Land Resource Investigation Using Remote Sensing and Geographic Information System: A Case Study

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Abstract

Present study is an attempt to investigate land resources using Remote Sensing (RS) and Geographic Information System (GIS) for proper management and sustainability of agricultural lands selecting a development block of Gauriganj , Amethi district, Uttar Pradesh, India. The multispectral Landsat 7 ETM+ images of the year 2015 were processed in ERDAS Imagine 9.1 and Arc GIS 9.3 software for land use/ land cover investigation and degraded land mapping. The study was mainly based on standard visual image processing technique. Some digital image processing techniques such as image enhancement, classification and band ratioing etc., were also applied for generating ad-on-data for visual image processing. The ground truth and training data collected from field survey were also incorporated in the image processing. In the study area seven land use / land cover classes i.e., built-up area, fallow lands, Rabi crops, Kharif crops, double cropped area, lake/ponds, salt affected lands and waterlogged area were identified and mapped through processing of Rabi (February) and Kharif (September) season's satellite images of the year 2015. In the study area four types of degraded lands i.e. salt affected lands (strong), salt affected lands (moderate), waterlogged area (permanent), waterlogged area (seasonal) were also mapped . The study proves effectiveness of satellite data, RS and GIS techniques in land resource inventory and mapping. This study may helpful in proper management of land resources for agricultural sustainability in the study area.

Keywords: *Remote Sensing, Geographic Information System, Landsat 7 ETM+ images, ERDAS Imagine 9.1, Arc GIS 9.3, Land use/ land cover, Land degradation.*

1. Introduction

Land is the most valuable natural resource for production of food, fuel and many other essential goods required to meet human and animal needs [1]. It is fundamental to the well-being and productivity of natural ecosystems and agriculture [2]. Lal [3] has described the land resource as "finite, fragile, and non-renewable". It embodies soil, water, flora and fauna, and involves the total ecosystem [4]. In a broader sense, land includes the atmosphere, the earth's surface and subsurface, hydrology, plants, animals, people and their interactions [5]. The socio-economic conditions of people in any region where agricultural practices are predominant in economic activities are largely associated with its quality and nature of land and their utilization. Over exploitation of land resources in agricultural practices without understanding its sustainable limits has caused extensive land degradation causing serious threat to present and future agricultural growth and sustainability. Hence, the land degradation has been a major global issue during 20th century and will remain important for 21st century of its adverse impact on agronomic productivity, the environment, and its effect on food security and quality of life [6]. The land degradation can in effect contribute to low agricultural productivity as its limits the ability of food for both human and livestock. India ranks very high among the developing countries in respect of both, extent and severity of land degradation. The data on the nature, extent and kinds of degraded lands of the country have been projected by various agencies from time to time. It is estimated that out of the total 328.8 million hectares of geographical area of the country about 175 million hectares are severely affected by soil erosion, soil Salinization /alkalization, water logging, ravine/gully, soil nutritional loss etc .The problem of water logging, salinization /alkalization and ravine infestation has affected are estimated area of 6, 7 and 3.97 million ha respectively [7]. In a study it was assessed that about sixty per cent of the crop land in the country is suffering from land degradation problems [8], [9], [10] and is incapable to produce the adequate food for sustainable livelihood of people distributed on it. About 40 percent of the total degraded lands 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 percent, it would be 1.37 billion .Four hundred million tons of food grain would be needed to feed this population [11]. It would therefore be necessary to plan agricultural land management on sustainable basis. In this context investigation of land resources at micro level may prove a better input.

In the recent years, the geo-spatial technology of RS coupled with GIS provides a powerful mechanism, not only to monitor natural resources and environmental changes but also permits to analyze the information of other environment variables [12].It has emerged as popular viable substitute for land resource inventory due to its cost effectiveness and technological soundness [13] and offer permanent and authentic record of spatial patterns [14].One of the most important distinguishing characteristics of RS, relative to other data acquisition approaches, is that it can provide detailed, quantitative land surface information at large spatial coverage and at frequent temporal intervals [15]. The RS data due to its perspective view, multi-spectral, multi-resolution and frequent monitoring capabilities make its well-suited for inventory of land use/land cover pattern and their dynamics over any large areas. The recent advancement in digital image processing techniques have brought about a profound acceptance of the application of satellite remote sensing data in land resource inventory, mapping and change detection [16],[17],[18],[19],[20], [21], [22],[23],[24],[25].Spectacular developments in the field of GIS to synthesize various thematic information with collateral data have not only made this technology effective and economical but also a tool to arrive at development strategies for sustainable land and water resources management [26]. Geographical Information Systems (GIS) have proved to be immensely helpful in the organization of the huge database generated through space technology [27].The utility of GIS in the analysis and modelling of integrated information is well established [28]. GIS has been used in the development of digital databases, assessment of status and trends of resources utilization of the areas and to support and assess various resource management alternatives [29]. Realizing the importance of land resource inventory in sustainable land resource management and planning, present study is an attempt to investigate and analyse the spatial patterns of land use / land cover pattern and degraded lands through processing Landsat 7 satellite images of year 2015 in the core of GIS environment for the Gauriganj Block, Amethi district, Uttar Pradesh, India.

2. Materials and Methods

2.1 Study Area

The study area , Gauriganj block (falls between latitude $26^0$7' 5'' to 26^0 10' 5'' N and longitude 81^0 36'45'' to 81^0 45' 18'' E) of Amethi district (Fig.1) which lies in the middle Ganga plain in the eastern part of the Uttar Pradesh, India. It covers an area of 207.56 km^2, characterized by an even and featureless plain, composed of deep and fertile alluvium deposited by the Ganga River and its tributaries. The area enjoys the typical tropical, semiarid, monsoonal type of climate characterized by a dry and hot spring/early summer, a hot rainy season, a warm autumn and a cool winter [30]. The average annual rainfall is 977 mm, mainly received between July and September [31]. The winter rains are irregular and scanty. The mean maximum and minimum annual temperatures are 47.5^0 C and 4.1^0 C, respectively. The soils of the study area have been classified as Aquic Petrocalcic Natrustalf [32] and represent a large area of man induced salt affected lands occurring in the Ganga alluvial plains. The block is economically backward and majority of the population (about 80 per cent) earns livelihood from agriculture and other allied activities. The preliminary field investigation of the study area revealed the serious problem related to agro-environment and land resources like occurrence of salt affected lands, sever water logging problem, lack of vegetation cover, fluvial erosion and soil loss, unscientific farm practices, lack of proper planning and scientific management practices, lack of soil and water conservation measures, low level of environmental awareness and literacy among farmers etc. Hence there is an urgent need to investigate land use/ land cover and degraded lands at micro level using modern geo-informatics technologies of RS and GIS. This study may prove a better input in managing agro-ecological problems in this study area.

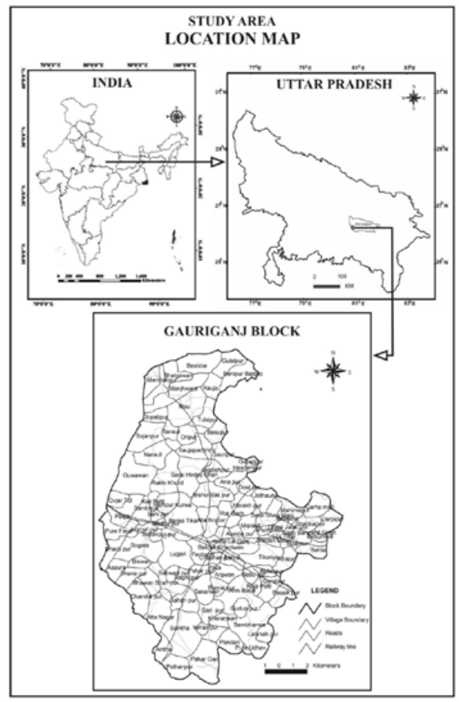

Fig. 1 Location of the study area

2.2 Data and Software Used

Satellite data:

- Landsat 7 Enhance Thematic Mapper (ETM+), Multi-spectral data of February, 2015 (bands - red, green and blue, 30m resolution) obtained from http://glcf.umiacs.umd.edu.
- Landsat 7 Enhance Thematic Mapper (ETM+), Multi-spectral data of September, 2015 (bands - red, green and blue, 30m resolution) obtained from http://glcf.umiacs.umd.edu.
- Google Earth high resolution images (source: http://www.google earth.com).

Maps and reports:

- Village boundary map prepared by National Natural Resource Database Management System (NRRDMS), Sultanpur (U.P.).
- Survey of India (SOI) topographical sheets numbered 63 F (scale 1:250000), 63F/11, 63 F/12, 63 F/ 16 at scale 1:50000.
- Soil Survey Report (source: Sharda Sahayak C.A.D. Project 1988, Lucknow).

Field survey:

- Field training data collected through selective field survey with Garmin GPS map 76Cx handset in the month of March and September, 2016.
- Information pertaining land use/ land cover through informal interview of the local people.

Software:

- Geographic information system software of Arc GIS 9.3(ESRI).
- Remote sensing software of ERDAS Imagine 9.1 (Leica Geosystems, Atlanta, U.S.A.).

2.3 Methods

The study was performed through following methodological steps-

i. In order to investigate the land resources of the study area Landsat 7 ETM+ satellite images of the years 2015 was downloaded through Global Land Cover Facility (GLCF) Network. The Landsat images provided by GLCF Network were radiometrically and geometrically (ortho-rectified with UTM/WGS 84 projection) corrected. Further, the sub-setting of satellite image was performed in Arc GIS 9.3 software for extracting study area by taking geo-referenced out line boundary of Gauriganj block.

ii. A reconnaissance survey of study area was carried out with SOI toposheets, hard copy of satellite data and GPS hand set following major roads, canals and important landmark points for a general understand of geographical conditions of the study area. The training data was also collected from the fields regarding various land use / land cover calsses. To know the geographical coordinates of the selected training sites, Garmin GPS map 76Cx handset was used.

iii. The classification system of land use/land cover and degraded lands was developed following NRSC classification scheme and a legend was formed to identify the tonal behavior of the major land use/ land cover types and land degradation classes on the imagery.

vi. Satellite Images were enhancement to improve contrast for better delineation of land use/ land cover and land degradation types and prepared various false color composites combining different bands to yield varied levels of information. In order to improve the interpretation of land use/ land cover classes and degraded lands specific spectral enhancement methods like Principle Component, Edge enhancement, NDVI etc. were also attempted. The generated information was used as an add-on data set to supplement the existing onscreen interpretation on false color composite of imageries.

vii. Preliminary on screen visual image interpretation was carried out for identifying land use /land cover classes and land degradation considering standard image interpretation keys like tone, texture, size, pattern ,association, ancillary and legacy data. Digital image classification using both supervised and unsupervised methods were also carried out for feature identification.

viii. The doubtful areas on interpreted images were identified and listed for the ground verification and preparation of field traverse plan to cover maximum doubtful sites in the field.

ix. The ground truth were collected from selected sample ground points through field visit in months of February (2016) and September (2016) for validating interpreted information on satellite images. The Garmin GPS map 76 Cx (Garmin Taiwan) was used during field work for locating field check points.

x. The final maps of land use/ land cover and degraded lands were prepared by incorporating the finding of ground truth validation analysis.

xi. In order to evaluate accuracy of interpreted land use/land cover and land degradation maps, randomly sampled 250 points on reference image were selected and analyzed in ERADAS Imagine software using accuracy assessment option in the classification dialog. The classified layers were compared with ground truth data and Google earth high resolution image and an error matrix was prepared. The quantitative assessment of maps accuracy was performed by computing overall accuracy and Kappa Coefficient [33].

xii. All thematic maps were analyzed in Arc GIS 9.3 software to calculate area and other statistics. The village level database on land use/ land cover and land degradation were generated.

3. Results and Discussion

3.1 Land use/ land cover

The study area, derived after digitizing a map obtained from the NNRDMS, Sultanpur, using Arc GIS 9.3 work out to be 20791.02 ha. In the present study, on screen visual interpretation of Landsat 7 ETM+ data of February and September, 2015 was carried out in Arc GIS 9.1 for land use / land cover mapping in term of image elements like tone, color, texture, shape, size, association, spectral responses, etc. The visual image interpretation techniques incorporating field check/ training data, digital image processing techniques and

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ancillary data gave good results for land use/land cover mapping. The overall land use / land cover classification of study area was found to be satisfactory. The accuracy assessment results for land use/land cover map were obtained about 91.22 percent of overall and 0.7983 Kappa accuracy. In the study area, nine land use / land cover classes were identified and mapped i.e., Built-up area , Fallow lands, Kharif crops , Rabi crops, Double cropped area, Lakes/Ponds, Land with scrub, Salt affected land and Waterlogged area (Fig.2) .

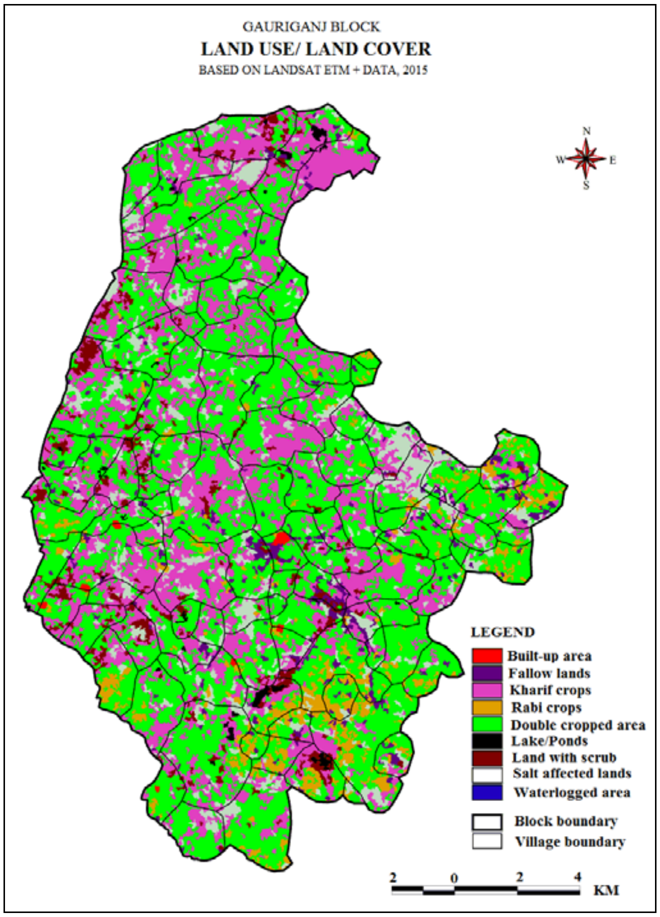

Fig.2 Land use/ land cover map, 2015

The statistics derived through GIS analysis on land use / land cover classes are given in Table 1 and Fig.3.

Table 1 Land use/ land cover status in Gauriganj block, Amethi district, 2015

Land use/Land cover Class	*Area in ha.*	*Percent*
Built-up area	42.91	0.21
Fallow lands	562.53	2.70
Kharif Crops	6185.41	29.75
Rabi Crops	1050.57	5.05
Double Cropped area	10214.35	49.12
Lakes/Ponds	113.95	0.54
Land with scrub	691.07	3.32
Salt affected land	1893.00	9.10
Waterlogged area	32.33	0.15
Total geographical area	20791.02	100

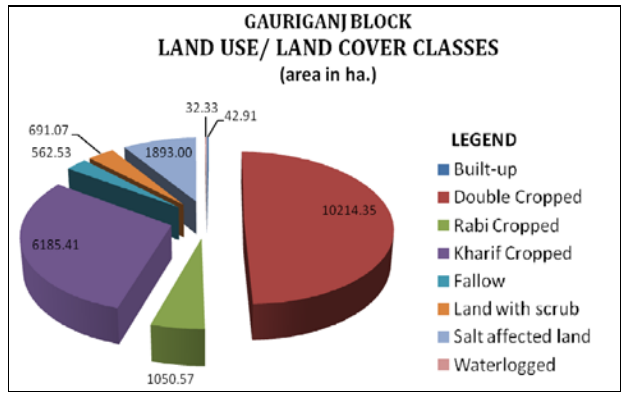

Fig.3 Land use/ land cover status, 2015

The built-up area appear on Rabi season image in bluish green tone in core built-up area and bluish tone in periphery with small to medium size, irregular and discontinues shape, clusters non-contiguous or scattered pattern. The total area observed under this class was 42.91 ha (0.21%). Gauriganj urban centre, Balipur Khurdwan, sogara, Asura, Bahanpur, Ramaipur, Aintha, Argawan, Jagmalpur, Dharupur, Sakarwara, Katra lalganj etc cover the major parts of the built-up lands in the Gauriganj block.

The fallow land described as that agricultural land, which is taken up for cultivation, but is temporarily allowed to rest/un-cropped for not less than one year. It appear on image in yellow to greenish blue color of different size, regular to irregular in shape. The pattern varies from contiguous to non-contiguous, associated with cropland. It accounts for only 2.70 per cent (562.53 ha.) of the total geographical area. The spatial analysis of the distribution of the fallow lands reveals that the villages in southern and eastern parts of the study area having maximum area under fallow lands. The highest percentage of the fallow land were recorded in Basthan (30.85%) followed by Amiya (20.29%), Babupur (19.38%), Balipur Khurdwan (19.15 %), Pachehri (14.19 %), Garha Mafi (11.59 %), Lal Shahpur (11.45%), Sujapur (10.91%)

and Darpipur (10.41%) villages. The spatial extent of follow land in any region depends on several factors such as rainfall, irrigation facilities, soil conditions and socio-economic conditions.

The mono cropped area where only kharif crops (crops grown between June and October) are grown coincides with the southwest monsoon season. On the satellite image they appear in bright red to red in color, with varying shape and size in a contiguous to non- contiguous pattern. Mono- cropped area during kharif season were mapped on 6185.41 ha (29.75 %). The mono-cropped area during Kharif season was found in the villages where the agro-ecological conditions for Rabi crops area not suitable. These villages are located mostly in north, west and middle part of the study area. The highest percentage of Kharif cropped lands was observed in Benipur Baldeo (75.92%) followed by Gopalipur (65.04%), Lugri (57.02%), Bisundaspur (56.64%), Mohanpur (51.84%), Bastidai (50.88%) , Tikariya (46.13%), Rauja (45.27%), Gopalpur (44.92%), Biswan (44.63%), Sogara (43.09%), Barna Tikar (42.41%), Sultanpur (42.30%), Bhatgawan (42.11%), Itaujapachhim (41.59%), Sujanpur (40.63%) villages.

The mono cropped (Rabi) areas are associated with area under assured irrigation irrespective of the source of irrigation. These areas in the Gauriganj block were delineated on the satellite image of Rabi season in bright- red to red color. These areas were mapped on 1050.57ha (5.05% of the total cropped area) in the block. The high percentage of mono cropped (Rabi) land was recorded in Gudunpur (41.40%), Ismailpur (36.39%), Chhitepur (31.67%), Gopalipur (28.14%), Kharanwan (27.88%), Darpipur (23.83%), Anni Baijal (21.34%), Samhanwa (19.60%), Pure Udhao (18.92%), Pandri (18.00%), Chandipur (17.89%), Behta (17.19%), Saripur (17.19%), Garha Mafi (16.67%), Lal Shahpur (14.39%), Basaikpur (13.67%), Mahimapur (12.86%), Hasrampur (11.33%) and Dhani Jalalpur (10.99%) villages.

The double cropped area is the lands that are cropped during both Rabi and Kharif seasons that often seen associated with intensely irrigated areas. This type of land use class accounts 100214.35 ha (49.12%) in the study area. The highest percentage of double cropped land was recorded in Jehumawi (84.66%) followed by Hasrampur (83.85%), Gundur (82.25%), Sujapur (81.00%), Belkhaur (80.20%), Basupur (75.67%), Basaikpur (73.84%), Jagdishpur (73.72%), Palia (73.48%), Sahbajpur (72.52%),Gopalipur (71.64%),Dharupur (70.46%), Aintha (68.91%), Madhupur (68.84%), Lila Tikar (68.09%), Rajgarh (66.33%), Sarai Hirday Shah (66.19%) while , the lowest percentage was recorded in Babupur (12.52%) followed by Benipur Baldeo (13.56%), Jethauna (20.51%), Lugari (23.14%), Gopalipur (24.05%), Sarai bhagmani (24.32%) villages.

The lake/ponds comprise area of surface water, either impounded in the form of ponds, lakes and reservoirs. These are clearly seen on FCC in shades of blue to black, depending upon turbidity and depth of water body. The total area under lakes and ponds was estimated 113.95 ha (0.54%) in the study area. The highest percentage of area under lake/ponds was observed in Saraipur (11.24%) followed by Gulalpur (10.02%), Pandri (6.92%), Banwaripur (6.43%), Saintha (2.10 %), Jagmalpur (1.68%), Paiga (1.62%), Gvjar Tol (1.37%).

The wastelands that do not qualify for placement under any of the wasteland categories are placed under land with scrub class. It was observed that scrub land often appear like fallow in Rabi season and looks like crop land in Kharif season, which could be discriminated using multi-date satellite data. They appear in light yellow to brown to greenish blue depending on the surface moisture cover and vary in size from small to large having either contiguous or dispersed pattern and associated with agricultural lands around them. About 691.07 ha (3.32%) of the study area was under this category of land use. As shown in Fig. 3, the villages having higher percentage of area under this land use class are located mostly in north, west and southern part of the study area. The highest percentage was observed in Kaji Patti (24.61%) followed by Bhawan Shahpur (17.39%), Pandri (16.17%), Asura (14.55%), Sembhue (14.11%), Gvjar Tol (13.04 %), Bastidai (12.88 %), Amiya (11.75%), Banwaripur (11.64%), Guwawan (11.58%), Biswan (11.*55%)* villages.

The salt affected land is generally characterized as the land that had adverse effect on the growth of most plants due to the action or presence of excess soluble or high exchangeable sodium. Alkaline land has an Exchangeable Sodium Percentage (ESP) of about 15, which is generally considered as the limit between normal and alkaline soils. The most common salts are carbonates and bi-carbonates of sodium and calcium. Salt-affected lands can be easily identified by their high reflectance. They appear in white to light blue color depending upon moisture content ranging small to medium size. Generally they are irregular in shape and discontinuous, closely spaced or dispersed depending on their location and hence are detectable in areas of light colored soils. Irregular blanks in Kharif season are indicative of salinity and alkalinity. About 1893.00 ha (9.10%) of the study area was found under this category of land use. These lands were distributed in all the villages (except four villages Hasrampur, Mohanpur, Balipur Khurdawan and Gopalipur of the study area. The highest percentage was observed in Jethauna (47.91%) followed by Sarai Bhag Mani (46.92%), Paharpur (38.51%), Dhani Jalalpur (31.59%), Babupur (26.75%), pure Udhao (26.71 %), Mahimapur (24.32 %), Sarauli (23.85%), Basthan (22.41%), Dostpur (20.25%), Ramipur (18.42%) village.

The waterlogged area are saturated with water, either by surface congestion, flooding or high groundwater table throughout depth of a root zone, for a period, long enough to limit the productivity of land . The signature of the land with surface ponding appeared in various shades of blue colour with smooth texture with discrete patches of various sizes. Some waterlogged areas was identified in post-monsoon image only whereas some waterlogged areas appeared in more than one season image. The sub surface waterlogged areas were appeared as purplish to bluish shades depending on the wetness. About 32.33 ha (0.15%) of the study area was observed under this category of land use. These lands were found in Bhawan Shahpur (7.47%) and Sujanpur (5.37%) villages.

3.2 Degraded lands

Land degradation is the major agro-ecological problem in this study area. In the study area, five land degradation classes viz., Salt affected land (Strong), Salt affected land (Moderate), Waterlogged Area (Permanent), Waterlogged Area (Seasonal) and Land with or without scrub were identified and mapped using RS and GIS techniques. The accuracy analysis reveals 88.19 per cent average accuracy, 92.72 per cent overall accuracy, and 0.925 Kappa coefficient values for Rabi season data and 90.45 per cent, 93.47 per cent and 0.958 respectively, for Kharif season data. The degraded lands together constitute 20.04% (4171.51ha.) of total geographical area of the block. Figure 4 illustrates the spatial distribution of various land degradation classes in the study area.

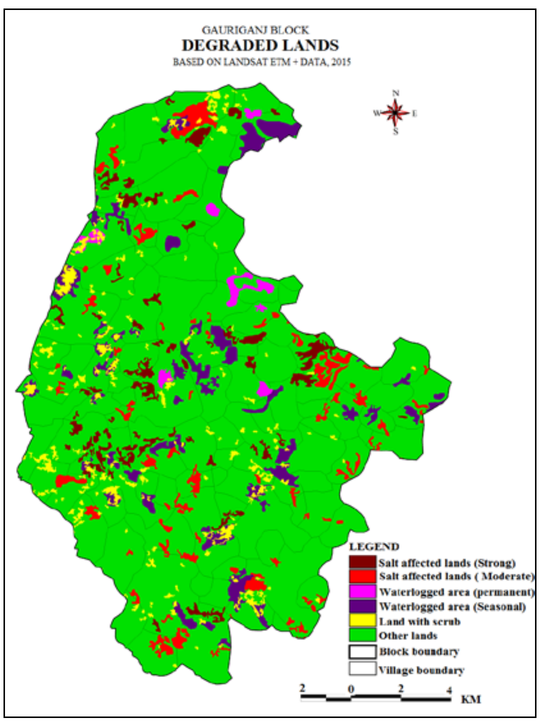

Fig.4 Degraded lands in Gauriganj block,Amethi district,2015

Total area under strongly salt affected land was observed on about 793.20.00 ha (3.81%) lands (Table 2 and Fig.5). The major occurrence of strongly salt affected land lies in Jethauna (33.86%), Biswan (22.23%), Gopalipur (20.14%), Sogara (16.28%), Rampur Kurwa (16.10%), Ramaipur (15.40%), Manjhwara (14.92%), Lugari (11.27%). It was also observed in Barna Tikar, Bishundaspur, Anapur, Misraului, Sarai Bhag Mani, Gulalpur, Sembhue, Rohshi Khurd, Pahar Ganj, Katra Lal Ganj, Pachehri, Amiya, Oripur villages on 5 to 10 per cent of their geographical area.

Table 2 Status of degraded lands in Gauriganj block, Amethi district, 2015

Land Degradation Class	*Area in ha.*	*As % to total area*
Salt affected land (Strong)	793.20	3.81
Salt affected land (Moderate)	964.10	4.63
Waterlogged Area (Permanent)	247. 54	1.19
Waterlogged Area (Seasonal)	1475.60	7.09
Land with or without scrub	691.07	3.32
Total	4171.51	20.04

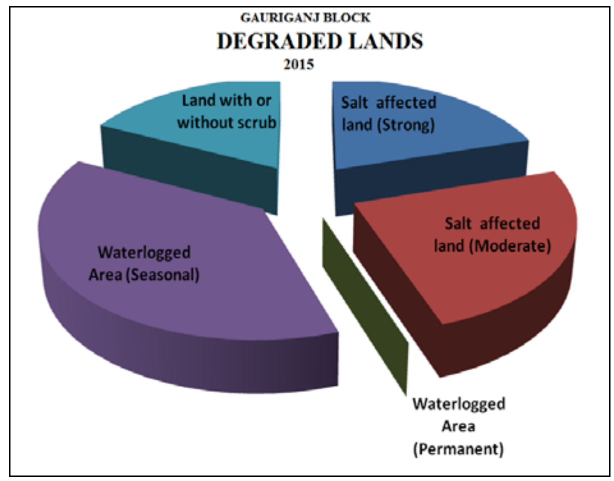

Fig.5 Status of degraded lands in Gauriganj block,Amethi district,2015

The moderately salt affected land appears as grayish white with red and white mottle color on the image. They are characterized by poor crop growth. The Rabi season satellite image was found suitable to map moderately salt-affected lands in the study areas.It accounts for 4.63 per cent (964.10 ha.) of the geographical area. Moderately salt affected lands cover about 8 per cent of the total geographical area and found in Sarai Bhagmani (33.63%), Sarauli (29.77%), Bastidei (25.49%), Paharpur (24.73%), Dhani Jalajpur (19.47%), Pathanpur (17.89%), Mahimapur (15.50%), Khajuri (14.49%), Sultanpur (14.12%), Dhanapur (13.36%), Lal Shahpur (11.87%), Sarai Barwand Singh (10.18%), Manmatipur (9.96%),Babupur (9.92%), Jethauna (9.88%), Madhupur (9.85%) and Sakarwara 98.30%). Out of 102 villages, 42 have nil or less than 1 per cent of their geographical area under this category. Remaining villages range between 1 to 8 percent.

The standing water for both Rabi and Kharif cropping seasons in low-lying areas included in permanent waterlogged area. These lands mostly observed on lower elements of terrain like local depressions those do not have adequate drainage, crop lands excluding paddy areas. They found on heavy textured soils like clay loams and clays or any soil with sub-surface impervious layer. On the satellite image they appear in light blue to very dark blue colours. This class of land degradation was mapped on 32.33 ha (0.15%) area and observed in 10 villages namely Gauripur (23.06%), Sujanpur (13.47%), Tulsipur (9.53%), Raj Garh (99.27%), Jagdishpur (8.71%), Gulalpur (6.41%), Barna Tikar (4.45%), Anapur (4.24%), Misrauli (2.13 %) and Benipur Baldev (1.36%).

Seasonal waterlogged areas were identified in Kharif season image only. Some time these areas appear as purplish to bluish shades depending on the wetness. It amounts to 1475.60 ha which was 7.09 per cent of the total geographical area of the block. Twenty villages of the block have higher percentage of area under this categories namely Benipur Baldeo (55.98%), Kaji Patti (35.48%), Bishundaspur (27.64%), Pandari (26.25%), Babupur (24.79%), Chittepur (22.47%), Sembhue (20.98%), Madhopur (20.94%), Kharanwan (20.46%), Saripur (19.98%), Dhani Jalalpur (17.39%), Guwawan (17.24%), Sarai Barwand Singh (16.97%), Darpipur (16.47%), Biswan (15.61%), Bhawan Shah Pur (15.20%), Banwaripur (14.82%), Argawan (14.67%), Oripur (14.37%) and Tikaria (13.47%).

The scrub lands often appear like fallow in Rabi season and look like crop land in Kharif season, which could be discriminated using multi-date satellite data. They appear in light yellow to brown to greenish blue depending on the surface moisture cover and vary in size from small to large having either contiguous or dispersed pattern and associated with agricultural lands around them. About 691.07 ha (3.32%) of the study area was observed under this category. The villages having higher percentage of area under this category were located mostly in north, west and southern part of the study area. The highest percentage was found in Kaji Patti (24.61%) followed by Bhawan Shahpur (17.39%), Pandri (16.17%), Asura (14.55%), Sembhue (14.11%), Gvjar Tol (13.04 %), Bastidai (12.88 %), Amiya (11.75%), Banwaripur (11.64%), Guwawan (11.58%), Biswan (11.55%).

4. Conclusions

Sustainable land resource management and planning in any region requires reliable and up-to-date information on the current status of land use/ land cover and their spatial patterns. RS technique coupled with GIS served as a very effective in meeting these requirements. The synergistic use of these modern spatial technologies helped to evolve an 'action plan' which was quite useful in planning for sustainable use of land resources to meet the needs of the current as well as future generation.

Acknowledgments

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