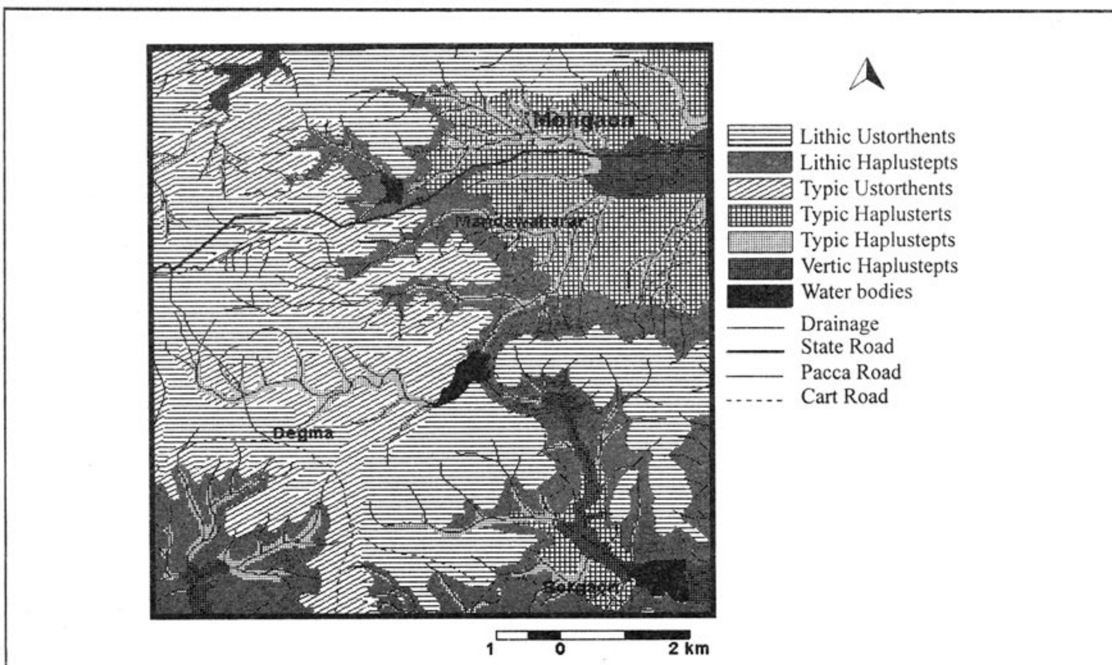

Fig. 7. Soil map of the study area.

Deep, moderatly well drained, 10 YR4/2, 3/3 and clayey textured Mohgaon-9 soils are developed on slightly eroded narrow valleys with level to nearly level slopes. Deep, moderatly well drained, 10 YR4/2, 3/3 and clayey textured Mohgaon-10 soils are developed on very slightly eroded main valley floors with level to nearly level slopes and these soils are consisting fine to very fine corestones. The analysis of relationship between landforms–soils reveals strong inter-relationship among the properties of landforms and their associated soil characteristics.

Conclusion

The analysis of IRS-1D-LISS-III data reveals that, there are ten distinct geomorphological units under denudational and depositional landforms. Nearly level to level slopes (0-1%) are associated with pediments, narrow valleys, main valley floor and plateau tops of the study area. Steep (30-50%) and very steep slopes (>50%) are mainly confined to escarpments, linear ridges and isolated mounds and are prone to erosional hazards. Slight erosion occurs in narrow valleys, moderate erosion occurs in plateau top, isolated mounds, plateau spurs, rolling plains and pediments. Moderately well drained soils were found in rolling plains, pediments, narrow valleys and main valley floor and excessive drained soils were found in linear ridges and escarpments. Soils on the subdued plateau are associated with strong stoniness (>40%), whereas, the soils on pediments, rolling plains, main valley floor have very slight surface stoniness (>3%). The soils on linear ridges, rolling plains, pediments, narrow valleys and mainvalley floor are dark brown to very dark greyish brown (10YR) and others are darker in color (5YR). The light red to dark red and light brown colour of satellite imagery is associated with the soil colour ranges from 7.5 YR to 10 YR. The soils having the colour of 5YR are coincide the areas with light to light brown and light gray colour of the satellite imagery. The clay loam texture is noticed in the middle horizon of soil pofile in some geomorphic units. The stucture of the soils are medium week subangular blocky structures are found in plateau top, isolated mounds, linear ridges, escarpments, plateau spurs, subdued plateau, narrow valleys and main valley floor. The lower horizon of the soils in pediments have coarse, strong, angular blocky structures.

Soil depth shows wide varition in in terms of image characteristics, nature and extent of different geomorphic units. Very shallow soils were found on the plateau top, isolated mounds and shallow soils are found on linear ridges, escarpments, plateau spurs and rolling plains. The landforms, which are having the image characteristics of light to light brown and light grey colour with coarse texture are associated with shallow to very shallow soils. Moderately deep soils are also found on subdued plateau and narrow valleys and deep soils are found pediments and main valley floor. These landforms are associated with the image charactiristics of brown and light red to dark red colour with fine texture. The analysis of inter-relationship between landforms and soils show distinct inetractive processes between them, which are mainly governed by bedrock geology, hydrological systems and climate. The study clearly demonstrated the capabilities of IRS-ID LISS-III data in delineation of distinct geomorphological units in association with drainage and elevation parameters and analysis of their processes based on the field observations. The study also reveals that delineated geomorphic units based on satellite data can be effectively used for soil mapping and to analyse their site and morpholiogical characteristics. The generation of geo-spatial database on geomorphology and soils in GIS and overlay of geomorphological units on other thematic maps of soils was found more effective to analyse the inter-relationship between charactersistics of geomorphological units and soils.

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