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Characterization of landforms and land use/land Cover in basaltic terrain using IRS-P6 LISS-IV and Cartosat-1 DEM data: A case study

NISHA SAHU, G.P. OBIREDDY, NIRMAL KUMAR, M.S.S. NAGARAJU, RAJEEV SRIVASTAVA AND S. K. SINGH

ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur-440 033, India

Abstract: In the present study, an attempt has been made to integrate the IRS-P6 LISS-IV (5.8 m) image with Digital Elevation Model (DEM) derived from Cartosat-1 stereo data for delineation of landforms and analysis of land use/land cover of Miniwada panchyat, Nagpur district on basaltic terrain of central India. Besides the available generic rational polynomia coefficient (RPC's), the additional ground control points (GCP's) were collected from Google Earth's image of the study area to georeference CARTOSAT-1 stereo data at 2.5 m resolution. Using Leica Photo grammetric Suite, the DEM of the study area was extracted at 10 m resolution to extract terrain parameters such as elevation, slope, aspect, hillshade, drainage, *etc*. Using the SOI toposheet on 1:50,000 scale, the two seasons IRS-P6 LISS-IV (5.8 m) images were georeferenced by collecting minimum GCP's. Cartosat-1 DEM was visually interpreted and seven major landforms were identified, namely plateau top, scarp slopes, plateau spurs, pediment, undulating plains, valley and floodplain (depositional) and grouped them under erosional and depositional landforms based on their processes and gneisses. Two seasons IRS-P6 LISS-IV data were visually analysed and six land-use/land-cover classes were identified, namely single crop, double crop, orchard, land with and without scrub, and degraded forest. Based on the delineated landforms and land use/land cover classes, the relationship was established to analyze the various biophysical process. The study demonstrates that the ortho-rectified images generated using IRS-P6 LISS-IV and Cartosat-1 DEM will be of immense help in delineation of distinct landforms and land use/land cover classes.

Key words: Cartosat-1 DEM, IRS-P6 LISS-IV, Landform, Land use/ land cover

Introduction

Geomorphological mapping involves the identification and characterization of the fundamental units of the landscape. The scope has further expanded with the landform maps widely used in various fields of resource surveys, environmental analysis, hydrological studies and many more applications. The use of digital data sources, such as digital elevation models (DEMs) and LISS-IV satellite data can speed up the completion of digital databases and improve the overall quality, consistency and reliability of the database. Traditionally, landform delineations were carried out using aerial photography. With the increasing availability of digital elevation models (DEMs), a surface is characterized by attributes such as elevation, slope, aspect, plan and profile curvature, and flow accumulation to obtain relief or surface topography units (Moore *et al.* 1993), and these provide greater functionalities than the qualitative and nominal characterization of topography (Aksoy *et al.* 2009; Reddy *et al.* 2004). A DEM is an electronic model of the Earth's surface that can be stored and manipulated in a computer. A DEM can be manipulated to provide many kinds of data that can assist the surveyor in mapping and giving a quantitative description of landforms (Ardak *et al.* 2010; Sankar *et al.* 2010).

The Digital Elevation Model (DEM) has become an inevitable component of geospatial data and in remote sensing applications *viz.*, agriculture, watershed management and development, hydro-geomorphology, urban morphology, disaster management *etc*. With the launch of Cartosat-1, the high-resolution stereo data beamed from twin cameras onboard Cartosat-1 mission facilitates topographic mapping up to a large scale (Srivastava *et al.* 2006). The primary advantage of Cartosat-1 data is seen as generation of Digital Elevation Model (DEM) for production of Orthoimage and 3D terrain visualization of large tracts of landmass at fairly large scale. Cartosat-1 is the first operational remote sensing satellite capable for providing in-orbit stereo images with 2.5 m nadir resolution and 27 km swath. Cartosat-1 has proved its potential in natural resource management and large scale mapping.

The use of high resolution satellite data to complement topographic information has been suggested by several researchers to correct satellite data distortions arising from topographic variations of the landscape and to provide additional data for the precise delineation of landform units, which improves the mapping of natural resources. The elevation information available in the Survey of India toposheet (Srivastava and Saxena 2004) or coarse-resolution Shuttle Radar Topographic Mission (SRTM) digital elevation model (Velmurugan and Carlos 2009; Young and White 1994) is inadequate for precise delineation of landforms, which is very important for cadastral-level soil mapping. Ahmed *et al.* (2007) and Krishna-Murthy *et al.* (2008) generated and validated digital elevation models using stereo data from Cartosat-1 under different terrain conditions and used for orthoimage generation. The recent availability of digital elevation models in different forms and from different sources facilitates the 3D viewing of the landscape to enhance feature representation and the human perception of spatial entities (Ziadat 2010). The Cartosat-1 DEM provides the opportunity for 3D perspective viewing of an area for precise and accurate delineation of landforms, generation of contours at smaller intervals, and derivation of information on the slope of land. The study of Cartosat-1 stereo data and products reveals DEM accuracy of about 4m (Ahmed *et al.* 2007). The integration of Remote Sensing within a GIS database can decrease the cost, reduce the time and increase the detailed information gathered for soil survey. Particularly, the use of Digital Elevation Model (DEM) with LISS-IV data is important to derive landscape attributes that are utilized in landforms characterization (Rajankar *et al.* 2012; Pachpor *et al.* 2012). Satellite Photogrammetry techniques have been extensively used by the scientific community in deriving high resolution DEM, ortho image and terrain parameters such as slope, contours, drainage *etc*. Keeping these applications in view, the current study aimed at exploitation of DEM derived from Cartosat-1 stereo data for delineation of landforms.

Materials and Methods

Study area

Miniwada Panchayat is situated in Katol tehsil, 45 km to the west of Nagpur district of Maharashtra (Fig.1). The panchayat includes three villages Miniwada, Mhasala and Malkapur which lies between 21°08' to 21°12' latitudes and 79°08' to 79°15' longitudes and covers an area of 1621 hectares. The elevation ranges from 407 to 472 m (WGS 84 datum) above mean sea level (MSL). The climate is mainly hot sub tropical type with mean annual temperature of 28°C and mean annual rainfall of 1088 mm. The area qualifies for *hyperthermic* soil temperature regime. The geology of the study area is covered by basaltic lava flows, commonly known as Traps. Due to rapid cooling after extrusion, the resultant basaltic rocks possess an aphanitic texture, which is generally dark gray to dark greenish gray in colour. Columnar joints and spheroidal weathering are vital features of these rocks. The main field crops are cotton (*Gossypium spp.*), soybean (*Glycine max*), pigeonpea (*Cajanus cajan*), gram (*Cicer arientinum*), wheat (*Triticum aestivum*) etc. The natural vegetation comprises of teak (*Tectona grandis*), babul (*Acacia spp.*), palash (*Butea frandosa*), neem (*Azadirachta indica*), mahua (*Madhuca longifolia*) *etc.*

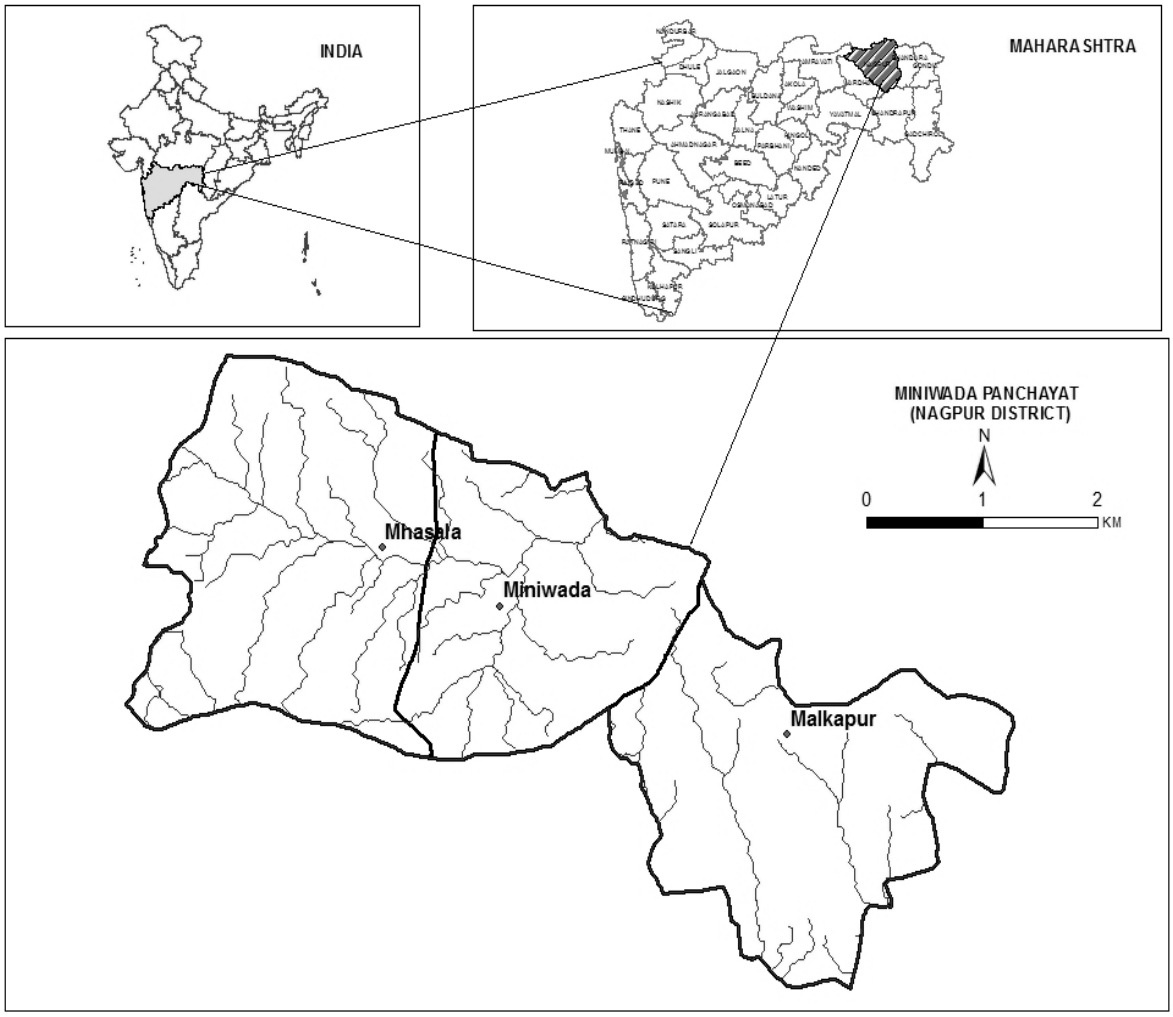

Fig.1. Location map of Miniwada panchayat, Katol tehsil, Nagpur district

Data used

Survey of India (SOI) toposheet (55K/12) was used for georeferencing and cadastral map of the study area was procured from MRSAC, Nagpur. Multi-temporal geo-referenced IRS-P6 LISS-IV and Cartosat-1 stereo pairs have been used for identification of landform and extraction of DEM. Table.1 shows details of satellite data used in the study area.

Table. 1 Details of satellite data used in the study area

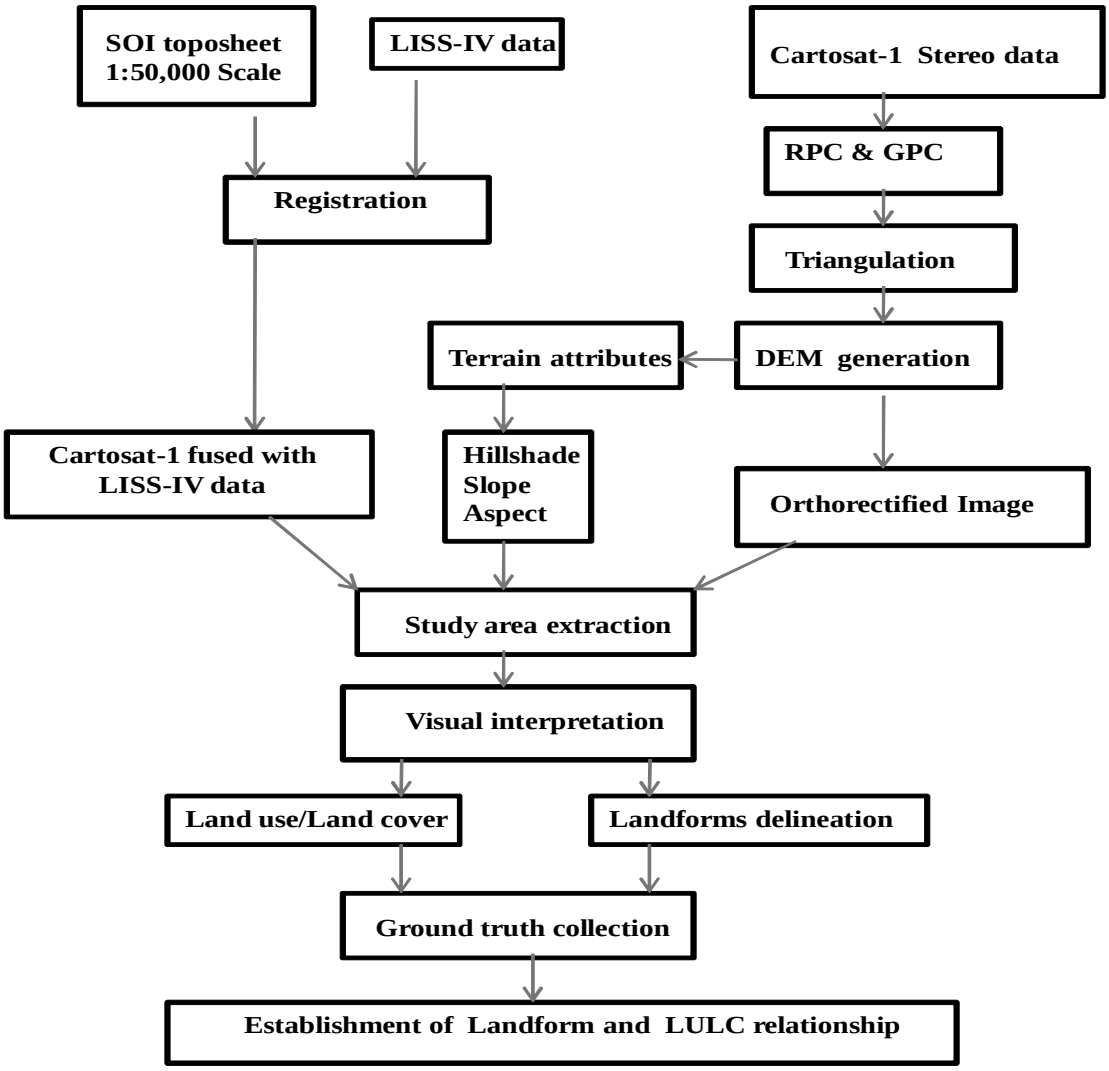

Fig. 2 Flowchart of the methodology adopted in the study

Georeferencing of base maps

Based on Survey of India toposheet (55 K/12) on 1:50,000 scale, IRS-P6 LISS-IV data (5.8 m) data (05.10.2012 and 15.04.2013) were georeferenced using WGS 84 datum, Universal Transverse Mercator (UTM) zone 44N projection in ArcGIS desktop10.1. The cadastral map of the panchayat which was in LCC projection was reprojected to UTM. The rasterized cadastral map and LISS-IV data were co-registered using orthorectified Cartosat-1 data as a reference. Fig. 2 shows the flowchart of the methodology adopted in this study.

DEM extraction from Cartosat-1 Stereo Pairs

For DEM and ortho-image generation from Cartosat-1 stereo pairs, LPS was used in the study. The block project was assigned horizontal and vertical coordinates with UTM projection and WGS 84 datum. The stereo pair images, band (a and band f) were added to the frame. The interior and exterior orientations corresponding to the Rational Polynomial Coefficients (RPC) files were carried out. LPS automatically generated the tie points; manually some more tie points were added for even distribution throughout the image. Triangulation was performed to check the accuracies of all the tie points. Manually GCPs were added and again triangulation was carried out. The overall image root mean square error (RMSE) achieved was 0.512 pixels. DEM was generated with a cell size of 10 m and finally used for orthorectification using ERDAS Imagine software.

Cartosat-1 fused with LISS-IV data

A high resolution Linear Imaging Self Scanner (LISS-IV) multispectral data (bands 2, 3 and 4) with 5.8 m resolution was sharpened with the orthorectified Cartosat-1 data using ERDAS IMAGINE software. This resulted in the sharpening of the multi-spectral LISS-IV data with resultant spatial resolution of 2.5 m due to higher resolution of Cartosat-1 panchromatic image.

Landform delineation and land use/land cover analysis

The delineation of landforms was done using on screen image visual interpretation techniques. Geomorphic features were interpreted based on key image elements such as shape, tone or colour, pattern, shadow, association and texture. Different band combinations of satellite data were used to generate a false colour composite (FCC) for image interpretation and on screen mapping. Landform analysis was carried out using elevation information available in the DEM generated from the Cartosat-1 stereo pair and hill shade generated from the Cartosat-1 DEM using ArcGIS software. Orthorectified Cartosat-1 data along with hillshade were superimposed on the Cartosat-1 DEM and a stereo view generated. Using the stereo tool, the area was visually interpreted systematically for various landforms in the study area. The Cartosat-1 sharpened with LISS IV data of two seasons (October, 2012 and April, 2013) were visually interpreted using visual image interpretation. The boundaries of the forest were digitized from the Survey of India toposheet and transferred as a layer to satellite data and various land use/land cover classes were interpreted. The cadastral map was superimposed over the land use/ land cover map to understand the distribution in different fields of the villages. The study area was traversed for identification of different landform units, slope, land use/ land cover classes and correlated with image interpretation units using GPS. The boundaries were verified and corrected wherever found necessary.

Results and Discussion

Terrain analysis

Precise delineation of landforms is very important for cadastral-level soil mapping (Nagaraju *et al.* 2014; Martha *et al.* 2012). Using hillshade information generated from the Cartosat-1 DEM and 3D perspective viewing of the area, various landforms were delineated based on visual interpretation. Slope information was derived from the high-resolution Cartosat-1 DEM and reclassified into different slope classes similar to the work done by Reddy and Maji (2003). Furthermore, the Cartosat-1-sharpened with IRS-P6 LISS-IV data were used to segment the area into precisely defined different land-use/ land-cover classes.

Slope

The slope information was derived from the Cartosat-1 DEM (Nagaraju *et al.* 2014). After eliminating the speckle effects due to the high-resolution DEM, the raster slope map was reclassified into seven slope classes, *viz*. nearly level (0–1%), very gently sloping (1–3%), gently sloping (3–5%), moderately sloping (5–10%), strongly sloping (10–15%), steeply sloping (15–30%), and very steeply sloping (>30%).

Landforms delineation and characterization

Using stereo vision, the area was characterized into plateau top (450-470 m), scarpslopes (450-460 m), plateau spurs (425-445 m), pediment (430-450 m), undulating plain (415-430 m), broad valley (415-430 m), narrow valleys (415-425 m) and floodplain (408-415 m) (Fig. 3 and Table.2). The major landforms were further subdivided based on elevation. The pediments were subdivided into upper (440-450 m) and lower pediments (430-440 m), whereas the undulating plain was further subdivided into upper (425-430 m) and lower (415-425 m).

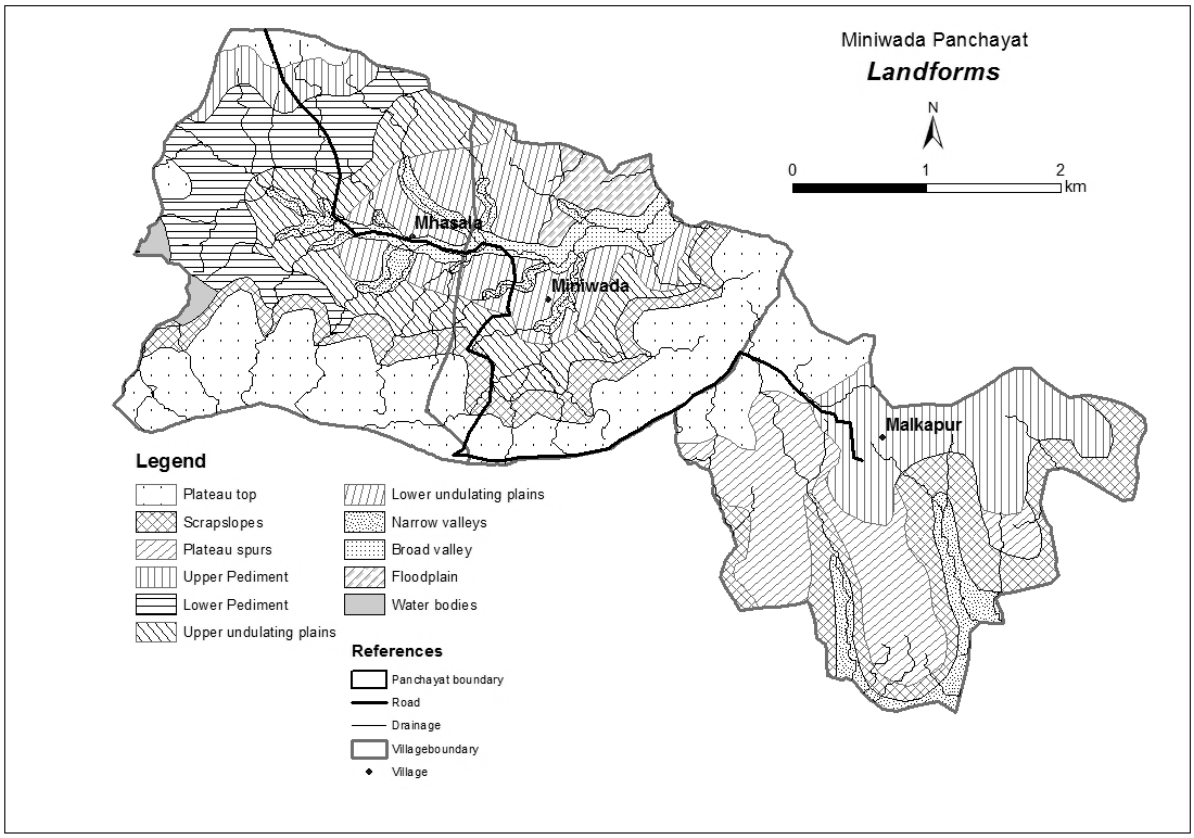

Fig. 3. Distinct landforms of Miniwada panchayat derived from Cartosat-1 DEM data

Table.2 Image and physical characteristics of different landform unit

Landform	Texture	Tone/Colour	Shape and Size	Pattern	Elevation	Landuse/ land cover	Slope	Area	%
Plateau top	Coarse	Light gray to dark gray	Circular to elongated	Scattered	450-470	Single crop, Land with and without scrub	Nearly level to moderate	385.2	23.3
Scarpslopes	Fine	Light red to dark red	Irregular and linear	Contiguous	450-460	Degraded forest	Strong to steep	239.1	15.1
Plateau spurs	Coarse	Light gray to dark red	Irregular and elongated	Linear and contiguous	425-445	Single and double crop	Very gentle to moderate	176.2	11.0
Upper pediment	Coarse	Light gray to dark gray	Irregular and elongated	Contiguous	440-450	Single crop, land without scrub	Nearly level to moderate	176.1	11.0
Lower pediment	Medium	Light gray to dark red	Irregular and elongated	Contiguous	430-440	Single and double crop, orchard	Nearly level to moderate	151.3	9.1
Upper undulating plains	Medium	White to dark red	Irregular and elongated	Contiguous	425-430	Single crop, orchard	Nearly level to moderate	163.4	10.2
Lower undulating plains	Medium	White to dark red	Irregular and elongated	Contiguous	415-425	Single and double crop	Very gentle to gentle	153.1	9.1
Broad valley	Fine	Light red to dark red	Linear	Linear and Contiguous	415-430	Double crop	Nearly level to gentle	46.3	3.0
Narrow valley	Fine	Light gray to dark red	Irregular and linear	Isolated and linear	415-425	Single and double crop	Nearly level to gentle	91.2	6.0
Floodplain	Coarse	Light gray to light red	Irregular and elongated	Scattered	408-415	Single crop	Nearly level to gentle	33.0	2.2

Plateau tops have a steep side, flat top and are elevated far above the surrounding area. They are formed by erosional processes and as a result of upward movements of the Earth's crust by tectonic plates moving together. This unit characterized by nearly level to moderate slopes and occupies 24 percent of the TGA. The low fertile soil and gentle slopes are favorable for a single crop, land with scrub and land without scrub. Plateau spurs are ridge or lateral extension descending from a plateau having lesser elevation. This unit occupies 11 percent of the TGA and characterized by very gentle to moderate slopes. Single and double crops are mostly practiced in this landform unit. Scarpslopes are steep slope that occurs from erosion and separates two relatively level areas of differing elevations. They are formed either by differential erosion of sedimentary rocks, or by vertical movement of the Earth's crust . This unit is a transition from one series to another series of a different age and composition. They occupy 15 percent of TGA with strong to very steep slopes. The dominant landuse/ landcover in this landform unit is degraded forest. Upper pediment appears as more or less wide terraces and a clear break of slope between the gently sloping pediment and the steeper regions of the slope above it. They are concave in longitudinal profile and flat surface of bedrock that occurs at the base of a mountain. They occupy 11 percent of TGA with nearly level to moderate slopes. Due to erosional process only single crop is practiced in this landform. In lower pediment unit water passes across the pediment by laminar sheet flow, but if this is disturbed, the flow becomes turbulent and gullies develop due to excess deposits. They are characterized by nearly level to moderate slopes with single crop, double crop and orchard land use/land cover with an area of 9 percent of TGA.

Upper Undulating plains are well to moderately well drained unit formed by side to side alternation of movement. This unit has a wavelike motion and it bends with successive curves in alternate directions. It covers an area of 10 percent of TGA with nearly level to moderate slopes. The dominant land use/land cover in this unit is single crop and orchard. Lower undulating plains are formed by the deposits of the sediments by erosional processes from upper undulating plains. This unit occupies 9 percent of TGA with very gentle to gentle slopes mainly cultivated to single and double crops.

Narrow Valleys are hollow or surface depression of the earth with very steep sides and a wide, flat floor formed by actions of fluvial deposition or the gradual wearing down of the land by water. This unit occupies 6 percent of TGA with single and double crops. In broad valley the erosional agents brought foreign sediments from upland areas and deposition occurred. The shape has been influenced and characterized by the stream flowing through it. The rivers with steep gradients have produced steep walls and a bottom. This depression consists of moderate to deep soils with double cropped area and occupies nearly 3 percent of TGA.

Floodplain is an area of land adjacent to a stream that stretches from the banks of its channel to the base of the enclosing valley walls and formed by a meander eroding sideways as it moves downstream. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. However, in the lowest stretch of a river it begins to deposit sediment and the valley bottom becomes a floodplain. They occupy nearly 2 percent of TGA and the dominant land use/ land cover is single crop.

Land use/ land cover analysis

The Cartosat-1 fused with LISS-IV data of two seasons (October, 2012 and April, 2013) were visually interpreted and six land use/ land cover classes were identified namely double crop, single crop, orchard, land with and without scrub and degraded forest. Double cropped area is mainly practiced in the landform which is dominant by depositional processes such as lower pediment, lower undulating plains and in broad and narrow valleys with nearly level to gentle slopes. Wheat, gram and vegetables crops are grown which occupies an area of 7.12 percent of TGA. Single crop occupies 41.17 percent of TGA and practiced in almost all landforms except scarpslopes due to strong to steep slopes. Soybean and cotton is spread in

maximum area of cultivation. Orange orchards occupy 1.48 percent of TGA with nearly level to moderate slopes in lower pediment and upper undulating plains. Degraded forest is prominent in scarpslopes covering an area of 30.5 percent with strong to steep slopes. The vegetation comprises of teak (*Tectona grandis*), babul (*Acacia spp.*), palash (*Butea frandosa*), mahua (*Madhuca longifolia*) *etc*. Other land uses like settlements, nala, land with and without scrub and waterbodies contribute the remaining percent 19.73 percent of TGA.

Landforms and land use/land cover relationship

An attempt was made to critically evaluate the different land use/land cover types spread on different landforms and to study their relationship (Table.3). The land use/ land cover categories such as single crop, double crop, orchard, land with and without scrub, and degraded forest were identified and mapped from the study area (Fig.4 and Fig. 5). Major part of the study area is covered with single crop (41.17%) mainly cotton, soybean, sorghum *etc.* in all landforms except valley and scarslopes. About (0.37%) of the study area is under settlements and streams (2.84%). Water bodies occupied (0.92%) of area. About (30.5%) of the study area is under degraded deciduous forest in scarp slopes. Due to erosional processes and steep slopes this unit is not at all suitable for cultivation. The dominant vegetations are teak, babul, palash, neem, mahua etc. From the satellite data of two seasons *Rabi* and *Kharif* the agriculture area could be clearly delineated as single crop and double crop. Valleys and floodplains are formed by depositional processes, therefore this unit is mineral rich zone with nearly level to gentle slopes suitable for double cropping (7.12%) mainly wheat, gram, vegetables, *etc*.

Table 3. Landform and Land use/Land cover relationship of study area

Sl. No.	Landform	Land use/ land cover	Description
1.	Plateau top	Single crop Land with scrub	Soybean and cotton are grown in this landform with nearly level to moderate slopes and partly covered by land with scrub.
2.	Scarpslopes	Degraded forest	Due to strong to steep slopes this landform is covered by degraded forest with vegetation teak, palash, mahua, babul *etc*.
3.	Plateau spurs	Single crop Double crop	Mainly soybean, cotton intercropped with pigeonpea and in few areas where water deposits double crop wheat, gram is practiced.
4.	Upper pediment	Single crop	Due to erosional processes only single crop soybean is cultivated with nearly level to moderate slopes.
5.	Lower pediment	Single crop Double crop Orchard	In this landform sediments derived from uplands deposit and therefore in certain parts double crop is practiced, however, majority area is under single crop.
6.	Upper undulating plains	Single crop Orchard	Drainage condition is favorable for orchard with nearly level to moderate slopes and remaining area under soybean.
7.	Lower undulating plains	Single crop Double crop	Due to depositional processes, this unit is rich in sediments and as per the availability of irrigation facilities single and double crop is practiced.
8.	Broad valley	Double crop	Wheat, gram, vegetables are practiced in this landform due to availability of water with nearly level to gentle slopes.
9.	Narrow valley	Single crop Double crop	This landform unit is fertile due to deposits of minerals from uplands and therefore throughout the year crop is cultivated in this region.
10.	Floodplains	Single crop	Soybean is mainly practiced with nearly level to gentle slopes.

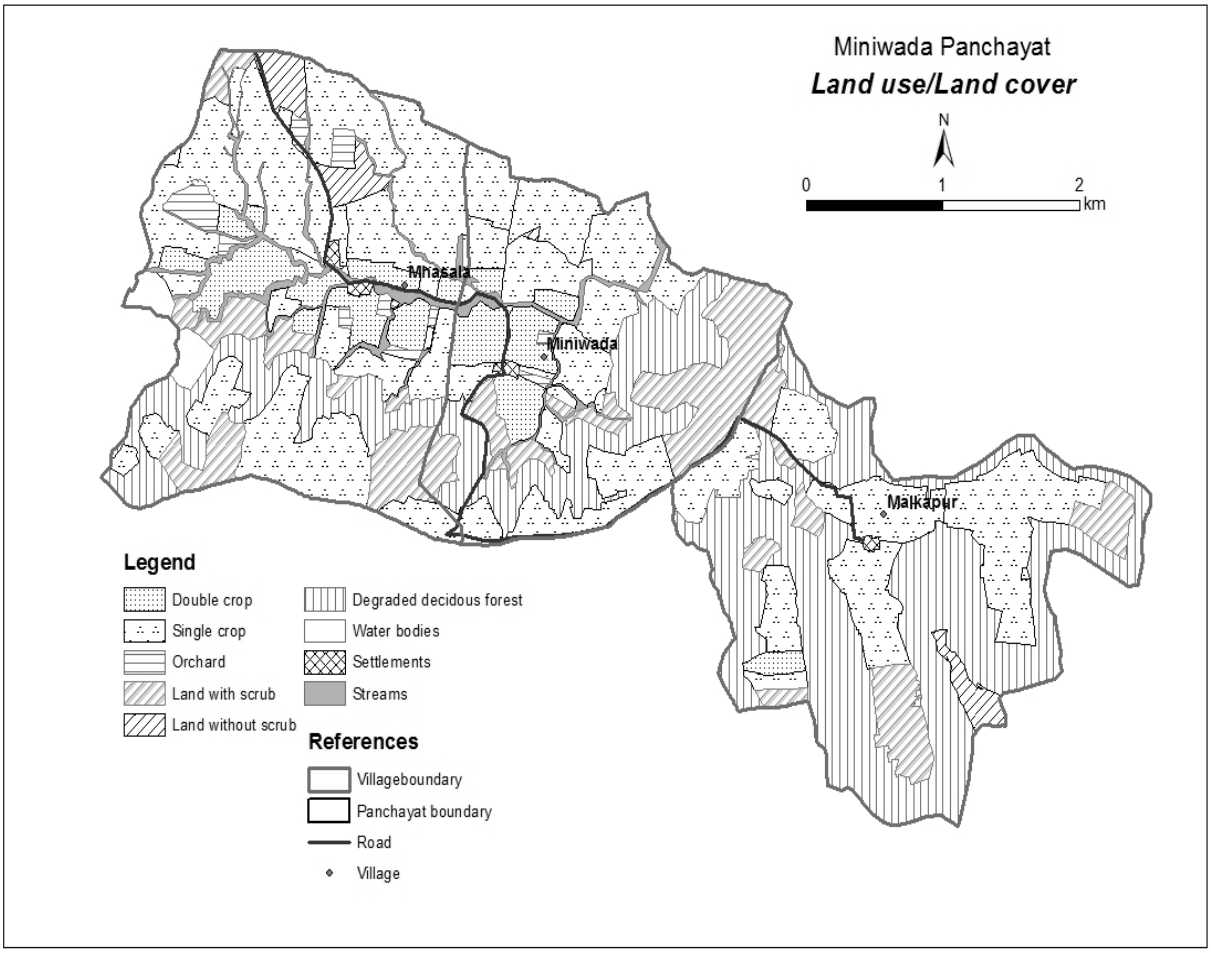

Fig. 4. Land use/land cover classes of Miniwada panchayat derived from IRS-P6 LISS-IV (October, 2012 and April, 2013) data

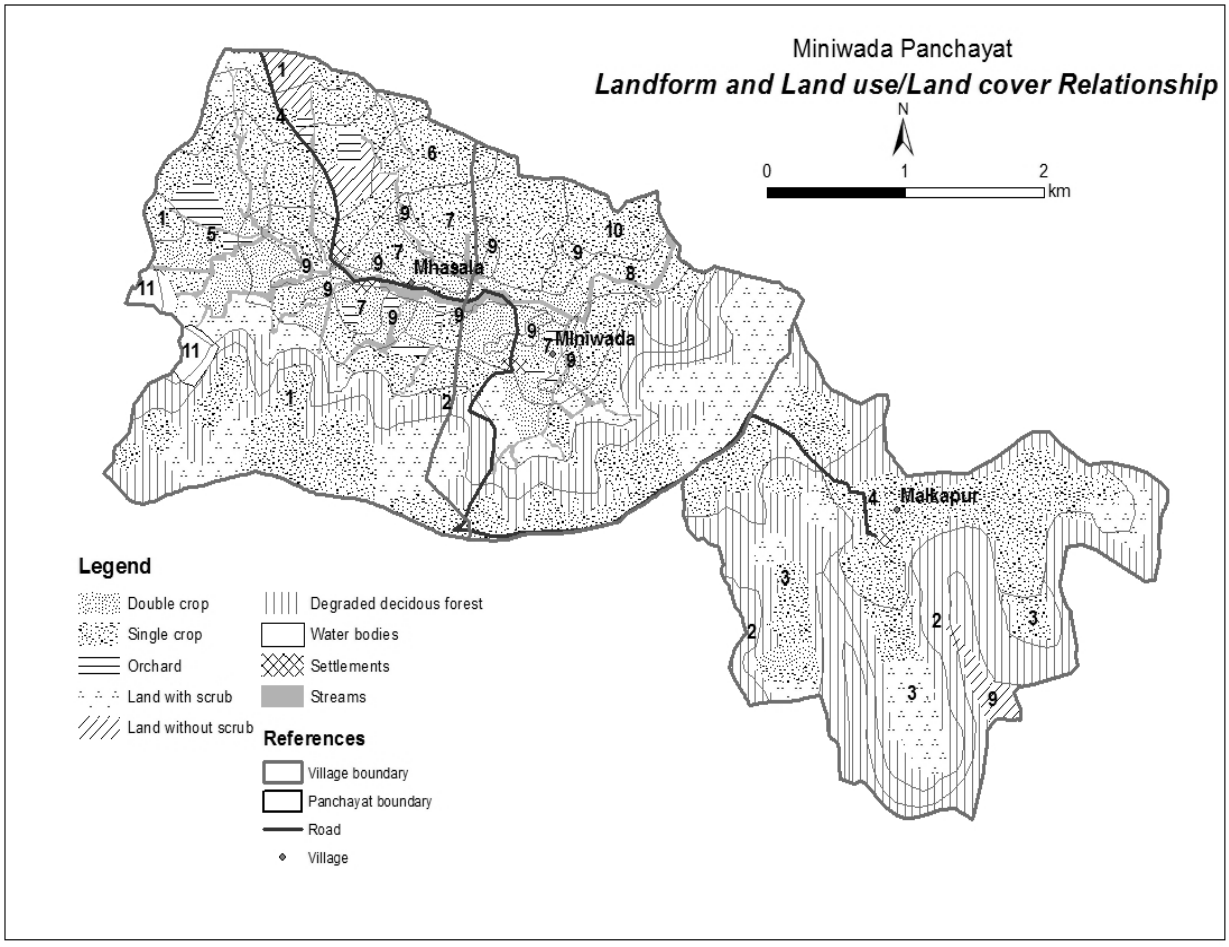

Fig. 5. Landform and Land use/Land cover relationship in Miniwada panchayat (Landform represented in numeric)

Conclusions

The study demonstrates the utility of Cartosat-1 DEM in delineation of distinct landform units by using key interpretation features such as image tone, hill shade and terrain shadow. The major landform units identified in the study are plateau top, scarp slopes, plateau spurs, pediment, undulating plains, broad valley and narrow valley. These landforms have developed mainly due to the control slope position and moisture availability. A detailed land use/land cover map consisting of six classes namely double crop, single crop, land with and without scrub, orchard and degraded forest were delineated. About 41.17% of the study area is covered with single crop in all landforms except in valleys and scarp slopes. Double crop is mainly practiced in lower undulating plains and valleys due to higher availability of moisture and rich in minerals. This study highlighted that the 10 m DEM from Cartosat-1 and LISS-IV (5.8 m), can be effectively used for the mapping of geomorphic features as well as land use/land cover at large scale (1:10,000) due to their high resolution imaging capability. The delineated distinct landforms in study area can be used for soil resource inventory, quantification of groundwater potential zones and village level agricultural land use planning.

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