Chapter 7
Soil Resource Inventory for Meeting Challenges of Land Degradation: A Remote Sensing Approach

Dinesh Kumar Tripathi

Abstract In this study an attempt has been made to delineate, map out, and generate database on soil resources for meeting challenges of land degradation in irrigated agro-ecosystem using geospatial tools of remote sensing (RS) and geographic information system (GIS). Gauriganj block, Amethi district (lies between 26° 7′5″ N to 26° 19′5″ N latitudes and 81° 36′45″ E to 81° 45′18″ E longitudes), Uttar Pradesh was selected for study. The space born multispectral Landsat 7 ETM+data of year, 2014 and corresponding survey of India Topographical sheets numbered 63 F/11, 63 F/12, and 63 F/16 were applied for soil survey. The satellite image of the study area was processed using standard visual image interpretation approach incorporating field check and attribute data in ERDAS imagine 9.1 and ARC view 3.2a software. Digital image processing techniques were also applied for generation ad-on-data for visual image interpretation. On the basis of satellite image analysis and information regarding soil surveys conducted earlier under Sharda Sahayak C.A.D project (1988) Lucknow (U.P.), entire study area was classified into 83 soil interpretation units. The database on both units was generated in GIS environment considering USDA soils classification system. The soils of the study area were grouped into two orders, four sub-orders, five great groups, six subgroups, five families, and seven series. The study reveals that the RS and GIS techniques can be used in an effective manner in soil resource investigation and mapping. This study may prove a better input in proper management of degraded lands in the study area.

Keywords Remote sensing · Geographic information system · Landsat 7 ETM+data · ERDAS imagine 9.1 · Arc view 3.2a · Field check · Soil interpretation units

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7.1 Introduction

Soils are fundamental to the well-being and productivity of agricultural and natural ecosystems (Singer and Ewing 2000). It is finite, fragile, and nonrenewable natural resource (Lal 1995). The continuous deterioration of their quality due to land degradation processes in agro-ecosystem has been an issue of global concern because it poses a serious threat to human well-being. In agriculture-based countries like India, it is a great challenge before scientists, researchers, and decision-makers. Over exploitation of soil resources without understanding its sustainable limit has caused extensive soil degradation and causing serious threat to present and future agricultural growth and sustainability. In a developing country like India where agriculture is a main stay of the economy, soil degradation has emerged as a serious threat. As per the reports of the Department of Agriculture and Co-operation (DAC 1994), all the various categories of degraded land were spread over about 107 million hectares area. It is estimated that six billion tons of soils are eroded from crop land each year (Narayan and Babu 1983). In some studies, it is accounted that about sixty percent cropped soil in India is affected from degradation problems (Sehgal and Abrol 1994; Mandal and Mandal 1996; Biswas et al. 1999) and has become incapable to produce the adequate food for sustainable livelihood of people distributed on it. About 40% of the total degraded soils of the country are still under cultivation which is an indication of environmental ignorance as well as farming compulsion of the peoples who are engaged in a perpetual war of friction with land resources. On the other hand today the population has exceeded one billion and by 2025 at the current growth rate of 1.6%, it would be 1.37 billion. Four hundred million tons of food grain would be needed to feed this population (Patil 2003). It would therefore be necessary to plan the proper management of land resource considering sustainability measures. The reliable and up-to-date information on spatial extent, property, and limitations of soil resources is a prerequisite for soil resource conservation and land degradation management in any region. Proper inventory and mapping of soils serve to gain spatial information on the soil resources and primarily help in solving agro-ecological and land resource management problems for any region.

The conventional soil survey and mapping techniques are expensive, tedious, and time-consuming task. It needs a number of in situ measurements to locate soil boundaries. In the recent years, as both RS and GIS are cost effective and technologically sound geospatial tools, they have emerged as popular viable substitutes. Rawashdeh and Saleh (2006) offer permanent and authentic record of spatial patterns (Prakash and Gupta 1998). These techniques have been proved to be most efficient, economical, and reliable for comprehensive inventory of soil resourses and land use pattern. RS data helps detection of soil boundaries admirably because of variations in spectral response of the different soils, attributable to their varied physical make-up and chemical composition (Karale 1992). The spectral reflectance of soil is governed by its properties such as color, texture, organic matter, and minerals. The collection of information on these characteristics differences by remote sensing techniques reduces fieldwork, overcomes errors associated with subjectivity and is able to generate soil map of inaccessible areas.

In India, several studies were carried out on soil survey in deferent regions using aerial photographs (Karale et al. 1970). During early 1980s satellite RS techniques which were used in soil mapping, attracted the attention of scholars and researchers. Initially, works on soil resource mapping using satellite data were carried out by Mirajkar and Srinivasan (1975), NRSA (1976, 1978, 1979, 1981) Venkataratnam and Rao (1977) and Venkataratnam (1980). Several scholars used digital image processing techniques in soil surveys and demonstrated its potential (Venkatratnam 1980), Kudrat et al. (1990), Karale (1992), Ravisankar and Thamappa (2004), Rao et al. (2004) and Milind et al. (2011). Simultaneously, several GIS modeling techniques were also used by scholars to draw reliable and useful informations from soil maps (Kudrat et al. 1990; Saha et al. 1991; Kudrat et al. 1995, 1997). Keeping these in view, a micro level soil inventory was carried out in the Gauriganj block, Amethi district, Uttar Pradesh (India), to generate database on soil resources using modern geospatial tools of RS and GIS. Present study is aimed to identify and delineate the soil units using Landsat 7 ETM+image (2014) and collateral data, map out the soil resources in ERDAS Imagine 9.1, and Arc GIS 9.3 software adopting USDA soils classification system, generate village level database on soil types for land degradation management and analyze spatial pattern of soil types in the study area.

7.2 Study Area

The study area has been undertaken in Gauriganj block (falls between latitude 26° 7′5″ to 26° 10′5″ N and longitude 81° 36′45″ to 81° 45′18″ E) of Amethi district, Uttar Pradesh, India (Fig. 7.1) which lies in the middle Ganga plain. It covers an area of 207.56 km^2, characterized by an even and featureless plain, composed of deep and fertile alluvial deposits. The area falls under typical tropical, semiarid, monsoonal type of climate. The hot and dry summer, hot rainy season, warm autumn and cool winter is its characteristics (Mishra and Sharma 2003). The area receives 977 mm average annual rainfall mainly in rainy season between the months of July and September (Sharma et al. 2001) whereas the winter receives irregular and scanty rainfall. The average annual minimum and maximum temperature in the study area is recorded as 4.10 °C and 47.5 °C, respectively. Soil Survey Staff (1994) has classified soils of this area as "Aquic Petrocalcic Natrustalf" and accumulation of salts above the soil surface is the main feature in a large area. The block is economically underprivileged and majority of the population (about 80%) earns livelihood through agricultural and allied activities. Land degradation is a major environmental issue in this area.

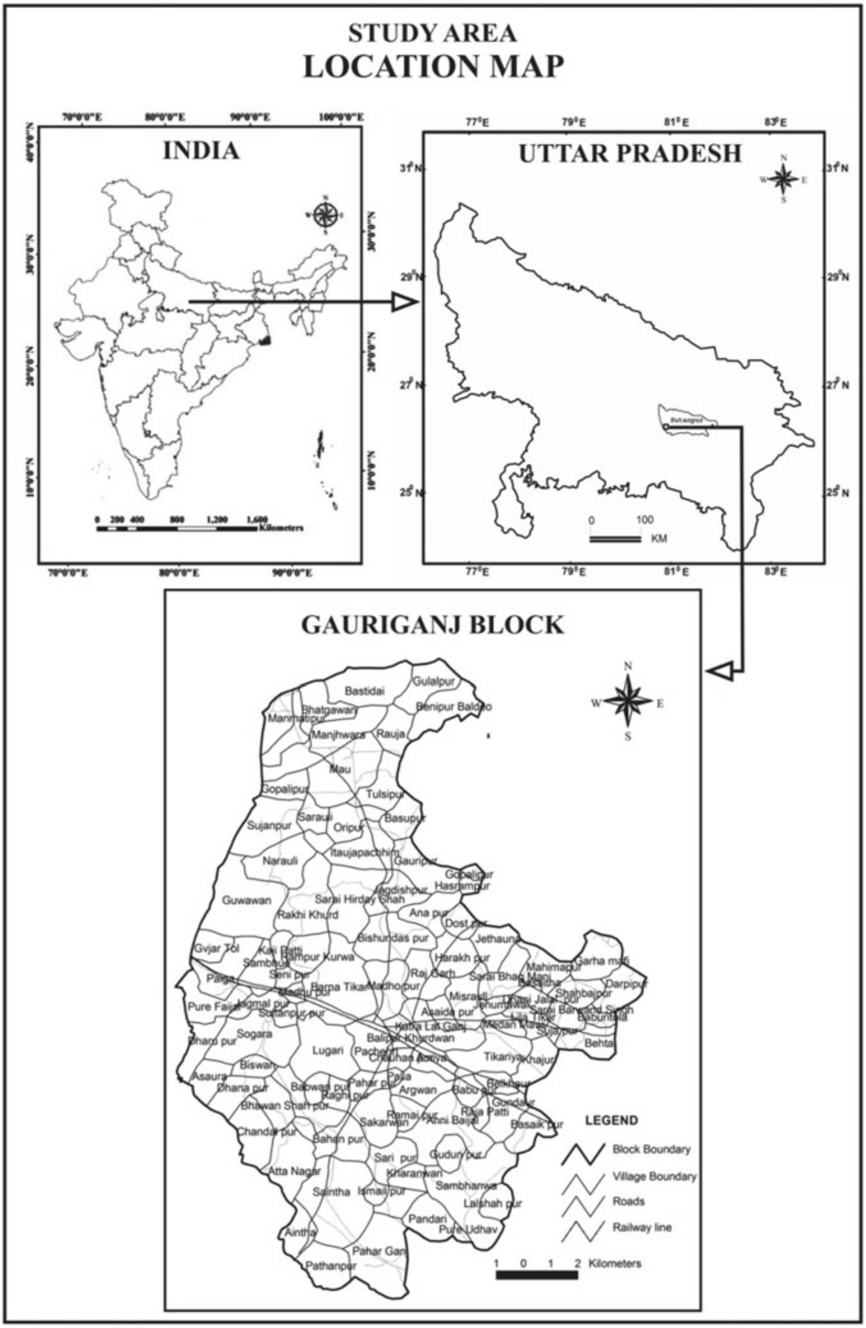

Fig. 7.1 Study area map

Table 7.1 Characteristics of the Lansat-7 ETM+data

Sl. no.	Parameters	Characteristics
1	Spectral range (mm)	0.4–2.4
2	Spatial resolution (m)	30
3	Swath width (km)	185
4	Spectral resolution	Variable
5	Spectral coverage	Discrete
6	Number of bands	7
7	Spectral bands used in this analysis WL (nm)	Band-1:450–520 (nm) Band-2:530–610 (nm) Band-3:630–690 (nm) Band-4:780–900 (nm) Band-5:1550–1750 (nm) Band-7:2090–2350 (nm)

Source Landsat 7 science data users handbook (2004)

7.3 Materials and Methods

7.3.1 Data Used

In this study data used and their sources are: (i) Landsat-7 ETM+multi-spectral images (30 m resolution) acquired in the year 2014 (source: http://glcf.umiacs.umd.edu). Table 7.1 depicts the Characteristics of the Lansat-7 ETM+data used in this analysis, (ii) Google Earth Images (source: http://www.googleearth.com), (iii) Village boundary map prepared by National Natural Resource Database Management System (NNRDMS), Sultanpur (U.P.), (iv) Survey of India (SOI) Topographical sheets numbered 63 F (scale 1:250000), 63 F/11, 63 F/12, 63 F/16 at scale 1:50000, (v) Training/ground truth data collected through selective field survey with GPS handset (Garmin GPS map 76 Cx) in the month of May, 2014, (vi) Soil Survey Report (source Sharda Sahayak C.A.D. Project 1988, Lucknow), (vii) Information regarding land use/land cover collected through the local people informal interview, (viii) GIS/RS packages of Arc GIS 9.3 (ESRI) and ERDAS Imagine 9.1 (Leica Geosystems, Atlana, U.S.A.).

7.3.2 Database Preparation

In order to investigate the soil resources Landsat 7, ETM+satellite image for the years 2014 was downloaded through Global Land Cover Facilities Network (GLCF). The Landsat-7 ETM+image provided by GLCF Network was ortho-rectified (UTM/WGS 84 projection) and radiometrically corrected. The sub-setting of satellite image was performed in Arc GIS 9.3 software to extract study area from the entire image using geo-referenced out line boundary map of Gauriganj block. Subsequently, the data normalization was performed for reducing spatial variation in reflectance caused by sun elevation differences and radiometric gain setting. Primarily, radiance values were calculated in ERDAS Imagine modeler using DN values of the image. The formula given by Markham and Barker in 1986 (Landsat 7 Science Data Users Handbook 2004) was used in this process.

$$L* = (L_{max} - L_{min})/Qcal_{max} * Qcal + L_{min}$$

where $L* =$ spectral radiance at the sensors aperture W/(m^2.sr.um), Qcal = Calibrated Digital Number, $Qcal_{max}$ = maximum possible DN value (255), L_{max} & L_{min} = maximum/minimum scaled spectral radiance value for a given band (provided in the header file). The radiance values further converted into reflectance using the following formula-

$$\rho P = (\pi * L\lambda * d2)/(\mathrm{ESUN}\lambda * \cos\theta s)$$

where ρP = effect of planetary reflectance, $L\lambda$ = band radiance (w/m^2/ster/μm), d = distance of earth from Sun (in astronomical units, $d = 0.997052$ for this case), ESUNλ = mean solar exo-atmospheric irradiances for given wavelength in watts/m^2/μm/ster, θs = solar zenith angle in degrees.

To know the condition of vegetation cover on the soil the most frequently used Normalized Difference Vegetation Index (NDVI) was applied on reflectance image. The NDVI, is the ratio, respects the absorption of photosynthetic active radiation and hence it directly relates to the photosynthetic capacity of plants and energy absorption (Sellers1985; Myneni et al. 1995). The band 3 (Red) and band 4 (Near Infrared) of Landsat-7 ETM+data were used to obtain the NDVI using following formula:

$$\mathrm{NDVI} = (\mathrm{DNIR} - \mathrm{DNR}/\mathrm{DNIR} + \mathrm{DNR})$$

where DNIR = digital numbers of Infrared band, DNR = digital numbers of Red band.

By design, the NDVI varies between −1.0 and +1.0, where NDVI ranging between 0.1 and 0.7 typically represents vegetation cover. Higher levels of healthy vegetation cover in any region are associated with higher NDVI values, while NDVI values near zero indicate the less green vegetation. The prepared NDVI image was used during image processing for soil mapping.

7.3.3 Visual Image Interpretation

The major outcome of this study is the mapping and evaluation of soil resources of the study area. Various methods to delineate soil boundaries in remote sensing image data are in vogue in which visual interpretation method was used in most of the cases (Karale et al. 1981; Biswas 1987). However, computer-based digital image processing methods have also been used in soil mapping (Epema 1986; Kudrat et al. 1990; Korolyuk and Sheherbenko 1994) and recommended as a potential tool (Lee et al. 1988; Kudrat et al. 1992). In the present study, on-screen standard visual image interpretation method was employed. Before the image interpretation, a preliminary general traversing of study area was undertaken and some observations were recorded at few places. A legend was formed to identify the tonal behavior of soils and land use/land cover classes on the image. During this field visit, training data were also collected for digital image analysis. Garmin GPS map 76 Cx handset was used to locate training data collection sites. The visual interpretation of image was performed in Arc GIS 9.3 considering image elements (such as tone, texture, shape, size, pattern, site, and association), author's background knowledge, and collateral data and terrain conditions. Eighty-three soil interpretation units were identified and delineated on False Color Composite (FCC) of the satellite data. To improve the image contrast for better delineation of soil boundaries, spectral enhancement and band combination techniques were used. NDVI and classified (maximum likelihood method) images were used as add-on data set to supplement the existing onscreen interpretation on False Color Composite of Landsat 7 ETM+imagery. The information pertaining to soil profile and their physical, chemical, and biological properties collected earlier in Sharda Sahayak C.A.D. Project 1988, Lucknow (U.P.) were incorporated during the entire soil mapping process.

7.3.4 Ground Truth Collection

In order to correlate the image elements and existence of soil units, a field visit was made again and ground truth was collected. After selecting sample sites, the pockets of land which were mapped as specific soil units were precisely located on the ground with the help of topographical sheets and observation was made regarding geotechnical elements.

7.3.5 Post-field Interpretation

According to field observations during ground truth, the preliminary interpreted soil units were finalized and soil maps were prepared. The units having similar soil characteristics were merged and seven soil series were proposed. The soils' series were further classified up to family level following USDA Soil Taxonomy system. Further, entire soil mapping and area estimation were performed in Arc GIS 9.3 software.

7.3.6 Accuracy Assessment

Accuracy assessment of soil maps was carried out through analyzing 250 randomly selected sample points on the reference image. The analysis was performed in Accuracy Assessment Option of ERADAS IMAGINE software. The ground truth data and Google earth high-resolution images were used for comparing mapped thematic layers and an error matrix was generated. The quantitative assessment of maps accuracy was performed by computing overall accuracy and Kappa Coefficient (Biahop et al. 1975).

7.4 Results and Discussion

7.4.1 Soil Mapping Units

The area under study was estimated to be 20,791 ha in Arc GIS 9.3 software. Visual image interpretation method incorporating field check/training collection and digital processing techniques like image enhancement, band combination, NDVI, maximum likelihood provide useful method for soil mapping. Delineation of soil boundaries on satellite image basically involves their characterization through on-screen visual interpretation in terms of image elements like color/tone, texture, shape, size, association, etc. In this study, visual interpretation of Landsat 7 ETM+data (2014) was performed in Arc GIS 9.1 for soil mapping. On the image of the study area, 83 distinct mapping units were delineated on the basis of their spectral responses (Fig. 7.2). Detailed information pertaining soil profiles and their physical, chemical, and biological properties of each mapping unit were collected from soil survey report of Gauriganj block, Sharda Sahayak Command Area Development Project, 1988, Lucknow (U.P.). The information on soil composition in the interpreted sample strips was extrapolated to unsampled area. The mapping units having similar soil composition were merged together and made as a single unit. In this mapping process seven soil series were recognized. The soils' units were further processed and mapped up to family level following USDA Soil classification scheme (Soil Survey Staff 2004, 2009, 2010). The entire soil mapping and area estimation were performed in Arc GIS 9.3 software.

7.4.2 Soil Orders and Suborders

The results of the soil mapping reveal that the study area has been classified into two soil orders, viz., Alfisols and Inceptisols (Fig. 7.3a and Table 7.2). The differentiation in orders is based on highly generalized criteria. It is generally based on soils' genesis related properties. Alfisols are the relatively high fertile soil which form in semiarid

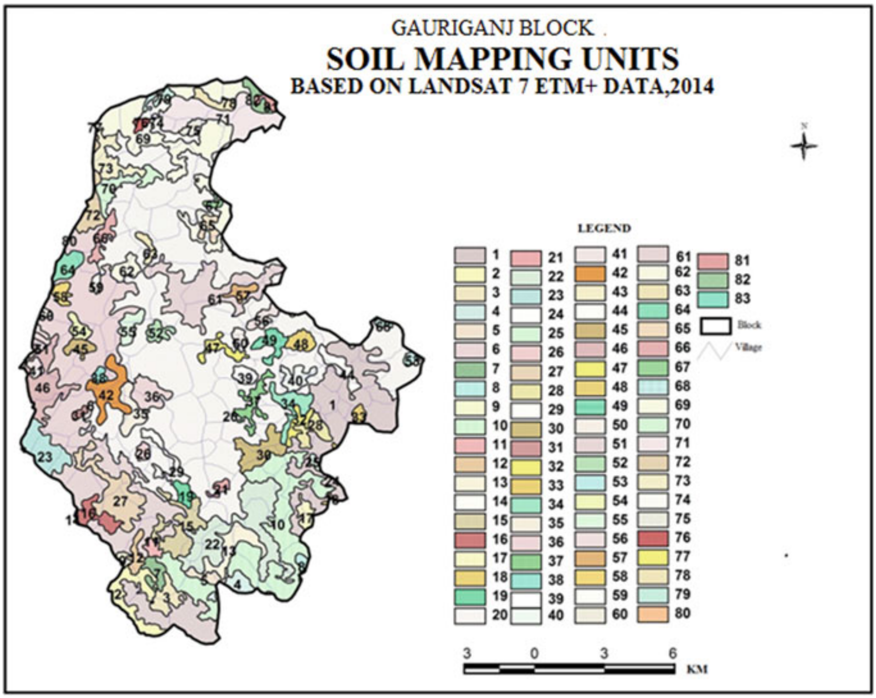

Fig. 7.2 Soil mapping units based on visual interpretation *Source* Landsat 7 data, 2014

to humid conditions. It contains clay-enriched horizon and native fertility. It contains aluminum and iron minerals but relatively low organic matter. It represents an area of 13,663.84 ha (65.72% of the total area) and can be observed in cultivated and low lying areas. The soils of Alfisole order were further classified into Aqualfs and Ustalfs, at suborder level based on soil moisture and temperature.

Aqualfs form in aquic situations of fluctuating water table. During the considerable part of the year, groundwater table is found near the surface. These soils cover about 47.22% area of the block (Fig. 7.3b). Ustalfs soils occur in subhumid to semiarid conditions. These soils accumulate the carbonates in or below the subsoil. These soils occur on 18.50% area of the block. Inceptisols are also mineral soils that have developed over subhumid and semiarid environments characterized by accumulation of clays, gypsum, and salt of translocated alluvium These soils represent an area of 6908.85 ha (33.23%). This soil order was classified into Ochrepts and Ustepts suborders. Ochrepts are characterized by an ochric epipedon (too little organic matter in upper surface, light color), a warm soil temperature regime and an ustic soil moisture regime found on about 3.78% of area. Ustepts (29.45%) are mainly drained freely and have an ustic moisture regime.

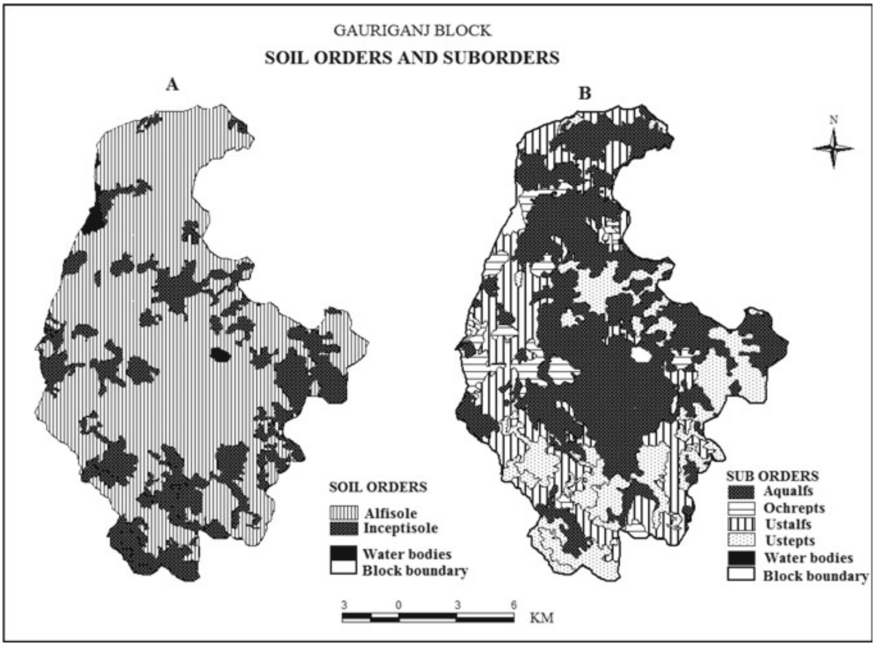

Fig. 7.3 Distribution of soil orders and suborders *Source* Based on Landsat 7 data, 2014

Table 7.2 Soil orders and Suborders in Gauriganj block, Amethi District (U.P)

Sl. no.	Soil order	Suborder	Area in ha	Area in %
1	Alfisols	Aqualfs	9817.51	47.22
		Ustalfs	3846.33	18.50
2	Inceptisols	Ustepts	6122.94	29.45
		Ochrepts	785.89	3.78
3	Waterbody		218.30	1.05
Total			20,791	100

Source Derived from satellite data analysis in GIS

7.4.2.1 Soil Great Groups and Subgroups

On the basis of the kind and sequence of soil horizons, soil suborders of the study area were further divided into great groups. Five great groups are recognized and mapped in the study area, namely, Epiaqualfs, Haplustalfs, Haplustepts, Natraqualfs, and Ustochrepts (Fig. 7.4a, and Table 7.3). **Epiaqualfs** are the Aqualfs that have an epipedon that rests on an argillic horizon without an abrupt textural change if the argillic horizon has low saturated hydraulic conductivity. These soils do not have a kandic horizon, a natric horizon, a fragipan, or a duripan (Soil Survey Staff 1999).

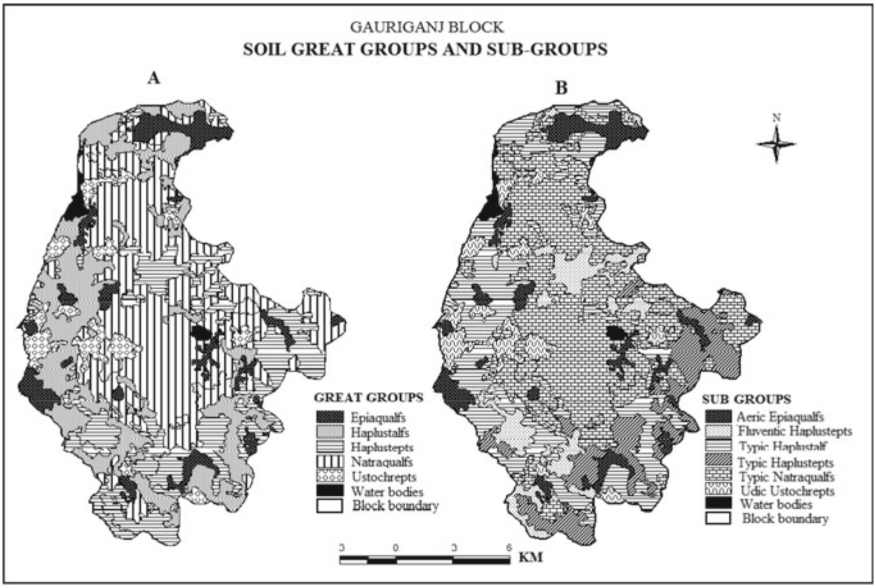

Fig. 7.4 Distribution of soil great groups and subgroups *Source* Based on Landsat 7 data, 2014

Table 7.3 Soil great groups in Gauriganj block, Amethi District (U.P)

Sl. no.	Great groups	Area in ha	Area in %
1	Epiaqualfs	1137.26	5.47
2	Haplustalfs	3846.33	18.50
3	Haplustepts	6122.94	29.45
4	Natraqualfs	8680.24	41.75
5	Ustochrepts	769.26	3.70
6	Water body	218.30	1.05
Total		20,791	100

Source Derived from satellite data analysis in GIS

These soils cover about 1137.26 ha (5.47%) area of the block. Haplustalfs are the Ustalfs that have an argillic horizon. Horizons, do not have a duripan that has its upper boundary within 100 cm of the surface, do not have a petrocalcic horizon within 150 cm of the surface, and do not have much plinthite. (Soil Survey Staff 1999). These soils occupy about 3846.33 ha (18.50%) area in the block.

Haplustepts which is freely drained Ustepts are calcareous at some depth or having high base status. These soils are found on 6122.94 ha (29.45%) area in Gauriganj block. Natraqualfs (Aqualfs that have a natric horizon and warmer temperature regime) and Ustochrepts cover 41.75 and 3.70% area of the block, respectively. On the basis of basic system of Soil Classification System prepared by Soil Survey Staff (1999), the soil great group is further a categorized into four subgroups, i.e., Aeric,

Table 7.4 Soil subgroups in Gauriganj block, Amethi District (U.P)

Sl. no.	Great groups	Area in ha	Area in %
1	Aeric Epiaqualfs	1137.26	5.47
2	Fluventic Haplustepts	1505.26	7.24
3	Typic Haplustalfs	3846.33	18.50
4	Typic Haplustepts	4617.68	22.21
5	Typic Natraqualfs	8680.24	41.75
6	Udic Ustochrepts	785.89	3.78
7	Water Body	218.30	1.05
Total		20,791	100

Source Derived from satellite data analysis in GIS

Fluventic, Typic, and Udic. Aeric subgroups represent the drier conditions of soil whereas the Fluvents soils distributed mainly on flood plain formed by recent water-deposited sediments. It contains an appreciable amount of organic carbon. The soils that do not have the characteristics defined for the other subgroups are kept into Typic subgroups. Udic soil is common in humid regions where moisture is sufficiently high throughout the year to meet plant requirements. In the study area, six subgroups are identified and mapped namely Aeric Epiaqualfs, Fluventic Haplustepts, Typic Haplustalfs, Typic Haplustepts, Typic Natraqualfs, and Udic Ustouchrepts. The spatial extent and distribution are depicted by Fig. 7.4b and Table 7.4.

7.4.3 *Soil Families and Soil Series*

On the basis of mineralogy, texture, and temperature, the subgroups are further classified into soil families which distinguish between clayey, loamy, and sandy soils. The soils of the Gauriganj block have been classified into five soil texture families, (Fig. 7.5a, Table 7.5) namely, Loamy, Coarse loamy, Fine, Fine loamy, and Fine silty. Loamy soils are highly fertile in nature which consist mainly an equal mixture of sand (30–50%) and clay (less than 30%) together with silt (30–50%) and humus. It can retain some amount of moisture and plant food even under adverse weather and climate conditions. It extends over a 22.21% (4617.68 ha) of the geographical area. This soil is well exposed in southeastern and eastern part of the block. There are some exposure around village Attanagar and Chandanpur and southwestern part of the study area. The coarse loamy is the coarse-textured soil which contains sand (50–70%) and silt (0–50%) with less than 20% clay. These are low water holding capacity soil and good for horticulture, legumes, groundnut, and Bajra. About 7.24% (1505.26 ha) of the total area is under course loamy soil. This soil is exposed in northeast and southwest parts of the study area. Fine-textured soils (Clay) cover an area 45.27% (9412.08 ha) of the total area of the block. These soils are found in middle and eastern parts of the block. About 3.78% (785.89 ha) area is under fine

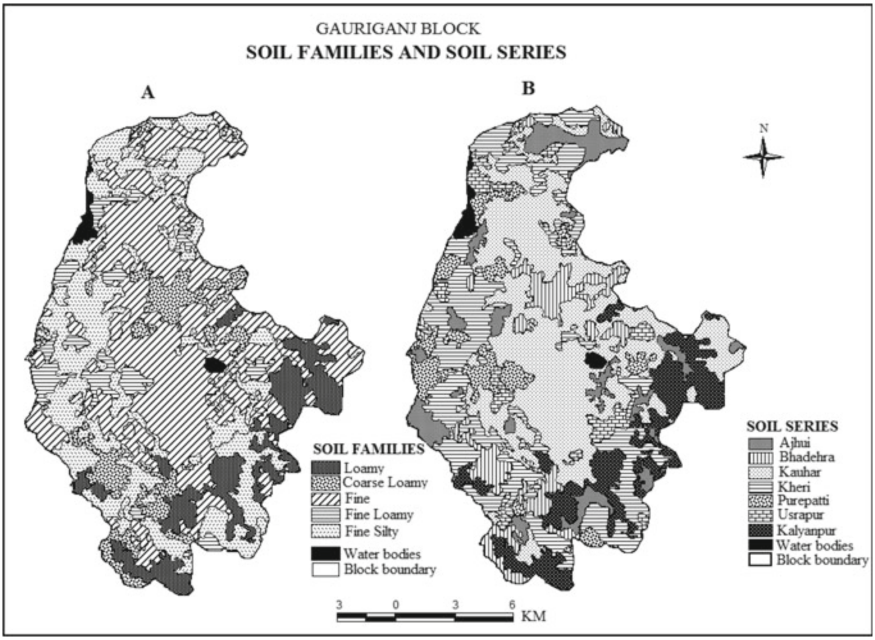

Fig. 7.5 Distribution of soil families and soil series *Source* Based on Landsat 7 data, 2014

Table 7.5 Soil families in Gauriganj block, Amethi District (U.P)

Sl. no.	Great Groups	Area in ha	Area in %
1	Loamy	4617.68	22.21
2	Coarse loamy	1505.26	7.24
3	Fine	9412.08	45.27
4	Fine loamy	785.89	3.78
5	Fine silty	4251.75	20.45
6	Water body	218.30	1.05
Total		20,791	100

Source Derived from satellite data analysis in GIS

loamy soils exposed in Sarai Bhagmani, Jehmawai, Barna Tikar, Lugari, Pure Faizal Dharupur, Jagmal Pur Madhupur, Sultanpur, Sogara, Basupur, Guwawan, Narauli, Pandari, Mau, and Gopalipur villages. The fine silty soils containing sand (0–20%) and silt (40–60%) with 40–60% clay exposed mostly in western and southern parts of the Gauriganj block. It amounts to 20.45% (4251.75 ha) of the total area.

The narrowest category soil in soil taxonomy is called soil series (Soil Survey Staff 1975). It consists of pedons (soil individual) that have similar pedogenesis, soil chemistry, and physical properties. Each series consists of pedons that have horizons similar in soil color, texture, structure, pH, consistence, mineral and chemical composition, and arrangement in the soil. In the study area, seven soil series were identified and mapped, viz., Ajhuri, Bhaderha, Kauhar, Kheri, Purepatti, Usrapur, Kalyanpur (Fig. 7.5b, Table 7.6).

Ajhuri

Ajhuri soil series belongs to Alfisole order, Aqualfs suborder, Epiaqalfs great group, and Aeric subgroup. It represents fine textured high fertile soil characterized by clay-enriched horizon, aluminum and iron minerals, relatively low organic matter, thermic or warmer temperature regime, and fluctuating water table. This soil is suitable for wheat, paddy, pulses, gram, peas, and oil seeds crops like mustered linseed, etc. It exposed in thirty villages covering an area of 1137.26 ha (5.47%) in Gauriganj block. Mapping units numbered 7, 13, 17, 18, 23, 25, 26, 31, 32, 37, 41, 43, 44, 53, 54, 55, 66, 67, 71, 77 represent the Ajhuri series (Fig. 7.2 and Table 7.7).

Bhaderha

Bhaderha soil series belongs to Inceptisols order, Ustepts suborder, Haplustepts great groups, Fluventic aplustepts subgroups, Coarse loamy family (mixed and Hyperthermic). It occupies on 1505.26 ha (7.24%) area over thirty-seven villages (Table 7.6) in the study area. Mapping units numbered 2, 5, 15, 27, 49, 50, 51, 52, 59, 61, 79, 80, and 81 represent the Bhaderha soil series. The soil of this series is coarse textured and consists of sand (50–70%), silt (0–50%) and clay (less than 20%) and suitable for horticulture, legumes, groundnut, and Bajra crops. The soil is characterized by medium fertility and low water holding capacity.

Kauhar

Kauhar soil series belongs to Alfisols order, Aqualfs suborder, Natraqualfs great group, Typic Natraqualfs subgroup and Fine textured soil family (mixed, Hyperthermic). Mapping units numbered 3, 9, 20, 28, 33, 38, 57, 60, 74, 78, 82, and 83 represent the Kauhar soil series. It covers an area of 8274.18 ha (39.80%) and occupies in forty-seven villages. It accounts for 3846.33 ha (18.50%) and illustrated by mapping units number of 6, 10, 14, 24, 29, 34, 47, 63, and 69.

Purepatti

Purepatti soil series is included under Inceptisols order, Ochrepts suborder, Ustochrepts great group, Udic Ustochrepts subgroup and Fine loamy family (mixed, Hyperthermic). This soil series occupies on 785.89 ha (3.78%) lands. Mapping units numbered 4, 11, 36, 40, 42, 45, 46, 62, 64, 65, and 70 represent the Purepatti soil series. This soil series was found in twenty-two villages.

Usrapur

Usrapur soil series belongs to Alfisols order, Aqualfs suborder, Natraqualfs great group, Typic Natraqualfs subgroup, and Fine Silty (mixed, Hyperthermic) family. It accounts for only 405.42 ha (1.95%) area. Mapping units numbered 8, 12, 21, 30, 35, 48, 58, 73, 75, and 76 represent the Usrapur soil series. This soil series is distributed over fifteen villages.

Table 7.6 Spatial Distribution of Soil Series in Gauriganj Block, Amethi District (U.P)

Sl. no.	Soil series	Area in ha	Area in %	Villages
1	Ajhuri	1137.26	5.47	Sogara, Tikariya, Sarai Barwand Singh, Sahbaj Pur, Mahimapur, Pure Fajil, Misrauli, Asaidapur, Katra Lal Ganj, Amiya, Darpipur, Saintha, Rauja, Benipur Baldeo, Gulalpur, Bastidai, Majhwara, Bhatgawan, Paiga, Guwawan, Sujapur, Narauli, Rampur Kurwa, Rohshi Khurd, Chhitepur, Banwari Pur, Pandari, Gundur, Belkhaur, Basupur, Tulsipur, Kharnwan, Samhanwa, Basaikpur, Dhanupur, Asaura, Dharupur and Manmatipur
2	Bhaderha	1505.26	7.24	Benipur Baldeo, Gulalpur, Bastidai, Gopalipur, Hasrampur, Gauripur, Anapur, Jagdishpur, Bishundaspur, Sarai Hirday Shah, Barna Tikar, Harakh Pur, Gvjar Tol, Dhanapur, Bhawan Shah Pur, Atta Nagar, Saripur, Saintha, Aintha, Pathanpur, Pahar Ganj. Pandari, Ismailpur, Bahanpur, Sakrawan, Bahanpur, Shah Pur, Ronhsi Buzurg, Chandaipur, Misrauli, Rajgarh, Paiga, Guwawan, Rohsi Khurd, Bhatgawan and Sujanpur
3	Kauhar	8274.18	39.80	Gulalpur, Bastidai, Manjhawara, Mautulsipur, Oripur, Sarauli, Itaujapachhim, Narauli, Sujanpur, Gauripur, Sarai Hirday Shah, Rohni Khurd, Barna Tikar, Madhopur, Raj Garh, Jethauna, Sarai Bagmani, Madhopur, Pachehri, Bali Pur Khurdawan, Katralal Ganj, Amiya, Argwan, Ramaipur, Anni Baijal, Saripur, Sakarwara, Paharpur, Lugri, Raghipur, Ronhsi Buzurg, Sogara, Garha Mafi, Darpipur, Saintha, Pathanpur, Aintha, Attanagar, Bahanpur, Paharganj, Palia, Chauhanpur, Rampur Kurwa, Bishundaspur, Mahimapur, Bhehta, Tikariya and Khajuri
4	Kheri	3846.33	18.50	Gulalpur, Bastidai, Bhatgawan, Manmatipur, Manjhwara, Rauja, Mau, Basupur, Sujanpur, Guwawan, Rohni Khurd, Kajipatti, Sembhue, Paiga, Gvjar Tol, Sogara, Biswan, Dhanapur, Chandaipur, Atta Nagar, Saintha, Bahanpur, Paharpur, Pandari, Samhanwa, Lal Shahpur, Raja Patti, Babupur, Anni Baijal, Gundaur, Basaikpur, Belkhaur, Medan Mawi, Raj Garh, Madhopur, Narauli, Pure Fajil, Senipur, Jagmalpur, Dharupur, Asura, Bhawan Shah Pur, Tikaria, Itaujapachhim, Tulsipur, Benipur Baldeo and Mahanpur

(continued)

Table 7.6 (continued)

Sl. no.	Soil series	Area in ha	Area in %	Villages
5	Purepatti	785.89	3.78	Mau, Gopalipur, Sujanpur, Guwawan, Narauli, Rohshi Khurd, Basupur, Pure Faijal, Paiga, Sembhue, Dharupur, Jagmalpur, Sultanpur, Barna Tikar, Sogara, Lugari, Saintha, Pandari. Jehumawi, Sarai Bhagmani, Madhu Pur and Senipur
6	Usrapur	405.42	1.95	Manjhwara, Bhatgawan, Manmattipur, Guwawan, Lugari, Jethauna, Argawan, Tikaria, Ramaipur, Lal Shah Pur, Saintha, Babupur, Anni Baijal, Barna Tikar and Sarai Bhagmani
7	Kalyanpur	4617.68	22.21	Garhamafi, Mahimapur, Sahbaj Pur, Sarai Barwand Singh, Baburitola, Behta, Sujapur, Lila Tikar, Khajuri, Belkhaur, Gundur, Basaik Pur, Samhanwa, Gudunpur, Anni Baijal, Saripur, Kharanwan, Chhitepur, Paharganj, Pathanpur, Aintha, Atta Nagar, Chandal Pur and Sakarwan

Source Derived from satellite data analysis in GIS

Table 7.7 Soil series and their association with soil constraints in Gauriganj block, Amethi District (U.P)

Sl. no.	Mapping units	Soil series	Soil classification	Texture
1	7, 13, 17, 18,23, 25, 26,31, 32, 37,41, 43, 44,53, 54, 55,66, 67, 71, 77	Ajhuri	Alfisols, Aqualfs, Epiaqalfs, Aeric Epiaqualf	Fine
2	2, 5, 15, 27, 49,50, 51, 52,59, 61, 79,80, 81	Bhaderha	Inceptisols, Ustepts, Haplustepts, Fluventic Haplustepts	Coarse loamy
3	3, 9, 20, 28, 33,38, 57, 60,74, 78, 82, 83	Kauhar	Alfisols, Aqualfs, Natraqualfs, Typic Natraqualfs	Fine
4	6, 10, 14, 24, 29,34, 47, 63, 69	Kheri	Alfisols, Ustepts, Haplustalfs, Typic Haplustalf	Fine silty
5	4, 11, 36, 40, 42,45, 46, 62,64, 65, 70	Purepatti	Inceptisols, Ochrepts, Ustochrepts, Udic Ustochrepts	Fine loamy
6	8, 12, 21, 30, 35,48, 58, 73, 75,76	Usrapur	Alfisols, Aqualfs, Natraqualfs, Typic Natraqualfs	Fine silty
7	1,16, 19, 22, 56, 68	Kalyanpur	Inceptisols, Ustepts, Haplustepts, Typic Haplustepts	Loamy

Kalyanpur

Kalyanpur soil series is classified under Inceptisols order, Ustepts suborder, Haplustepts great group, Typic Haplustepts subgroup, and Loamy (mixed, Hyperthermic) soil family. Mapping units numbered 1, 16, 19, 22, 56, and 68 represent the Kalyanpur soil series. It is distributed on 4617.68 ha (22.21%) and found in twenty-four villages.

7.5 Conclusion

In this study, Landsat 7 ETM+image of the year 2014 was processed for soil mapping and database generation. Visual image processing technique incorporating selected field check/training and collateral data was applied for this task. However, some digital image processing techniques such as spectral enhancement, band combination, NDVI, and image classification (maximum likelihood method) were also used as add-on data set to supplement the existing onscreen visual image processing. As per USDA soil classification system, soils of the study area were grouped into two orders, four suborders, five great groups, six subgroups, five families, and seven series. The study clearly demonstrates the usefulness of RS and GIS techniques for soil resource inventory, mapping, and database generation at micro level. During the post-field interpretation field check, it was observed that the salt-affected soil, waterlogging, soil erosion, deficiency of soil nutrients, etc. are the major human-induced soil related constraints in the study area that deteriorate the currying capacity of soil to support human population. The village level reliable soil database on spatial extent, types, and magnitude may prove a better input in micro level planning for proper management of degraded lands in the study area.

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