Land Use/Land Cover Change Analysis using Geo-Information Technology: Two Case Studies in Bangladesh and China

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Abstract
Land use/land cover (LULC) change plays a pivotal role in regional socio-economic development and global environment changes. In environment, where fragile ecosystems are dominant, the land cover change often reflects the most significant impact on the environment due to excessive human activities. So, LULC change analysis is essential to know the natural characteristics, extent and location, its quality, productivity, suitability and limitations of various land uses/covers. Present study was conducted to assess the LULC change in two distinct areas, the Bogra district of Bangladesh and Danjiangkou County of China, over the last 16 years (1988-2004) and 14 years (1991-2005), respectively. Landsat TM and IRS P6 LISS III images were used to analyze the overall changes of different LULC types in the two selected areas. To classify the satellite images for LULC, a fuzzy ARTMAP neural network supervised classification method was performed. A post classification comparison technique with GIS overlay was followed to derive the LULC changes. In this A study we focused the LULC dynamics, including statistics of spatio-temporal changes, trajectories/transformations of LULC and their relations to the selected physical environmental variables such as soil, slopes and altitude. The analysis revealed that the LULC of the two study areas were changed dramatically during the study periods, and considering the LULC dynamics, the results showed that LULC changes were related particularly to the pattern of the physical attributes; soil, slope and elevation. The relations between LULC change and physical properties of the environment, and the trajectories of the LULC depicted that the changes which took places during the study periods were mainly human induced, which might be the cause of soil and environmental degradation in the areas. Thus, more attention should be paid in these areas to protect environmental degradation, particularly for the eco-environmental sustainability.

1. Introduction

Land use/land cover (LULC) change is a common phenomenon in all over the world and becomes a central component in current strategies for managing natural resources and monitoring environmental change. Changes in the landscape are closely linked with the issue of our natural resources such as climate, soils, physiographic condition, water resources and biodiversity. Availability of accurate LULC information is essential for many applications like natural resource management, planning and monitoring programs. With the development of global change research, it is believed that human activities have great impact on the environmental change, particularly the exploitation and use of land, which caused land cover change and that would impact on global change also (Shi et al., 2000).

The advanced spatial technologies, remote sensing (RS) and geographic information systems (GIS) have paramount role in the understanding of our environment and management of resources. Therefore, RS and GIS have been widely applied to identify and analyze LULC change over the last few decades (Petit et al., 2001, Hathout, 2002, Pereira et al., 2002, Wu et al., 2006, Porter-Bolland et al., 2007 and Bin et al., 2007). Satellite remote sensing provides multi-spectral and multi-temporal data that can be used to quantify the type, amount and location of land use change. In contrast, GIS provides a flexible environment for displaying, storing and analyzing digital data which are necessary for the change detection. For landuse change detection, RS data from various sensors such as Landsat MSS, TM, ETM, SPOT HRV, IRS and AVIRIS are being used, and to demonstrate changes in multi-temporal approach, two or more sensors are considered (Mertens and Lambin, 2000, Roy and Tomar, 2001, Yang and Lo, 2002, Baskent and Kadiogullari, 2007 and Shalaby and Tateishi, 2007).

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The amount, rate and intensity of LULC change are very high in developing countries as human impacts on the land are increasing at an alarming rate (Rao and Pant, 2001). China is the world's third largest country, the most rapidly developing nation and home to 1.3 billion people. Since early 1980s, the unprecedented combination of economic development and population growth has led to a dramatic land transformation across China (Liu et al., 2005). On the other hand, Bangladesh is the most densely populated country in the world with a population of more than 114.5 million (BBS, 2005). High population density put tremendous pressure on the land (annual growth rate 1.9 %,) which is believed to be the main driving force leading to rapid alteration of land use/land cover across the country (World Bank, 2006). In order to achieve sustainable environmental management, both countries require accurate and up-to-date land use/land cover information that can help plan resource utilization and environmental monitoring. In addition, at national level, many countries are now seeking to monitor land use change as a basis for policy guidelines and action.

In recognition of regional change research, our study focuses on the analysis of LULC change in two developing countries, Bangladesh and China, over the last 16 years and 14 years, respectively using Landsat TM and IRS P6 LISS III multi-temporal satellite data with GIS. These two areas were select to perceive the nature and degree of LULC changes in a flat terrain and hill terrain which might be useful to know the environmental conditions contributing to such changes and to take initiative for the eco-environmental sustainability of two areas. In this study, it was hypothesized that in different landscape areas i.e. flat and hill terrain, there is a significant change in land use/land cover, and physico-environmental conditions and land-cover changes are closely related to each other and landscape diversity may have a considerable role. Accordingly, three physical environmental attributes; degree of slope, altitude and soil types were selected to understand the major explanatory factors for land use distribution and land use transformation. Human activity is a major force in affecting spatial and temporal pattern of land use change; however the underlying physical structure of a landscape often precludes in the study of land use change (Verburg and Chen, 2000). Therefore, in this study land use dynamics were studied to find out the characteristics of LULC change and various land cover modifications and transitions in relation to physico-environmental condition. However, the specific objectives of this study were (a) to investigate the potential of Landsat and IRS satellite imagery to classify the land use/land cover and changes in two specific areas; (b) to quantify the major changes in land cover over past 15 years; (c) to detect the relationships between LULC change and physical condition of the area and finally, (d) to compare the results of LULC change of two areas i.e. Bogra and Danjiangkou.

2. Study Area

This study was an attempt to analyze land use/land cover change in two areas, namely Bogra district of Bangladesh and Danjiangkou County of China (Figure 1). Bogra district is located in the north western part of Bangladesh. The spatial extent of Bogra district is between $24^{0}32^{\prime}30^{\prime\prime}$ to $25^{0}06^{\prime}34^{\prime\prime}$ N latitude and $88^{0}57^{\prime}50^{\prime\prime}$ to $89^{0}44^{\prime}00^{\prime\prime}$ E longitude with an area of 2911.90 km^2. The District enjoys a tropical climate with monsoon and periodic thundershower during summer.

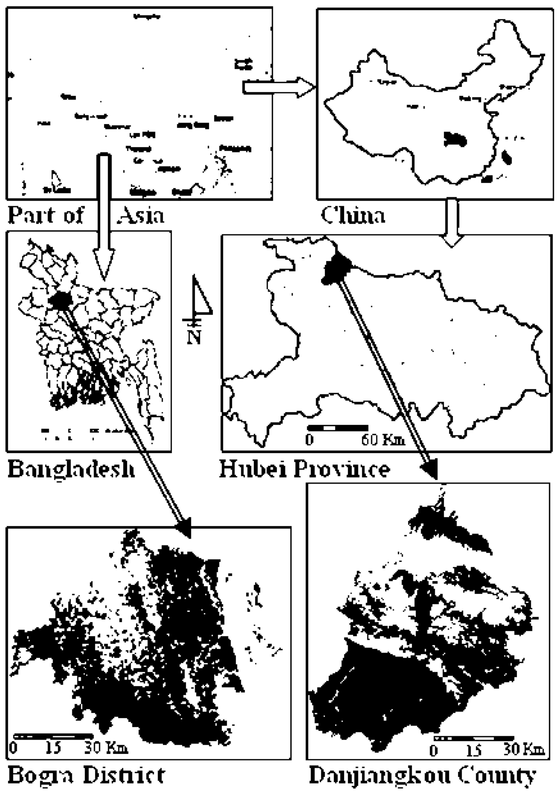

Figure 1: Location of the study area

Average minimum and maximum temperature of the District ranges between $21^{0}C$ and $31^{0}C$. The total rainfall was recorded 2417mm for the year 2004 (BBS, 2005). In this district loam, loam to silty clay loam, silty clay loam and sandy loam to sandy type of soils are the major groups of soils. Among these, loam and loam to silty clay loam (33.33% and

33.86% of the total area, respectively) are the main soil types (SRDI, 2005). The elevation ranges from 14m to 40m and almost all of the areas can be categorized as flat to nearly flat topography. Flood in the study area is a common phenomena and it affects the area to a varying extent almost every year. Bogra district has experienced many severe floods that have devastated the area like other parts of Bangladesh in the past (Rahman and Saha, 2008). Rice, potato, mustard, wheat are the major agricultural crops in this district.

Danjiangkou County is located in the north western part of Hubei Province of China. The spatial extent of this County is between $32^0 14' 19''$ to $32^0 58' 09''$ N latitude and $110^0 48' 06''$ to $111^0 34' 39''$ E longitude with an area of 3115.58 km^2 (Figure 1). This County enjoys a subtropical climate with monsoon during summer. Average minimum and maximum temperature of the County ranges between 14^0C and 20^0C. Average annual precipitation was 1116 mm of which 70% occurred between May and September. The elevation ranges from 151m to 1610m, and 60.58% of the total area is within 151m to 450m. Slope characteristics of the area represents that about 48.62% of the area is under gentle ($<10^0$) to moderate slope ($10\text{-}20^0$). The area under moderate steep slope ($21\text{-}30^0$) is also remarkable in the area (about 29.36%). Major soil groups of the area are loam, sandy clay loam, sandy loam and silty clay loam, however, sandy loam and loam soil are the dominant soil types (58% and 30.61% of the total area, respectively) in Danjiangkou County (NSSO, 2005). In this area, the main crops are corn, rice, rape and wheat.

3. Data Used and Methods

Four multi-spectral remotely sensed images were acquired from Landsat TM and IRS P6 LISS III satellites for this study. Landsat TM and IRS P6 LISS III images were acquired for the date of 11 November 1988 and 01 November 2004 for the Bogra District, and 9 September 1991 and 19 September 2005 for the Danjiangkou County, respectively. Ground truth data were obtained using GPS (Global Positioning System) in this study. Besides these, soil map of Bogra district by Soil Resource Development Institute of Bangladesh (SRDI, 2005), at scale 1:50,000, and soil map of Danjiangkou County by National Soil Survey Office (NSSO, 2005), at scale 1:220,000 were used. The topography/contour map (contour interval 10m) of Danjiangkou County was also acquired and used to generate a DEM map of Danjiangkou County. The overall methodology of this study is shown in Figure 2 and the details are discussed in the following sections.

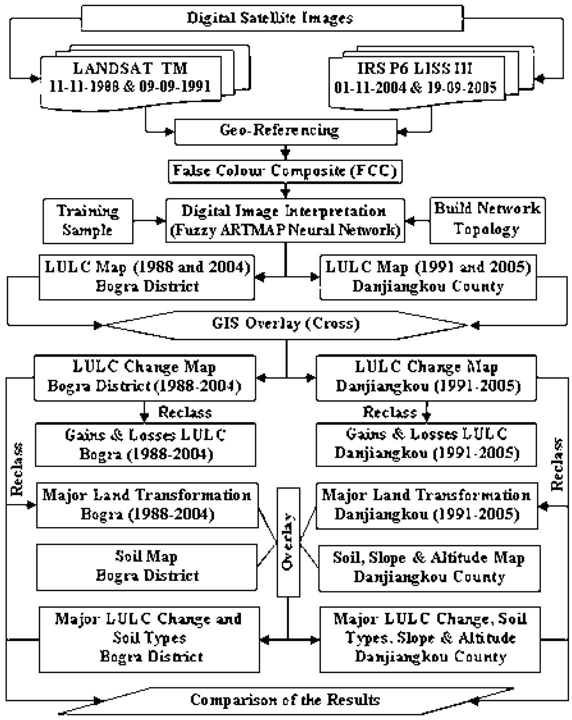

Figure 2: Overall methodology of the study

3.1 Image Processing-Geometric Correction

In this study two types of geometric correction procedure were used, *image-to-map* and *image-to-image*. The Landsat TM images were first spatially georeferenced to a universal transverse mercator (UTM) system using the first order affine transformation and resample with a nearest neighbour algorithm. To do so, ground control points were identified from topographic maps and a total of 26 GCPs for each scene were collected. A root mean square (RMS) error of less than 0.25 pixel was accepted and then resampled using 30m pixel size. Afterwards, in the image-to-image registration procedure, multi temporal IRS P6 LISS III images were geometrically corrected with respective validated geocoded Landsat images, used as a referenced image. For IRS P6 images, the root mean square errors were less than 0.25 pixels and these images were then resampled using the nearest neighbour algorithm with an affine transformation and 23.5m pixel size.

3.2 Image Classification-Fuzzy ARTMAP Neural Network

Apart from the data source systems, analysis technique plays a vital role for extracting information from the remotely sensed data (Atkinson and Tatnall, 1997). In recent time, artificial neural networks have been used extensively in multi-spectral image classification

(Hermann and Khazenie, 1992 and Foody and Arora, 1997). An artificial neural network simulates how a human brain processes spatial data problems. Neural networks are non-linear and can be conceived as a complex mathematical function that converts input data (e.g., remotely sensed imagery) to a desired output (e.g., a land cover classification). A fundamental difference between statistical and neural approaches to classification is that statistical approaches depend on an assumed *model*, whereas neural approaches depend on *data* (Atkinson and Tatnall, 1997). In the classification of remotely-sensed images, it is often difficult to distinguish some pairs of land cover types since mixture of pixels exist in different land cover types due to heterogeneous surface. To subdue the problem of mixed pixels, neurofuzzy technique is developed (Wang, 1990, Foody and Cox, 1994 and Foody, 1997) which combines the power of neural networks with fuzzy logic to enable fuzzy rules to be incorporated into the classification and enable the intrinsic uncertainty in classification to be represented and minimized (Atkinson and Tatnall, 1997). Therefore, in this study to classify the satellite data, a fuzzy ARTMAP neural network digital classification procedure was performed over FCC image (false colour composite), which was generated using NIR, red and green bands of the Landsat TM and IRS P6 images. Fuzzy ARTMAP neural network classifier of IDRISI Andes (Clark Lab, 2006) was used to classify the selected images. A comprehensive description of ART and Fuzzy ARTMAP models can be found in many literatures (e.g., Carpenter et al., 1991, 1992, Mannan et al., 1998 and Lopes et al., 2005). However, in the procedure of fuzzy ARTMAP, first training sites were chosen for each of the land use/land cover class in the sample set according to the land use classification level-1 (Lillesand and Kiefer, 2002). For choosing the training sample of each land use/land cover type, ground truth information was incorporated. Five classes *viz.* cropland, agricultural fallow, channel bar, built-up/settlement and water bodies were recognized as the major land use types in Bogra district of Bangladesh. On the other hand, for Danjiangkou County, ten classes *viz.* cropland, orchard, agricultural fallow, barren land/bare soil, water bodies, sandy/river bed, dense forest, moderate/low dense forest, road and built-up/settlement were recognized. Afterwards, to build the network topology, parameters (chosen, learning and vigilance) were selected and trained the network. Vigilance parameter for ARTa and ARTb were selected 0.99 and 1.00 for IRS P6 images, whereas vigilance parameter was selected 1.00 for both ARTa and ARTb for Landsat TM images to obtain the most accurate results. Chosen and learning parameters were selected 0.01 and 1.00, respectively for all images. Selection of appropriate value for the parameters, it is necessary to train and classify image with some set of scale parameters, and according to the objective of the study and prior knowledge of the study area (ground truth), suitable scale parameter has to be selected for final classification. Therefore, on the basis of visual inspection of the classified images using some set of scale parameters and cross validation with ground truth data, above mentioned parameters were selected for the final classification procedure of land use/land cover. Once the network topology was built using the selected parameters, the model can be run for the classification of image. In this study, accuracy assessment of the classification was performed using a *Kappa* statistics, and it was found that overall Kappa was 89% and 91% for the 1988 and 2004 images for Bogra District (Table 1), and 88% and 89% for the 1991 and 2005 images for Danjiangkou County, respectively (Table 2). A standard overall accuracy for land use/land cover map is set between 85% and 90% (Lins and Kleckner, 1996). Thus, the accuracy was therefore sufficient for the evaluation of land use/land cover changes for this study.

3.3 Land Use/Land Cover Change Detection and Analysis

Based on remote sensing imagery, there are many methods available to detect LULC change, such as image differencing, vegetation index differencing, selective principal components analysis, direct multi-date classification, post-classification analysis (Mas, 1999 and Coppin et al., 2004). In this study, to detect and analyze the changes in land use/cover, a post-classification comparison technique was used which is the most widely used change detection methods (Jensen, 1996). This method comprises overlaying, using a cross operation with the previously classified two images to be compared. Hence, for the change detection and analysis, LULC map of two specific years for each case study area were overlayed, analyzed and mapped, and area statistics were tabulated using *Cross* operation of ILWIS (Integrated Land and Water Information System) (Figure 2). In this process, from the cross table and map, different combinations were analyzed and reclassified as the changed and unchanged areas; gain and loss of each category and land transformation from each category of LULC. It may be noted here that change analysis was confined to the following perspectives: (i) area of change and no change, (ii) gain and loss of each

LULC and (iii) major transformations of each category of land use/land cover.

4. Results and Discussion

4.1 Land Use/Land Cover Change

The land use/land cover map of Bogra District and Danjiangkou County is shown in Figure 3. The Figure revealed that the cropland (including agricultural fallow) was the dominant LULC type in Bogra district whereas forest land (dense and moderate/low dense forest) was the dominant LULC type in Danjiangkou County during the study periods (Tables 1 and 2). These were mainly due to the phisico-environmental conditions of both areas. In Bogra district, almost all of the areas can be categorized as flat to nearly flat topography (elevation ranging from 14-40m) whereas landform of Danjiangkou County is dominated by gentle (>10^0), moderate (10-20^0) and moderately steep slope(21-30^0) with 151m to 450m elevation.

In LULC change assessment, unchanged and changed area over a specific time period is the most important. In reality, unchanged trajectories show the original condition of land cover. In land use change detection study, the focus should be on the analysis of unchanged and changed trajectories, because of their higher accuracy and meaningful indication of the irreversible change (Zhou et al., 2004). LULC change analysis based on post classification comparison showed that 68.72% of the total area of Bogra district was unchanged whereas in Danjiangkou County, 60.36% of the total area was unchanged over the study periods. Unchanged area was highest under the cropland (50.20% of the total area) in Bogra district (Table 3). Since forest area (dense and moderate/low dense forest) was highest in Danjiangkou, the highest proportion of unchanged area was also found in this category (Table 4). Therefore, the study indicated that the changed areas of LULC were larger in the Danjiangkou County than that of the Bogra district over the study periods.

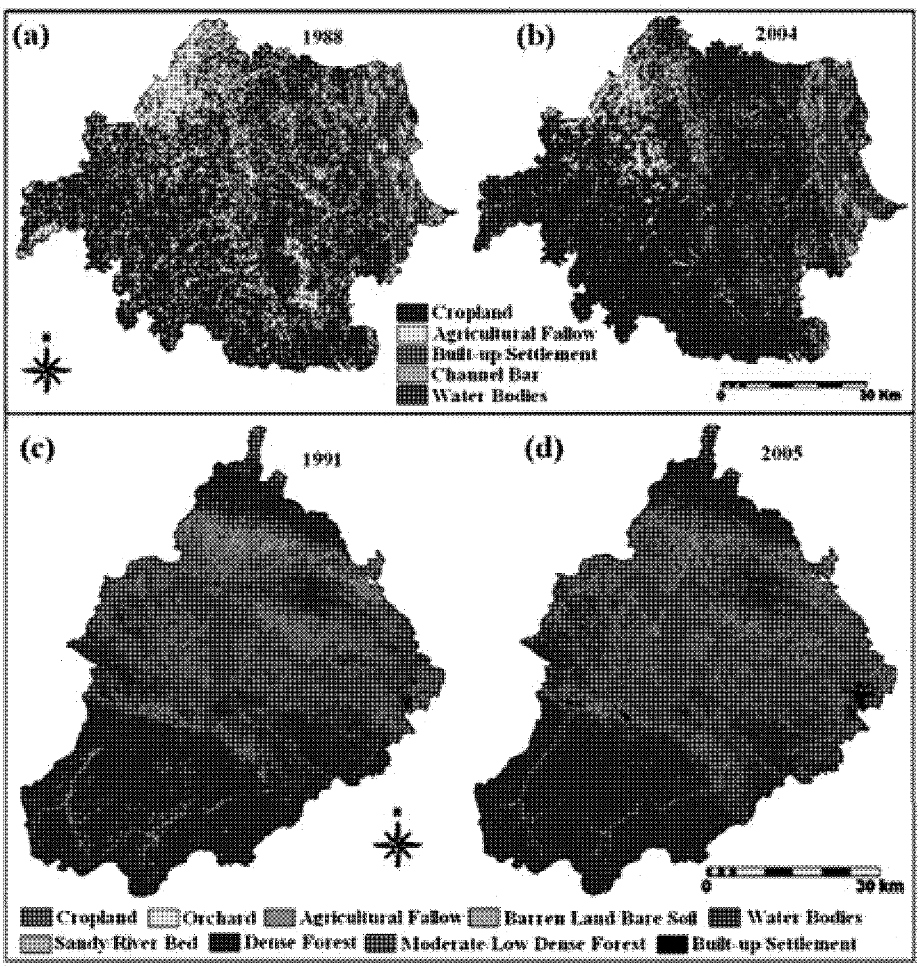

Figure 3: Land use/land cover map (a, b) Bogra District and (c,d) Danjiangkou County

Table 1: Bogra District: Land use/land cover classification (1988 and 2004)

Land use/land Cover	1988		2004		Deviation (% of the Total Area)
	Area (Hectare)	% of the Total Area	Area (Hectare)	% of the Total Area	
Cropland	167986.99	57.69	181877.75	62.46	+4.77
Agricultural Fallow	67996.95	23.35	31541.82	10.83	-12.52
Built-up/Settlement	22112.74	7.59	25510.24	8.76	+1.17
Channel Bar	7400.89	2.54	8801.27	3.02	+0.48
Water Bodies	25693.87	8.82	43460.36	14.93	+6.10
Total	291191.44	100.00	291191.44	100.00	-
Classification Accuracy: Over all Kapa=89% for 1988 and 91% for 2004					

Table 2: Danjiangkou County: Land use/land cover classification (1991 and 2005)

Land Use/Cover	1991		2005		Deviation (As % of the Total Area)
	Area in Hectares	% of the Total Area	Area in Hectares	% of the Total Area	
Cropland	17672.85	5.67	19869.29	6.38	+0.71
Orchard	135.59	0.04	5132.45	1.65	+1.60
Agricultural Fallow	14859.50	4.77	9496.28	3.05	-1.72
Barren Land/Bare Soil	17190.79	5.52	5100.02	1.64	-3.88
Water Bodies	22118.05	7.10	27987.26	8.98	+1.88
Sandy/River Bed	575.25	0.18	4251.86	1.36	+1.18
Dense Forest	149615.19	48.02	139467.11	44.76	-3.26
Moderate/Low Dense Forest	88724.05	28.48	98064.98	31.48	+3.00
Road	-	-	208.17	0.07	-
Built-up/Settlement	667.12	0.21	1980.98	0.64	+0.42
Total	311558.40	100.00	311558.40	100.00	-
Classification Accuracy: Over all Kapa=88% for 1991 and 89% for 2005					

Table 3: Bogra District: unchanged area between 1988 and 2004

Land Use/Land Cover-Unchanged Area	Area in Hectares	% of the Total Unchanged Area	% of the Total Area
Cropland	146187.00	73.05	50.20
Agricultural Fallow	16696.37	8.34	5.73
Built-up/Settlement	21702.82	10.85	7.45
Channel Bar	1386.69	0.69	0.48
Water Bodies	14136.56	7.06	4.85
Total	200109.44	100.00	68.72

Table 4: Danjiangkou County: unchanged area between 1991 and 2005

Land Use/Land Cover-Unchanged Area	Area in Hectares	% of the Total Unchanged Area	% of the Total Area
Cropland	3754.48	2.00	1.21
Orchard	74.46	0.04	0.02
Agricultural Fallow	2447.19	1.30	0.79
Barren Land/ Bare Soil	1544.77	0.82	0.50
Water Bodies	21898.25	11.65	7.03
Sandy/River Bed	575.25	0.31	0.18
Dense Forest	104549.58	55.60	33.56
Moderate/Low Dense Forest	52698.93	28.03	16.91
Built-up/Settlement	498.18	0.26	0.16
Total	188041.09	100.00	60.36

In change detection, the gain and loss of each LULC type was also analyzed and Table 5 depicts the gain and losses of each land use/cover category in both the areas. Table depicted that in Bogra district; between 1988 and 2004 the gain and loss areas of the cropland were 12.26% and 7.49% of the total area, respectively, meaning that a net gain of the cropland was 4.77% during the periods. The changed area of LULC depicted that in this area agricultural fallow land decreased very significantly, in association with the increase of cropland as shown in Table 5 and Figure 4a. In contrast, the gains and losses of land use category in Danjiangkou County showed that over the last 14 years time, cropland (corn) gained 5.17% of the total area while witnessed 4.46% lost, indicating a net gain of cropland was 0.71% of the total area between 1991 and 2005 (Table 6). Changed area of LULC further depicted that the dense forest area decreased very significantly, in association with the rapid increase of the moderate/low dense forest (Table 6 and Figure 4b). Though the dense forest area declined significantly (3.26% of the total area) in Danjiangkou County between 1991 and 2005, the moderate/low dense forest area increased simultaneously (3.00% of the total area), hence only 0.26% of the total area was deforested over the last 14 years in Danjiangkou. From this analysis it can be said that the major land use/land cover changes were consistent with natural or human events. For example, increase of water bodies in Bogra district was mainly due to the stagnant of flood water in the area over the study periods and in Danjiangkou this was mainly because of the construction of a Dam in the north east part of the area, which might be the cause of water logging or water spread of the area.

Changes in LULC affect the ecological landscape functions and processes. Environmentalist, planner and policy makers have interest not only to know the identification of the changed area over time and the statistics of gain and loss of the LULC category but also eager to understand the detail changes/transformations of LULC. Thus, the major transformations of LULC were also analyzed here to depict the detailed transformation of each category of LULC. Based on the classification scheme, major LULC change trajectories which were found in this study for two study areas are shown in Figure 5 which was based on Tables 7 and 8.

Table 5: Bogra District: Gain and loss in land use/land cover (1988-2004)

Land Use/Cover	Gains from Others			Losses to Others			Net Gains/Losses (As % of the Total Area)
	Area in Hectares	% of the Total Changed Area	% of the Total Area	Area in Hectares	% of the Total Changed Area	% of the Total Area	
Cropland	35690.75	39.19	12.26	21799.99	23.93	7.49	+4.77
Agricultural Fallow	14845.45	16.30	5.10	51300.58	56.32	17.62	-12.52
Built-up/Settlement	3807.42	4.18	1.31	409.92	0.45	0.14	+1.17
Channel Bar	7414.58	8.14	2.55	6014.20	6.60	2.07	+0.48
Water Bodies	29323.80	32.19	10.07	11557.31	12.69	3.97	+6.10
Total Changed Area	91082.00	100.00	31.28	91082.00	100.00	31.28	-

Table 6: Danjiangkou County: Gain and loss in land use/land cover (1991-2005)

Land Use/Land Cover	Gains from Others			Losses to Others			Net Gains/Losses (As % of the Total Area)
	Area in Hectares	% of the Total Changed Area	% of the Total Area	Area in Hectares	% of the Total Changed Area	% of the Total Area	
Cropland	16114.81	13.05	5.17	13918.37	11.27	4.46	+0.71
Orchard	5057.99	4.09	1.62	61.13	0.05	0.02	+1.60
Agricultural Fallow	7049.09	5.71	2.26	12412.31	10.05	3.98	-1.72
Barren Land/ Bare Soil	3555.25	2.88	1.14	15646.02	12.67	5.02	-3.88
Water Bodies	6089.01	4.93	1.95	219.8	0.18	0.07	+1.88
Sandy/River Bed	3676.61	2.98	1.18	0.00	0.00	0.00	+1.18
Dense Forest	34917.53	28.27	11.20	45065.61	36.49	14.46	-3.26
Moderate Dense Forest	45366.05	36.73	14.57	36025.12	29.17	11.57	+3.00
Road	208.17	0.17	0.07	-	-	-	-
Built-up/Settlement	1482.80	1.20	0.47	168.94	0.14	0.05	+0.42
Total Changed Area	123517.31	100.00	39.64	123517.31	100.00	39.64	-

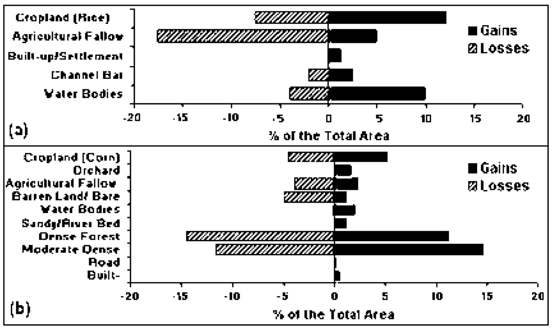

Figure 4: Gain and loss in LULC: (a) Bogra District: 1988-2004, (b) Danjiangkou County: 1991-2005

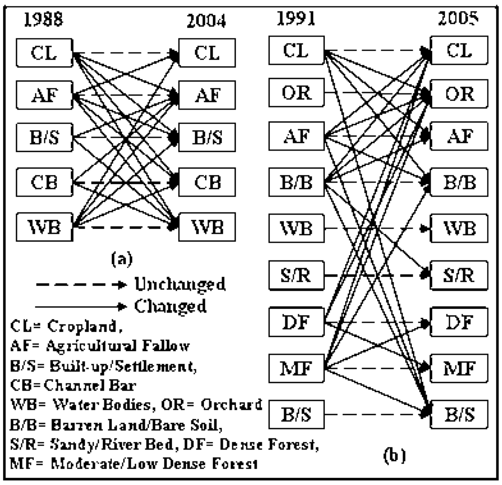

Figure 5: Major land transformations between the year (a) Bogra District, (b) Danjiangkou County

In Bogra district major land transformations were from the cropland, agricultural fallow and water bodies whereas, in Danjiangkou County major land transformations were from the forest (dense and moderate/low dense), barren land/bare soil, cropland and agricultural fallow. In Bogra district, cropland was converted mainly to the agricultural fallow (4.04%), water bodies (2.93%), channel bar (0.29%) and built-up/settlement (0.23%) and at the same time increase of cropland was mainly from the agricultural fallow (11.96%) and water bodies (0.27%). The increase of cropland (transformation to cropland) in this part was attributed to many factors such as increase of irrigation facilities, the use of HYVs (high yielding verities) seed, fertilizer etc. (according to the local farmers), the shifting of unstable stagnant flood water and the shifting of river courses. Moreover, increase of population also should have significant impact on the land use/cover change in Bogra district.

In Danjiangkou County, dense forest mainly converted to the moderate/low dense forest (14.05%), cropland (0.26%) and orchard (0.11%). While moderate/low dense forest was shifted mainly to the dense forest (10.40%), orchard (0.46%), cropland (0.33%), barren land/bare soil (0.29%) and built-up areas (0.07%) (Table 8). Area converted to orchard, cropland, barren land/bare soil and built-up/settlement from forest land indicating that the clearing of forest leading to land degradation. Decrease of dense forest might be the cause of over exploiting the forest resources as a source of energy and it may due to the lack of proper forest management system. Another explanatory factor may be increasing population pressure in the region, which increased 8.9% between 1991 and 2005 in Danjiangkou County. On the other hand, land transformation from moderate/low dense forest to the dense forest depicted the re-growth of forest in the area. Apart from these, it was interesting to note that barren land/bare soil was one of the major kind of land use class that was reclaimed (Table 8). During the study periods, barren land/bare soil decreased very significantly, in association with the increase of cropland and agricultural fallow as shown in Tables 2 and 8. It may be noted that this part of China has a serious soil erosion problem and the Government has many programs and planning to protect the land from soil erosion and consequently barren land/bare soil was reclaimed over the past decade. Moreover, a remarkable area of cropland was also transformed to the orchard (1.10%) during this period (Table 8) due to initiative to protect land from soil erosion and degradation.

4.2 Relations between LULC Change and Soil and Terrain Conditions

Land use/land cover characteristics and changes in land use/land cover influenced by many environmental factors. In our study, we focused on some important physical and environmental conditions of the area that influence land use/land-cover changes. The aim of this was to find out the physico-environmental conditions where major LULC changes were happened over the study periods. We focused on environmental variables that changes over space, but are generally stable in time such as soil, altitude and slope of the area. To know the changing pattern of LULC in respect to the physical environment; soil map, slope map and elevation map were crossed with the changed area map of LULC in this study (Figure 2). Since the terrain features of Bogra district is almost flat, only soil types were compared with major LULC changes for Bogra district.

The relations between major LULC transformations and soil types which are shown in Figure 6a and 6b confirmed that the major changes of LULC took places mainly in the loam, loam to silty clay loam and sandy loam to sandy soils in Bogra district, while the major changes were mainly in the sandy loam and loam soils in Danjiangkou County. Reclamation of cropland (for example from agricultural fallow to cropland) took place mainly on fertile soil such as the loam (40.43%) and loam to sitly clay loam soil (37.89%), while the transformation of land from cropland to built-up/settlement and channel bar were highest in the loam to silty clay loam soils (89.57%) and sandy loam to sandy soils (62.04%), respectively (Figure 6a). On sandy loam to sandy soil the main land use transformation was channel bar turned into agricultural fallow and water bodies in Bogra district.

Similarly, in Danjiangkou County, the land transformation from dense forest to orchard was dominant in the loam (43.45%) and sandy loam soil (44.79%), while the transformation of land from moderate/low dense forest to built-up/settlement and barren land/bare soil were highest in the sandy loam soils (72.38% and 68.63%) (Figure 6b).

On the other hand, relationship between major LULC changes and terrain conditions (slopes and altitude) confirmed that major changes of LULC in Danjiangkou mainly took place in the gentle sloping areas which was followed by moderate sloping areas and in the altitude of 151m to 300m which was followed by 301m to 450m (Figure 6d, 6c).

Table 7: Bogra district: Major changes/transformation in LULC (1988-2004)

Major Changes/Transformations		Area in Hectares	% of the Total Changed Area	% of the Total Area
From	**To**			
Cropland	to Built-up/Settlement	658.56	0.72	0.23
	to Channel Bar	843.20	0.93	0.29
	to Agricultural Fallow	11752.82	12.90	4.04
	to Water Bodies	8545.21	9.38	2.93
Built-up/ Settlement	to Agricultural fallow	79.14	0.09	0.03
	to Water Bodies	330.50	0.36	0.11
Channel Bar	to Agricultural Fallow	471.34	0.52	0.16
	to Water Bodies	5494.88	6.03	1.89
Agricultural Fallow	to Cropland	34835.94	38.25	11.96
	to Built-up/Settlement	1630.26	1.79	0.56
	to Channel Bar	1733.12	1.90	0.60
	to Water Bodies	12686.98	13.93	4.36
Water Bodies (Seasonal Flood Water)	to Cropland	775.82	0.85	0.27
	to Built-up/Settlement	798.89	0.88	0.27
	to Channel Bar	4693.86	5.15	1.61
	to Agricultural fallow	2450.10	2.69	0.84
Total		87780.61	96.38	30.15
Other Changes (Minor Transformations)		3301.39	3.62	1.13

Table 8: Danjiankou county: Major changes/transformations in LULC (1991-2005)

Major Changes/Transformations		Area in Hectares	% of the Total Changed Area	% of the Total Area
From	**To**			
Barren Land/ Bare Soil to Others	to Built-up/Settlement	593.16	0.48	0.19
	to Orchard	840.27	0.68	0.27
	to Cropland	5784.86	4.68	1.86
	to Agricultural Fallow	2875.40	2.33	0.92
	to Sandy/River Bed	3012.67	2.44	0.97
Cropland to Others	to Barren Land/ Bare Soil	1296.33	1.05	0.42
	to Built-up/Settlement	301.25	0.24	0.10
	to Agricultural Fallow	5581.89	4.52	1.79
	to Orchard	3433.16	2.78	1.10
Agricultural Fallow to Others	to Cropland	8509.39	6.89	2.73
	to Barren Land/ Bare Soil	1324.79	1.07	0.43
	to Built-up/Settlement	268.82	0.22	0.09
	to Orchard	471.97	0.38	0.15
Dense Forest to Others	to Cropland	800.06	0.65	0.26
	to Orchard	337.59	0.27	0.11
	to Moderate/Low Dense Forest	43784.24	35.45	14.05
Moderate/Low Dense Forest to Others	to Barren Land/ Bare Soil	918.27	0.74	0.29
	to Built-up/Settlement	221.96	0.18	0.07
	to Cropland	1014.51	0.82	0.33
	to Dense Forest	32414.47	26.24	10.40
	to Orchard	1431.99	1.16	0.46
Total		115017.05	93.12	36.92
Other Changes (Minor Transformations)		8500.26	6.88	2.74

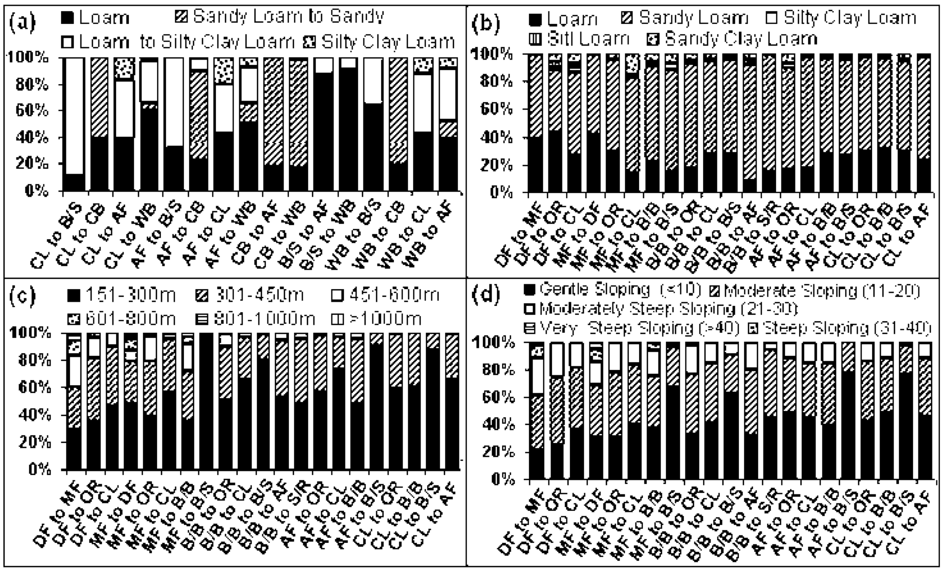

Figure 6: Graph shows the relations between major LULC transformation and soil types, slopes and altitude. (a) Bogra District, (b), (c) and (d) Danjiangkou County. Y axis of these diagrams represents the % of change. Details for abbreviations used in these diagrams are same as Figure 5.

In other words it may be said that these variables may have conditioned the land use/land cover changes in this area. On the other hand, linear regression analysis between major land trajectories and terrain characteristics reveled that the relationships between major land transformation and slope, and altitude were negatively correlated (negative trend line) in all the cases (Figure 7), meaning that the rate of land transformations or LULC changes were decreasing in respect to the increasing of slope and altitude of the area (Figure 7). Therefore, land-cover dynamics in two areas showed that land-cover changes were related particularly to the pattern of the physical attributes i.e. soil, slope and elevation. Though this study illustrated that the soil, slope and altitude constrained the LULC spatial pattern and changes, it also signified that the physical conditions were not directly influencing LULC changes rather it was because of human activities in these conditions; human activities (social, economical, cultural etc.) are generally more in these areas (good soil condition, low slope and altitude) than the areas of high altitude and slope due to the terrain complexity. Thus, the relations between LULC change and physical properties of the environment and the trajectories of the LULC confirmed that the changes took place over the study period were mainly human induced rather than natural. As a result, the changes in land use/cover leading to soil and environmental degradation of the area.

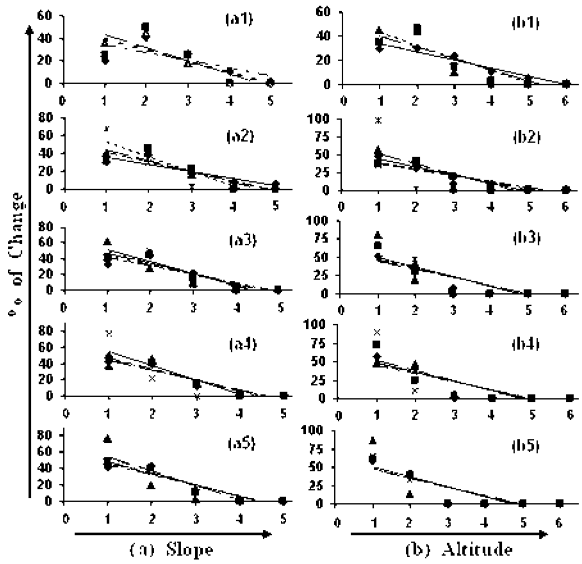

Figure 7: Linear regression: (a) between Slope and major land transformation, (b) between altitude and major land transformation. a1, b1- land transformation from dense forest to others; a2, b2- moderate/low dense forest to others; a3, b3- barren land/bare soil to others; a4, b4- agricultural fallow to others; a5, b5- cropland to others. 1, 2, 3, 4 and 5 represents gentle, moderate, moderately steep, steep and very steep slope for the case (a) and 1, 2, 3, 4, 5 and 6 represents 151-300m, 301-450m, 451-600m, 601-800m, 801-1000m, >1000m altitude for the case (b).

5. Conclusions

The main objective of this study was to detect the present perspective of LULC and to find out the nature of the LULC changes that have taken place in the last 16 years and 14 years in Bogra district and Danjiangkou County, respectively. It was found that the Landsat TM and IRS LISS III P6 images could be utilized satisfactorily in the areas where physico-environmental conditions are different. And fuzzy ARTMAP neural network was easy to use for the supervised classification of satellite images with *fuzzy ARTMAP* module of IDRSI Andes software. Land use/land cover change analysis showed that these two areas have undergone severe land cover change as a result of increased human activities during the study periods. Results form two different landscapes, flat and hill terrain areas shows that the LULC is changing over times even though different topography are exist and different LULC types are found over the land surface. For example, a considerable increase in built-up/settlement and agricultural land in Bogra district was taken place. On the other hand, the area of natural vegetation (dense forest) decreased considerably but moderate/low dense forest and orchard area was increased remarkably in Danjiangkou County. The most important land use change trajectories showed that in Bogra district, cropland converted mainly to the agricultural fallow, water bodies, channel bar and built-up/settlement and at the same time increase of cropland was mainly from the agricultural fallow and water bodies. In Danjiangkou County, dense forest was converted mainly to the moderate/low dense forest, cropland and orchard. On the other hand, moderate/low dense forest was shifted mainly to the dense forest, orchard, cropland and built-up areas. It may be noted that this study was based on two date images; therefore it indicated the changes between the time periods only; not for intermediate time between the years. Hence, transformations which have taken place may not be from one category to changed category directly. A sequence of images can be used for better understanding the transformation of land in a specific time periods. Further, the analysis also verified that this study was able to detect the relationship between different landscape parameters, spatial structures and transformations, and also confirmed the assumption that slope degree, altitude and soil types constrained land use pattern and determine land use change. For example, land use/land cover changes mainly took place in the loam and loam to silty loam soils in Bogra district and in the sandy loam and loam soil with gentle to moderate sloping and 151m to 450m altitude areas in Danjiangkou County. Although our results implied physical constraints of land-cover changes, the basic driving force behind land-cover changes can be assumed to be socio-economic factors/human activities. There are essentially different socio-economic forces influencing study areas, Bogra district and Danjiangkou County. Many other driving forces such as income, land tenure, regional planning and political decisions may influence land-cover changes in the study areas. Moreover, interactions between socio-economic condition, physico-environmental factors and land cover changes need to be considered. On the basis of the discussion and findings, this study revealed that integrating GIS and remote sensing provided valuable information to determine the nature of land cover changes especially the areas and spatial distributions of different land cover changes. This comparative study (in two different areas) also stated that the land use/land cover is dramatically changing in the region which is important for the development and implementation of targeted improved land management policies and interventions, and also for monitoring of ecosystem status and trend. Therefore, more attention should be paid in these regions to protect the degradation of soil, particularly for the eco-environmental sustainability.

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