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Characterization of landforms and soils in complex toposequence of Subarnarekha catchment, Chhotanagpur plateau using remote sensing and GIS

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Abstract: In the present study, an attempt has been made to characterize and classify the landforms and soils in Complex Toposequence of Subarnarekha catchment of Chhotanagpur plateau, Eastern India using Indian Remote Sensing (IRS)-ID LISS-III data and Geographic Information System (GIS). Terrain characterization has been carried out using ASTER (30m) digital elevation model (DEM) and Geocoded IRS-ID LISS-III data with adequate field surveys. The false colour composite (1:50,000 scale) of IRS-ID LISS-III was visually interpreted to generate landform map and the same has been used as base to conduct soil resource inventory. Shallow soils with moderately deep and deep soils occupied 8.1 per cent area, whereas, deep soils along with moderately deep, deep and very deep soils registered on another 18.6 per cent area of the sub-watershed. The soils of the sub-watershed have been grouped into six drainage class associations. The land capability groupings in the study area shows that moderately good cultivated soils covered 64.6 per cent area of which 26.3 per cent has moderate limitation of erosion and soil, The land irrigability groupings indicates that about 26.3 per cent area of the sub-watershed may be used safely under irrigation. The study demonstrates the utility of remote sensing and GIS data in characterization and classification of landforms and soils in complex toposequence of Subarnarekha catchment of Chhotanagpur plateau, Eastern India.

Key words: *GIS, landforms, satellite remote sensing, soils resource mapping, toposequence, chhotanagpur plateau*

Introduction

Watershed is a geo-hydrological unit area that drains to a common point and is considered as an appropriate physical unit for natural resources evaluation, planning and management. The concept of watershed management involves accurate and timely monitoring of natural resources more particularly soil resources using available latest technologies (Reddy *et al*. 2013; Gangopadhyay *et al.* 2014; Sahu *et al.* 2014). Soil is the base for every production system and knowledge on their properties, extent and spatial distribution is extremely important. Therefore, it is imperative to maintain soil resources to sustain the ecosystem (Beckett and Webster 1971; Gessler 1996). Relationship between the landform position and pedological processes determine the soil attributes in a toposequence (Birkeland 1990; Moore *et al.* 1993; Reddy *et al.* 1999). The dynamic inter-relationship between physiography and soils is utilized while deriving information on soils from satellite data (Kudrat *et al.* 1992). The factors involved in physiographic processes more or less correspond to the factors of soil formation. The geomorphic position on a toposequence plays a vital role for classification of landforms and characterization of soils. Landform units have been used as basic landform descriptors in soil resource mapping (Speight 1990). Standard soil survey helps to gather information about soil in a systematic manner regarding their genesis, extent, potentiality, limitations to assess their potentials and limitations for specific purpose. Quantitative information and spatial distribution of soil properties are among the main pre-requisites for achieving sustainable land management. The accuracy of soil information determines, to a large extent, the reliability of land resources management decisions (Bouma 2001; Mermut and Eswaran 2001; Salehi *et al.* 2003).

Remote sensing technology has demonstrated potential of identifying, characterizing and classifying the problems and potentialities of the natural resources. Satellite remote sensing data has emerged as a vital tool in soil resource survey and generation of information, which help to evolve the optimum land use plan for sustainable development at scale ranging from regional to micro levels (Sahu *et al.* 2015). Remote sensing technology together with GIS has spined off the new dimensions in storing and retrieving the data and to arrive at optimal solution/action plans for sustainable development. In the interpretation of satellite image for soil mapping, proper identification of land type, drainage pattern and drainage condition, vegetation, land use, slope and relief is very essential (Dwivedi 2001). In recent times, satellite remote sensing and GIS techniques are being effectively used in determining the quantitative description of the terrain features and geomorphological mapping (Reddy *et al.* 2002; Reddy and Maji 2003; Vishakha *et al.* 2013). Several authors have reported that the satellite remote sensing and GIS have proved as promising tools in soil resource mapping (Srivastava and Saxena 2004; Reddy *et al*. 2013). The potential utility of remote sensing data has been well recognized in mapping and assessing land attributes such as physiography, soils, land use/land cover (Solanke *et al*. 2005; Sarkar *et al*. 2006) and integration of these attributes to compute soil erosion (Potdar *et al*. 2003). In the present study we have carried out landform analysis and characterization using remote sensing data and GIS, which was subsequently used to carry out the soil resource inventory of Simana sub-watershed, a part of the Subarnarekha catchment, Jhargram sub-division of Paschim Medinipur district, West Bengal.

Materials and Methods

Study area

The Simana sub-watershed is located in hot dry sub-humid agro-ecological region of Chhotanagpur plateau and lies between 22°27'24'' to 22°38'18'' N latitudes and 86°47'06'' to 86°54'11'' E longitudes with an area of 9100 hectare under Subarnarekha Catchment of Paschim Medinipur district, West Bengal (Fig.1). The study area represents an undulating terrain, a lateritic upland, sloping towards the Chhotanagpur plateau. The geological formation of the sub-watershed is mainly granite-gneiss of Archaen period. It is an extension of the peninsular Chhotanagpur plateau and is made up of igneous rocks of the Archaen period as well as coal-bearing mudstone and quartzite of Carboniferous period. The study area belongs to hot dry sub-humid, sub-tropical climate with mean annual rainfall ranging from 1200-1300 mm. More than 90 per cent of the mean annual rainfall is received during July to September. The monsoon rain covers more than 90 per cent of the mean annual rainfall, which attains peak during July to September. The soil moisture control section (SMCS) remains partly or fully dry during December to May qualifying for 'Ustic' soil moisture regime. The mean summer and winter temperature of the area are 32.8°C and 25.0°C, respectively. The mean annual soil temperature being more than 22°C and the difference between mean summer and mean winter soil temperature being greater than 6°C at 50 cm depth, qualifies for 'Hyperthermic' soil temperature regime. Agro-ecologically, this area belongs to Chhotanagpur plateau, hot, dry and moist, sub-humid transitional eco-sub region with 150-180 days of growing period. The natural vegetation of the study area comprises Sal (*Shorea robusta*), Arjun (*Terminalia arjuna*), Kendu (*Diospyros exsculpta*), Mahua (*Madhuca Indica*), Palash (*Butea frondosa*), Bamboo (*Banbusa balcooa*), Palm (*Norassus flabellifer*), Date palm (*Phoenix dactylifera*), Kusum (*Schrebera swietenioides*), Neem (*Azadirachta indica*) *etc.*

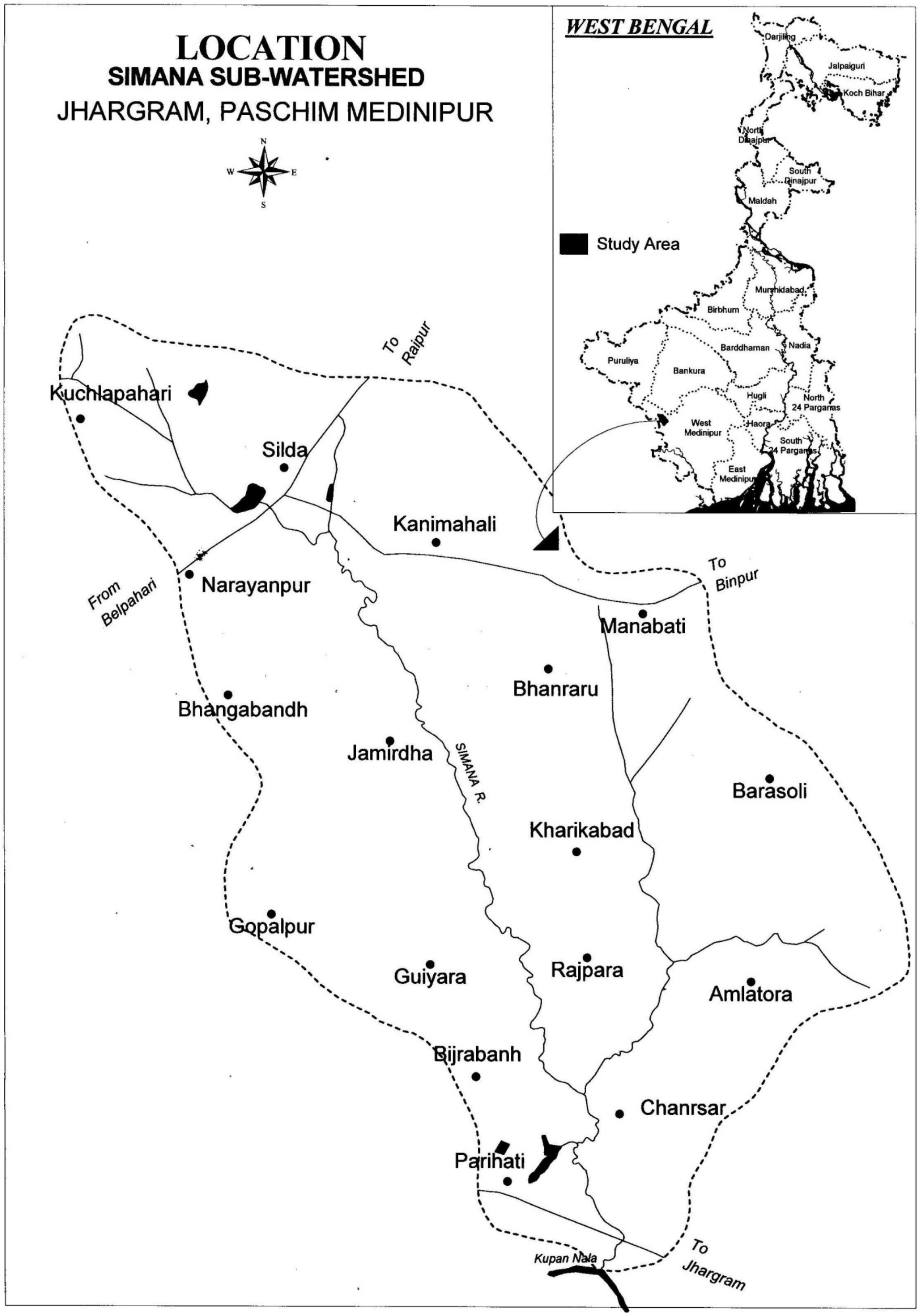

Fig. 1 Simana sub-watershed

Landforms mapping and characterization

The Geocoded IRS-ID LISS-III image (FCC) of September 2009 was visually interpreted for delineation of landform based on colour, tone, texture, size, pattern, association and field visit. IRS-ID LISS-III data has been analysed in conjunction with distinct lithological units, drainage pattern and contour information in delineation and characterization of distinct landform units (Reddy and Maji 2003). The boundary delineation of landform units has been carried out based on the changes in topographic slopes, relief patterns, crest type, drainage and image characteristics of the area. A rapid reconnaissance survey of the study area was undertaken prior to soil survey to understand the landform units and their processes, land use/land cover and their relationship with soils. It helps to derive information on landform units to establish the relationship between the image elements and landform characteristics.

Soil resource inventory and mapping

The soil resource inventory of Simana sub-watershed was carried out on 1: 50,000 scale by using the Survey of India Toposheet (73J/14), satellite imagery (FCC) and landform map as base. The information thus generated was transferred into the toposheet No. 73J/14 (1:50,000 scale) and the topobase was prepared for undertaking the soil survey following the procedure as outlined in the Soil Survey Manual. (Soil Survey Staff 1995). The standard false color composite (FCC) was generated from green, red and near infrared (NIR) spectral bands for onscreen visual interpretation in GIS to analyze the terrain features in characterization of distinct landforms for soil resource inventory and mapping in the watershed. The drainage, contour, geological units and land use/land cover types derived from toposheets and satellite imagery were also considered in delineation of different landform units. Depending upon the complexity of the terrain and land use/land cover conditions, the representative sites on different landform units in the watershed have been identified for detailed soil profile study (Reddy *et al.* 2013). The soil samples collected from different genetic horizons were air dried and analyzed for the physical and chemical properties *viz*., particle size class, pH, organic carbon, cation exchange capacity, exchangeable bases and exchangeable acidity (H^+ and Al^{3+}), available macro and micro nutrients *etc*. following standard procedures (Black 1965).

Development of soil resource database in GIS

For preparing the various thematic maps *viz*., sub-watershed boundary, drainage, water bodies, road network, contours and spot heights and soil map *etc*., the satellite data and SOI toposheets were used as inputs to Geo Media Professional GIS (Ver. 3.0) system. The maps were subsequently transformed to vector layers. These covers were projected and transformed to real world coordinates, edited, assigned polygon IDs and topopolygon was built for areas and polygons. Using the available profile-wise soil information (soil morphological and physico-chemical properties), attribute data was compiled for all the 21 mapping units of sub-watershed in GIS environment. This attribute data was linked to the spatial data. These were subsequently made into individual covers of soils by adding items in the Polygon Attribute Table (PAT) of soil coverage following map generalization procedures. These were subsequently made into individual covers using 'Dissolve Operation' thus forming different derivative layers of the study area. Thus thematic maps were prepared based on dominant and sub-dominant soil series according to their proportion in a particular soil map unit.

Interpretation of soil survey data

Soils of Simana sub-watershed have been evaluated for land capability classification following the USDA Land Capability Classification, which allocates land suited to cultivation in classes I to IV, land suited to grazing in class V-VII and forestry in class VI. Wild life and recreation is exclusively accommodated in class VIII. These classes were then divided into sub-classes based on the number and severity of several limitations. The limitations include erosion risk (e), wetness (w), rooting zone (soils) limitations (s) and climatic limitations (c). Following this criterion, based on the dominant soils of the mapping unit, the soils of the sub-watershed have been grouped in different capability classes and sub-classes *viz.*, VIe4s, IIIe2s, *etc*. The soils of the Simana sub-watershed were first grouped into soil irrigability classes according to their limitations for sustained use under irrigation, regardless of their location. The classes are defined in terms of degree of soil limitations. Soil irrigability classification is made on the basis of important soil characteristics *viz.* soil texture, depth, available water holding capacity, infiltration and permeability.

Results and Discussion

Analysis and characterization of landforms

The study of slope classes indicate that moderately sloping class alone covered 53.2 per cent area followed by gently sloping-moderately sloping association occupying 18.6 per cent area of the sub-watershed. Gently sloping along with moderately sloping and gently sloping slope class occupies 30.9 per cent area while very gently sloping along with the gently sloping slope class covers 7.4 per cent area of the sub-watershed and moderately steep sloping along with moderately sloping slope class occupies 8.2 per cent area of the sub-watershed. Based on the visual interpretation of the satellite imagery (IRS-ID LISS-III) generated from spectral bands 2,3 and 4 in conjugation with detailed ground truth data, five landform units were identified *viz.*, (1) moderately steeply sloping upland (2) moderately sloping undulating upland (3) moderately sloping terraced land (4) gently sloping low land and (5) narrow valley bottom (**Fig. 2a**). The image interpretation based on the photo-elements is presented in Table 1. The soil series association, soil depth and surface texture maps of the watershed are shown in figure 2b, 2c and 2d, respectively.

Table 1. Landform units and their image characteristics in Simana sub-watershed

Landform Unit	Tone	Texture	Size	Pattern	Association	Area (in ha)	% of TGA
Moderately steeply sloping upland	Dark blue, greenish yellow, white mixed with pinkish red	Fine to medium	Varying	Continuous elongated	Associated with elevated land, mostly gravelly, fallow; partly under plantation forest and cultivated for shallow rooted vegetable crops	744.3	8.2
Moderately sloping undulating upland	Dark red, pink mixed with white, blue, light gray and greenish yellow	Medium to coarse	Varying	Continuous elongated	Associated with moderately sloping up land cultivated for rainfed upland rice, maize, groundnut in kharif; partly cultivated for vegetables in rabi season and partly under plantation forest	2449.6	26.9
Moderately sloping terraced land	White, yellowish green, dull bluish gray, dark red and pink mixed	Coarse	Varying	Continuous elongated	Associated with terraced land, mostly cultivated for paddy, maize in kharif season; vegetables and mustard/sesame in rabi season	2390.7	26.3

Gently sloping low land	White, light blue, yellow, green and pink mixed	Medium to coarse	Varying	Continuous	Associated with low lying areas, overflows during kharif season and used for paddy cultivation in kharif season, partly cultivated for paddy in rabi season and pisciculture in the seepage tank constructed in this areas	2814.1	30.9
Narrow valley bottom	Pinkish red, light blue, yellowish gray and white mixed.	Medium to coarse	Varying	Continuous elongated	Associated with low lying areas, overflows during kharif season and used for paddy cultivation in both kharif and rabi season and vegetables in rabi season	670.3	7.4
Miscellaneous						31.0	0.3
Total						**9100.0**	**100.0**

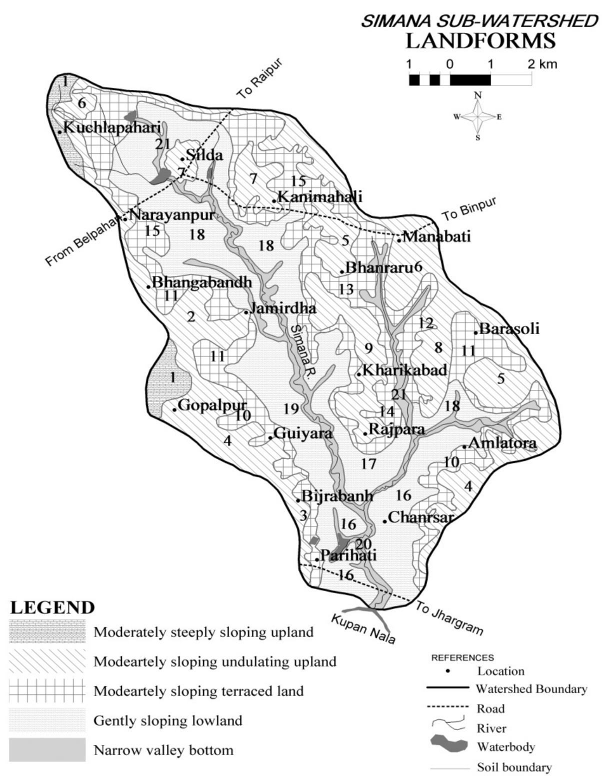

Fig. 2a Lanform map of Simana sub-watershed

Characterization and classification of soils in a toposequence

The development of soils on a toposequence often follows the way water moves through/ over the landscape. Based on the landform-soil relationship, twenty soil series have been identified and mapped as soil series associations in the sub-watershed (Fig. 2b). Soil physical and chemical properties are presented in Table 2. Soils of sub-watershed have been classified according to the criteria proposed by Soil Taxonomy up to family level (Table 3).

Table 2. Soil mapping units and their description

Soil mapping unit	Soil series association	Soil classification (Subgroup level)	Proportion of series in association	Area (ha)	% of TGA
1	Jaypur – Amlatora-1	*Lithic Ustorthents - Typic Rhodustalfs*	70: 30	223. 9	2. 5
2	Moitoria –Sarengasoli-1	*Lithic Ustorthents - Typic Haplustalfs*	60: 40	432. 4	4.8
3	Jaypur -Rangametya	*Lithic Ustorthents - Typic Rhodustalfs*	70: 30	88.0	1.0
4	Amlatora-1-Sarengasoli–1	*Typic Rhodustalfs- Typic Haplustalfs*	60:40	459. 9	5. 0
5	Kitajhuri 1 –Rangametya	*Typic Haplustalfs- Typic Rhodustalfs*	60:40	507. 9	5. 6
6	Sarengasoli-1 - Salgariya	*Typic Rhodustalfs- Typic Dystrustepts*	60:40	750.1	8. 2
7	Silda -Sarengasoli -1	*Typic Ustorthents- Typic Haplustalfs*	70: 30	214.7	2. 4
8	Rangametya -Salgariya	*Typic Rhodustalfs- Typic Dystrustepts*	60: 40	177. 4	1. 9
9	Kalaberia -Sarengasoli -1	*Typic Paleustalfs- Typic Haplustalfs*	60:40	339.6	3.7
10	Kitajhuri-2 -Dhobakuriya	*Typic Haplustalfs*- *Aeric Epiaquepts*	60:40	437.5	4.8
11	Amlatora 2 –Kitajhuri 2	*Aquic Haplustalfs- Typic Haplustalfs*	70: 30	533. 6	5. 9
12	Amlatora 2 - Mahulbani	*Aeric Endoaqualfs.- Oxyaquic Haplustalfs*	60:40	130.5	1.4
13	Mahulbani -Kitajhuri 2	*Oxyaquic Haplustalfs- Typic Haplustalfs*	60:40	196.7	2.2
14	Rajpara-Amlatora 2	*Aeric Endoaqualfs- Aeric Endoaqualfs.*	70:30	197.1	2.2
15	Dhobakuriya-Mahulbani	*Aeric Epiaquepts- Oxyaquic Haplustalfs*	70:30	895.3	9.8
16	Sarengasoli 2 –Amlatora 3	*Aeric Endoaqualfs*- *Fluvantic Haplustepts*	60:40	681.2	7.5
17	Amlatora 3 - Dhobakuriya	*Fluvantic Haplustepts- Aeric Epiaquepts*	60 : 40	363. 6	4. 0
18	Sarengasoli 2-Dhobakuriya	*Aeric Endoaqualfs- Aeric Epiaquepts*	60:40	1330.6	14.6
19	Amlatora 3 -Beniadihi	*Fluvantic Haplustepts - Typic Endoaquepts*	70: 30	438.7	4. 8
20	Bhursatora – Nachda	*Typic Endoaqualfs- Aeric Endoaquepts.*	60:40	244.6	2.7
21	Jamirdiha-Bhursatora	*Typic Epiaquepts- Typic Endoaqualfs*	60:40	425.7	4.7
	Miscellaneous			31.0	0.3
Total				**9100.0**	**100.0**

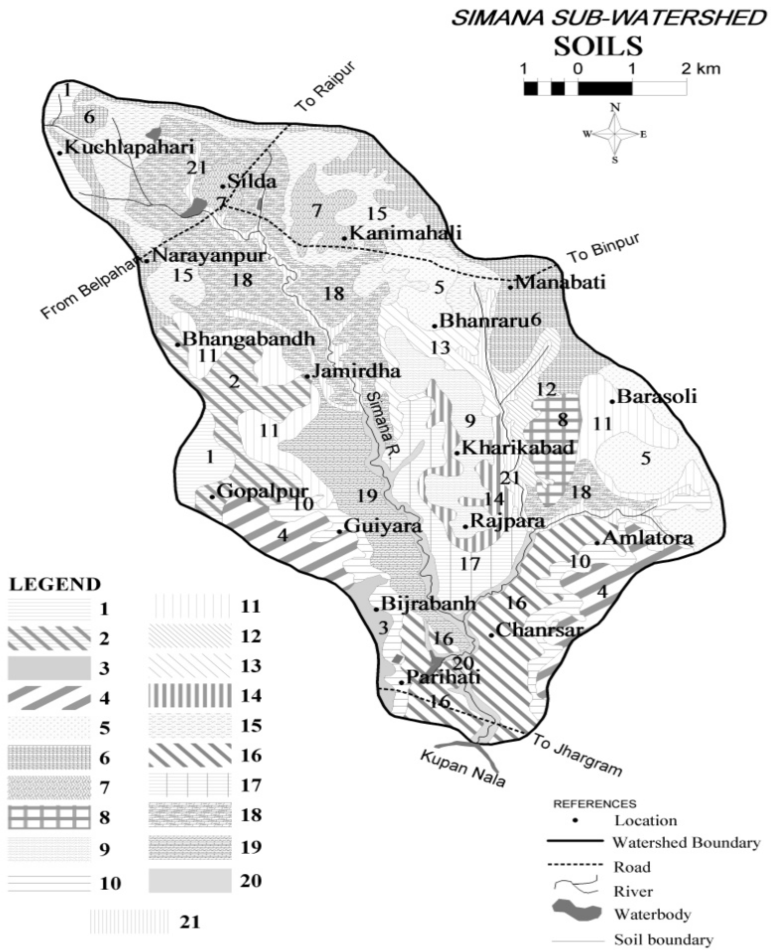

Fig. 2 b Soil map of Simana sub-watershed

Table 3. Physical properties of soils of Simana sub- watershed

Horizon	Depth (cm)	Particle size distribution (%)			Bulk density (Mg m^{-3})	Moisture retentions		AWC (%)
		Sand	Silt	Clay		0.3 Mpa	1.5 Mpa	
Jaypur series (Loamy- skeletal, mixed, hyperthermic family of *Lithic Ustorthents*) on steeply sloping upland								
A	0-11	49.5	33.3	17.2	1.6	30.2	11.8	18.4
Cr	11-35	Weathered parent materials						
Moitoria series (Coarse- loamy, mixed, hyperthermic family of *Lithic Ustorthents*) on steeply sloping upland								
Ap	0-19	50.1	38.4	11.5	1.8	28.6	9.8	18.8
Cr	19-40	Weathered parent materials						
Amlatora-1 series (Loamy-skeletal, mixed, hyperthermic, family of *Typic Rhodustalfs*) on moderately sloping upland.								
A	0-11	52.2	29.3	18.5	1.6	36.5	18.9	17.6
Bt1	11-27	48.2	26.5	25.3	1.7	37.0	19.2	17.8
Bt2	27-45	45.6	20.6	33.8	1.8	39.3	20.1	19.2
Cr	45-80	Weathered parent materials						
Sarengasoili-1 series (Fine-loamy, mixed, hyperthermic family of *Typic Haplustalfs*) on moderately sloping upland.								
A	0-13	61.3	30.2	8.5	1.5	32.5	17.5	15.0
Bt1	13-38	46.9	29.0	24.1	1.6	33.1	17.7	15.4
Bt2	38-60	52.8	22.0	25.2	1.7	34.5	18.0	16.5

Cr	60-90	Weathered parent materials						
Kitajhuri-1 series (Fine- loamy, mixed, hyperthermic family of *Typic Haplustalfs*) . on moderately sloping upland.								
A1	0-13	54.8	24.5	20.7	1.6	34.6	18.3	16.3
A2	13-35	47.9	33.2	18.9	1.7	35.0	18.6	16.4
Bt1	35-60	43.9	29.0	27.1	1.8	36.8	19.6	17.2
Bt2	60-90	44.5	25.2	30.3	1.9	39.0	21.5	17.5
Bt3	90-130	45.4	24.7	29.9	1.9	40.3	21.8	18.5
Rangametya series (Fine- loamy, mixed, hyperthermic family of *Typic Rhodustalfs*) on moderately sloping upland								
A	0-13	61.9	29.4	8.7	1.6	35.5	19.8	15.7
Bt1	13-38	53.5	27.1	19.4	1.7	35.9	19.8	16.1
Bt2	38-66	46.1	26.6	27.3	1.8	37.2	20.1	17.1
Bt3	66-98	48.6	25.2	26.2	1.8	39.7	21.9	17.8
Bt4	98-130	53.5	22.2	24.3	1.8	38.6	20.0	18.6
Salgariya series (Fine- loamy, mixed, hyperthermic family of *Typic Dystrustepts*) on moderately sloping upland								
Ap	0-13	43.5	28.6	27.9	1.5	36.4	19.2	17.2
Bw1	13-34	41.3	29.4	29.3	1.6	37.4	19.8	17.6
Bw2	34-60	50.7	25.8	23.5	1.8	38.0	20.2	17.8
Cr	60-90	----------------------- Weathered parent materials --------------------						
Silda series (Coarse- loamy, mixed, hyperthermic family of *Typic Ustorthents*) on moderately sloping upland								
A	0-9	35.8	47.4	16.8	1.8	30.2	18.5	11.7
Cr	9-55	------------------- Weathered parent materials --------------------						
Kalaberia series (Fine, mixed, hyperthermic family of *Typic Paleustalfs*) on moderately sloping upland								
A	0-11	58.2	21.8	20.0	1.7	36.4	19.2	17.2
Bt1	11-35	49.6	17.9	32.5	1.8	37.0	19.6	17.4
Bt2	35-65	43.7	22.9	33.4	1.8	38.5	20.4	18.1
Bt3	65-105	44.5	18.1	37.4	1.9	39.2	20.7	18.5
Bt4	105-150	41.3	19.7	39.0	1.9	40.0	21.2	18.8
Kitajhuri-2 series (Fine-loamy, mixed, hyperthermic family of *Typic Haplustalfs*) on moderately sloping terraced land								
Ap	0-13	34.8	45.8	19.4	1.6	34.5	18.9	15.6
Bt1	13-35	43.8	30.7	25.5	1.7	35.2	19.1	16.1
Bt2	35-70	37.0	30.5	32.5	1.7	36.0	19.2	16.8
Bt3	70-115	40.5	27.1	32.4	1.8	38.6	19.5	19.1
Bt4	115-150	37.2	27.5	35.3	1.9	39.1	19.8	19.3
Amlatora-2 series (Fine- loamy, mixed, hyperthermic family of *Aquic Haplustalfs*) on moderately sloping terraced land								
Ap	0-11	44.1	31.5	24.4	1.6	35.8	19.2	16.6
A2	11-30	58.5	25.8	15.7	1.7	36.1	19.0	17.1
Bt1	30-55	43.0	20.9	36.1	1.7	37.2	19.6	17.6
Bt2g	55-85	44.3	31.6	24.1	1.8	37.6	19.9	17.9
BCg	85-130	68.9	15.5	15.6	1.8	38.1	20.1	18.0
Dhobakuria series (Fine- loamy, mixed, hyperthermic family of *Aeric Epiaquepts*) on moderately sloping terraced land								
Ap	0-14	40.1	23.3	36.6	1.7	38.5	19.3	19.2
Bw1	14-45	55.2	16.9	27.9	1.8	38.8	19.4	19.4
Bw2	45-75	48.7	29.9	21.4	1.8	39.1	19.5	19.6
Bw3	75-120	49.6	28.8	21.6	1.9	39.8	19.8	20.0
Bw4	120-150	43.9	30.2	25.9	1.9	40.5	19.9	20.6
The Mahulbani- series (Fine-loamy, mixed, hyperthermic family of *Oxyaquic Haplustalfs*) on moderately sloping terraced land								
Ap	0-15	50.2	31.7	18.1	1.8	38.5	19.6	18.9
Bt1	15-40	50.2	18.9	30.9	1.8	38.9	19.7	19.2
Bt2	40-75	62.8	11.5	25.7	1.9	39.4	19.9	19.5
Bt3	75-105	43.1	29.6	27.3	1.9	39.6	20.0	19.6
Bt4	105-155	48.8	14.2	37.0	2.0	40.1	20.4	19.7
Rajpara series (Fine, mixed, hyperthermic family of *Aeric Endoaqualfs*) on moderately sloping terraced land								
Ap	0-12	14.1	51.2	34.7	1.6	35.6	18.2	16.4
A12g	12-35	11.1	50.8	38.1	1.6	35.8	18.6	17.2
Bt1g	35-75	10.7	48.0	41.3	1.7	37.5	19.0	18.5
Bt2g	75-120	12.8	50.5	36.7	1.7	37.9	19.4	18.5
Bt3g	120-160	26.1	41.4	32.5	1.8	38.6	19.8	18.8

Sarengasoli -2 series (Fine, mixed, hyperthermic family of *Aeric Endoaqualfs*) on gently sloping low land								
Ap	0-15	26.6	50.5	22.9	1.7	36.7	17.5	19.2
Bt1g	15-40	24.5	39.2	36.3	1.8	37.2	17.8	19.4
Bt2g	40-75	17.3	36.6	46.1	1.8	38.5	18.6	19.9
Bt3g	75-120	12.1	39.6	48.3	1.9	39.0	18.9	20.1
Bt4g	120-150	9.9	37.9	52.2	1.9	39.8	19.2	20.6
Amlatora-3 series (Coarse- loamy, mixed, hyperthermic family of *Fluventic Haplustepts*) on gently sloping low land								
Ap	0-14	49.5	26.5	24.0	1.6	30.8	12.3	17.5
A2	14-38	69.8	17.3	12.9	1.7	31.5	12.8	18.7
Bw1	38-75	67.8	16.6	15.6	1.7	32.3	13.5	18.8
Bw2	75-125	64.1	21.5	14.4	1.7	33.4	13.8	19.6
Bw3	125-160	51.5	29.3	19.2	1.8	34.0	14.2	19.8
Beniadihi series (Fine- loamy, mixed, hyperthermic family of *Typic Endoaquepts*) on gently sloping low land								
Ap	0-13	49.6	29.4	21.0	1.6	35.8	17.2	17.6
Bw1g	13-40	47.1	23.7	29.2	1.7	36.1	17.7	18.4
2Bw2g	40-75	48.2	30.2	21.6	1.7	36.6	17.8	18.8
3Bw3g	75-110	57.7	17.4	24.9	1.8	37.6	18.1	19.5
4Bw4g	110-155	68.3	16.8	14.9	1.8	38.1	18.5	19.6
Bhursatora series (Fine, mixed, hyperthermic family of *Typic Endoaqualfs*) on gently sloping narrow valley bottom								
Ap	0-13	27.8	58.1	14.1	1.7	36.8	19.6	17.2
Bt1g	13-40	24.3	39.7	36.0	1.8	37.5	19.6	17.9
Bt2g	40-75	23.1	34.7	42.2	1.9	38.8	20.4	18.4
Bt3g	75-105	22.5	35.2	42.3	1.9	39.5	20.9	18.6
Bt4g	105-150	20.0	38.0	42.0	2.0	39.8	20.9	18.9
Nachda series (Fine, mixed, hyperthermic family of *Aeric Endoaquepts*) on gently sloping narrow valley bottom								
Ap	0-14	9.5	52.5	38.0	1.7	36.7	18.5	18.2
Bw1	14-38	10.8	48.0	41.2	1.8	37.2	18.8	18.4
Bw2g	38-78	10.2	46.3	43.5	1.8	38.5	19.6	18.9
Bw3g	78-115	11.2	43.1	45.7	1.9	39.0	20.0	19.0
Bw4g	115-150	8.9	42.6	48.5	2.0	39.8	19.2	20.6
Jamirdiha series (Fine, mixed, hyperthermic family of *Typic Epiaquepts*) on gently sloping narrow valley bottom								
Ap	0-13	14.5	51.3	34.2	1.8	38.5	20.2	18.3
Bw1	13-40	13.4	50.8	35.8	1.9	38.8	20.5	18.3
Bw2g	40-85	10.0	48.5	41.5	1.9	39.5	20.8	18.7
Bw3g	85-120	11.1	45.2	43.7	2.0	40.5	21.2	19.3
Bw4g	120-155	12.6	41.6	45.8	2.0	40.8	21.5	19.5

Soils of moderately steeply sloping upland

The soils of the moderately steeply sloping uplands were gravelly, very shallow to shallow, well to somewhat excessively drained, brown to dark red, gravelly loam to sandy loam rest on weathered parent materials, supporting quick growing forest species *viz*. Eucalyptus, Akashmoni *etc*. or pasture land/cultivation of shallow rooted vegetables. These were mapped as Jaypur, Moitoria series, which were classified as a member of loamy-skeletal, mixed hyperthermic family of *Lithic Ustorthents* and coarse-loamy, mixed hyperthermic family of *Lithic Ustorthents* sub groups of Entisol soil orders, respectively. These soils were subjected to serious erosional problems and were extensively mapped under wasteland, open shrubs and forest vegetation. Terrain condition, shallow depth, gravelly nature are the major constraints of these soils.

Soils of moderately sloping undulating upland

The soils of the moderately sloping undulating uplands were moderately deep to deep, well drained, dark yellowish brown to dark brown, sandy loam to sandy clay loam on the surface; strong brown to red, clay loam to sandy clay loam soils in the sub-surface. These were covered with plantation forest/forest species dominantly and were cultivated at places for cashew and vegetables. Soils were grouped with Sarengasoli, Amlatora-1, Kitajhuri, Rangamatya, Salgeriya, Kalaberia soil series, which were classified as members of fine-loamy, mixed, hyperthermic family of *Typic Haplustalfs*; loamy-skeletal, mixed, hyperthermic family of *Typic Rhodustalfs*, fine-loamy, mixed, hyperthermic family of *Typic Rhodustalfs*; fine-loamy, mixed, hyperthermic family of *Typic Dystrustepts* and fine, mixed, hyperthermic family of *Typic Paleustalfs* of Alfisol, and Inceptisol soil orders. Undulating topography, coarser soil texture, low ground water level are the major constraints of these soils.

Soils of moderately sloping terraced land

Soils of moderately sloping terraced lands were deep to very deep, moderately well to imperfectly drained, light yellowish brown to gray brown, loam to sandy clay loam on the surface, brown to light brownish gray, sandy loam to sandy clay in the sub-surface. These were supported by summer and winter paddy, maize, mustard and vegetables *etc*. Soils have medium to high available water capacity and were moderately eroded. Soils were grouped with Mahulbani, Kitajhuri-2, Amlatora-2 soil series, which were classified as members of fine-loamy, mixed, hyperthermic family of *Oxy-aquic Haplustalfs*; fine-loamy, mixed, hyperthermic family of *Typic Haplustalfs* and fine-loamy, mixed, hyperthermic family of *Aquic Haplustalfs* sub-groups respectively of Alfisol soil orders. Coarser surface texture, imperfect drainage and low fertility are the major constraints of these soils.

Soils of gently sloping low land

Soils of gently sloping low lands were deep to very deep, moderately well to poorly drained, light grayish brown to light brownish gray, sandy loam to silt loam on the surface, light brownish gray to dark gray brown and sandy loam to clay in the sub-surface with redoximorphic features. These are cultivated for summer and winter paddy, vegetables and linseed. Soils have high available water capacity and are slight to moderately eroded. Soils were grouped with Sarengasoli-2, Amlatora-3, Dhobakuriya, Beniyadihi, Rajpara soil series, which were classified as members of fine, mixed, hyperthermic family of *Aeric Endoaqualfs*; coarse-loamy, mixed, hyperthermic family of *Fluventic Haplustepts*; fine-loamy, mixed, hyperthermic family of *Aeric Epiaquepts*; fine-loamy, mixed, hyperthermic family of *Typic Endoaquepts*; fine, mixed, hyperthermic family of *Aeric Endoaqualfs* respectively in Alfisol and Inceptisol soil orders. Heavy texture, excess moisture in the post monsoon season, poor drainage etc. are the major constraints for agricultural production.

Soils of narrow valley bottom

Soils of narrow valley bottoms were deep to very deep, imperfectly to poorly drained, light brownish gray to yellowish brown, silt loam to silty clay loam on the surface, light brown to gray brown, clay loam to silty clay in the sub-surface with redoximorphic features. These were used mainly for summer and winter paddy. Soils have high available water capacity and slight erosion problems. Impaired internal drainage of these soils was the major problem which restricted the choice of crops. Soils were grouped with Bhursatora, Nachda, Jamirdiha soil series, which were classified as the members of fine, mixed, hyperthermic family of Typic Endoaqualfs; fine, mixed, hyperthermic family of Aeric Endoaquepts and fine, mixed, hyperthermic family of Typic Epiaquepts sub-groups, respectively in Alfisol and Inceptisol soil orders. Heavy texture, excess moisture in the post monsoon season, poor drainage, high ground water level is the major constraints for agricultural production.

Land capability classification

The land capability groupings study in the study area indicates that moderately good cultivated soils covered 64.6 per cent area of which 26.3 per cent was affected with moderate limitation of erosion and soil, whereas extent of moderate limitations of wetness and flooding was 38.3 per cent. Steep land and fairly good land occupied 15.6 and 19.5 per cent area in the sub-watershed. The land capability classes and land capability sub-classes are shown in figure 2e and table 4.

Table 4. Land capability classification in Simana sub-watershed.

Land Capability Subclass	Description	Soil Map Units	Area	
			Area (in ha.)	(%) of TGA
VIe_4s	Steep land, shallow to moderately deep soils on moderately to moderately steeply sloping gravelly upland; productivity is limited by severe erosion, rapid runoff, low moisture holding capacity and nutrient reserve; suitable for grazing or forestry or both	1,2,3,4, 7	1418.9	15.6
IVe_2s	Fairly good land, moderately deep to deep soils on moderately sloping undulating upland; productivity is limited by moderate erosion, low moisture holding capacity, nutrient reserve; suitable for and occasional cultivation in rotation with forestry or pasture or orchards	5, 6, 8,9	1775.0	19.5
$IIIe_2s$	Moderately good cultivable land, good soil on moderately sloping terraced land subjected to water erosion and moderate problems of soils and suitable for cultivation with careful selection of crops adapted to soil limitations	10,11,12,1 3, 14, 15	2390.7	26.3
$IIIw_2$	Moderately good cultivated land, good soil on gently sloping low land and narrow valley with moderate limitation of wetness; suitable for cultivation with careful management of excess water and selection of crops adapted to wet condition	16, 17, 18,19, 20,21	3484.4	38.3
	Miscellaneous		31.0	0.3
Total			**9100.0**	**100.0**

Land irrigability classification

The land irrigability groupings indicates that about 26.3 per cent area of the sub-watershed may be used safely under irrigation. The steeply sloping land covering 8.2 per cent area, were not recommended for sustained use under irrigation. About 38.3 per cent area represents lands possessing severe limitations of drainage and soil while lands with moderate limitations of drainage and soil covered 26.3 per cent area of the sub-watershed. The moderately sloping upland, covering 26.9 per cent area, can be accommodated for sustained use under irrigation provided proper soil and water conservation measures are adopted. The land irrigability classes and irrigability sub-classes are shown in figure 2e and table 5.

Table 5. Land irrigability classification in Simana sub-watershed

Land Irrigability Sub-class	Soil Irrigability Sub-class	Description	Soil Map Unit	Area	
				Mapping area (in ha.)	(%) TGA
2ds	B	Lands that have moderate limitations of drainage and soils for sustained use under irrigation.	10,11,12, 13,14,15	2390.7	26.3
3ds	C	Lands that have severe limitations of both drainage and soils for sustained use under irrigation.	16,17,18, 19,20,21	3484.4	38.3
3ts	D	Lands that have severe limitations for sustained use under irrigation due to unfavorable topography, soil depth, texture, permeability etc.	4,5,6,7,8,9	2449.6	26.9
4ts	E	Lands that are marginal for sustained use under irrigation due to unfavorable topography, soil depth, texture, permeability etc	1, 2, 3	744.3	8.2
		Miscellaneous		331.0	0.3
			Total	**9100.0**	**100.0**

Soil-landform relationship

The soils of the moderately steeply sloping uplands were gravelly, very shallow to shallow, well to somewhat excessively drained and these soils were subjected to serious erosional problems and were extensively mapped under wasteland, open shrubs and forest vegetation. The soils of the moderately sloping undulating uplands were moderately deep to deep, well drained, and these were covered with plantation forest/forest species dominantly and were cultivated at places for cashew and vegetables. Soils of moderately sloping terraced lands were deep to very deep, moderately well to imperfectly drained and these were supported by summer and winter paddy, maize, mustard and vegetables *etc*. Soils have medium to high available water capacity and were moderately eroded. Soils of gently sloping low lands were deep to very deep, moderately well to poorly drained, and these were cultivated for summer and winter paddy, vegetables and linseed. Soils have high available water capacity and were slight to moderately eroded. Soils of narrow valley bottoms were deep to very deep, imperfectly to poorly drained, and these were used mainly for summer and winter paddy. Soils have high available water capacity and slight erosion problems. Impaired internal drainage of these soils was the major problem which restricted the choice of crops.

Conclusions

The study reveals that terrain characterization through analysis of ASTER (30m) data for broad landform units and high resolution IRS-1D LISS-III satellite data in GIS environment with necessary field verifications will be of immense help in deriving reliable information on distinct landform units in a toposequence. The soils in the sub-watershed were grouped under the Order Inceptisols, Alfisols and Entisols. The analysis of landform-soil relationship indicates that topographic position governs soil depth, surface drainage, AWC and chemical properties like OC, pH as well as their differential distribution within the soil profile. The present study has given an insight into the problems and potentials of the soils in the study area with respect to the characteristics of soils under different landforms. The result indicated that soils developed under different landforms of the complex terrain of Subarnarekha catchment of Chhotanagpur plateau differ widely in depth, erosion, drainage and land use. The study further reveals that shallow, skeletal soils on moderately steeply sloping upland are under severe threat of degradation and need to be protected through afforestation, bench terracing etc. Strongly to moderately acidic, sandy loam to sandy clay loam soils having low fertility status on moderately sloping undulating upland may be improved through the addition of organic matter, growing leguminous crop and thereby enhancing soil health and productivity. The deep to very deep, fine soils of the gently sloping low land and narrow valley may be conserved through the adoption of appropriate soil and water conservation measures and the excess moisture can be stored in the seepage tanks, which can be reused for rabi cultivation/ fish (pron) cultivation. The study demonstrates the utility of remote sensing data and GIS technologies supplemented with sufficient ground truth as an efficient and effective way in terrain characterization and soil resource inventory in a toposequence in the complex terrain of Subarnarekha catchment of Chhotanagpur plateau and establish soil–landform relationship to characterize the landform and soil properties, which in turn can efficiently be utilized for conservation and management of the soils for increasing productivity.

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