LAND-USE CHANGE ANALYSIS OF DISTRICT ABBOTTABAD, PAKISTAN: TAKING ADVANTAGE OF GIS AND REMOTE SENSING ANALYSIS

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ABSTRACT

During the last decade, District Abbottabad of Pakistan has gone through extensive land-use changes due to accelerated developmental and educational advancements, urbanization, and a major earthquake in Pakistan (2005). The study was conducted to analyze and quantify the changes in land-use that occurred during 1998-2009 and the transition rate among different land-use types to better understand the complex inter-relationships and to provide a base-line for further studies of drivers of land-use change in the region. The possible causes and impacts of land-use change were discussed. Advance geographic information system (GIS) and remote sensing (RS) techniques were applied to map and analyze land-use changes. Land-use maps for the years 1998, 2005, and 2009 were developed. A transition matrix of land-use was calculated for 1998-2009. The results show an increase of 2.83 % and 9.3 % in forest and settlements areas, respectively; whereas bare land has decreased significantly by 11.4 %. Of the area converted to settlement, 34.13 % was from bare land and 32.98 % was from vegetative land. The data collected and analyzed would be useful for examining the relationship between land-use conversion and its socio-economic drivers.

Keywords: *Land-use change, Geographic information system (GIS), Remote sensing (RS), Pakistan.*

1. INTRODUCTION

District Abbottabad is located in Hazara division of Khyber Pakhtunkhwa province of Pakistan with the total area of 1,967 square kilometers [1]. With its good weather and beautiful landscape, district Abbottabad attracts people from all over Pakistan. Some come for tourism and some to seek education from a large number of emerging educational institutions. Tourism is one of the important sources of economic activity in Abbottabad [2]. In summers, when temperatures in the plains of Pakistan rise to well above 45 degrees, a large number of tourists come to Abbottabad to enjoy its pleasant climatic conditions. The district is now witnessing rapid population growth, which is affecting its environmental conditions. It is going through extensive land-use changes over the last few years. The most significant driving forces of land-use change in this region have been the 2005 earthquake [3], pleasant weather, and emerging higher education institutions, which inclined people to migrate from adjoining areas to this district. This trend has increased the need and demand of residential and commercial areas which resulted in raised prices of land available. This situation has led to deforestation and conversion of forest, grass land and agricultural land into residential colonies and commercial areas (hotels, restaurants, and markets). Due to lack of appropriate land-use planning and measures for sustainable development, these haphazard developments and construction activities led to lowering water-table, contamination of drinking water sources, flood like situations during heavy rains, increasing vehicles and recurrent traffic congestion and air pollution problems, which traditionally were not characteristic of district Abbottabad. These changes have the potential to undermine the long-term harmonious people-environment relationship. Hence, it is essential to study land-use change for the selection, planning, and implementation of land-use schemes. This study also assists in monitoring the dynamics of land-use due to the changing demands of the growing population in the district.

Remote Sensing (RS) and Geographic Information System (GIS) have been recognized as powerful and effective tools and are widely applied in detecting the spatio-temporal dynamics of land-use and land-cover (LULC) [4]. RS method cost effectively provides abundant, multi-spectral, multi-temporal, and real-time data and turns it into information valuable for understanding and monitoring land development patterns and processes and for building land-use data sets [5]. GIS has powerful function of storing, analyzing, and displaying geo-referenced data necessary for change detection [6]. The combination of RS and GIS has inestimable advantages compared to traditional methods, and is highly effective in monitoring dynamic changes of the land-use/land-cover. Based on RS, the researchers can obtain valuable multi-temporal data for monitoring land-use patterns and processes, and GIS techniques make possible the analysis and mapping of these patterns [7-8]. In this paper the land-use changes in district Abbottabad spanning 11 years from 1998-2009 have been analyzed.

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2. DATA COLLECTION AND ANALYSIS

2.1 Data Acquisition

Three Landsat TM, ETM, and ETM+ images of 1998, 2005, and 2009 were acquired from United States Geological Survey (USGS) [9]. However, these images were not of high quality. The data of land-use was acquired from Landsat image by experts interpretation. The satellite images of study area were taken in autumns of 1998, 2005, and 2009. Bands 3, 2, and 1 were used for Red, Blue, and Green, respectively. The district Abbottabad map with information of General Topography (GT), location, road network, forest, and water bodies was obtained from Survey of Pakistan [10]. The scale of the map is 1:250,000. The GT sheet was used for preparing GIS layer.

2.2 GIS Data Processing

In order to use GT sheets in GIS it is necessary to geo-reference GT sheets, i.e. to align it with existing geographically referenced data. Six ground control points were used to geo-reference the sheets. For geo-referencing Global Mapper was used [11]. Geo-referencing of GT sheets is very important to create GIS layers as it accurately sets the ground coordinates on scanned topographic map. After geo-referencing GIS layers were created in ArcView 3.1 software [12], and were later used in identifying land-use classes.

2.3 Remote Sensing Image Processing

Prior to interpretation, digital images were processed with standard procedures. The study region was clipped with the image using the software, ENVI 4.7 [13]. The satellite images were processed using methods of geo-referencing, radiometric correction [14] and image enhancement. Geo-referencing was necessary for subsequent GIS data integration. Each scene was geo-referenced by using 30 ground control points (GCPs) identified and selected from a topographic map at a scale of 1:250,000, followed by using the corrected image as a reference for image-to-image registration of all other band-images. The random distortion method was used for geometric correction of the images [15]. The study was supported with field survey investigation for having a general understanding of the area.

2.4 Satellite Image Classification

On the basis of field survey five land-use classes were identified in the district Abbottabad, i.e. settlement, vegetative land, forest, water body, and bare land. Land-use maps were acquired by classifying our satellite image. Maximum Likelihood (ML) [16] decision rule of supervised classification was applied. After applying ML classification sieved and clumped operations were carried out from post classification in order to improve the appearance of the output thematic image. The post-classification process removes high-frequency spatial variance (or noise) from the classified image. This is achieved by analyzing the neighborhood for each pixel and removing the scattered single pixels (sieve process), and then merging the small patches of pixels together to make more continuous and coherent units (clump process). This process was carried out on each satellite image using ENVI 4.7.

2.5 Accuracy Check

Each classified image was checked for accuracy by using swipe technique. Accuracy of supervised classification mainly depends upon analyst s approach to understand marked differences in land-use classes and capability of sorting out small variation occurrence in reflectance values of different land features. The images aligned perfectly when overlaid on the original images.

3. RESULTS AND DISCUSSIONS

3.1 Land-Use Distribution for the Years 1998, 2005, and 2009

The land-use change was analyzed by performing GIS and RS analysis. The integration of GIS and remote sensing techniques provided unique and useful information regarding land-use change. However, accuracy of the results obtained from the analysis depends upon expert s skills and decisions on how to separate out different pixels of different land-use features. In the present study, classified image of each year was used to determine class area. Imagery was classified for five land-use classes. Land-use classes identified were settlement, vegetation, water, forest and bare land. Table-1 presents class area and percent cover for different land-use classes for years 1998, 2005, and 2009.

Table-1 depicts increase in the area of settlement for the year 2009. This can be attributed to the upward trend of migration to the district due to its progress in education sector, increased development activities, seasonal activities and pleasant weather conditions.

Table-1: Land-use Distribution for each Land-use Class for the years 1998, 2005, and 2009

S.No.	Land use Classes	1998		2005		2009	
		Area (Km^2)	(%)	Area (Km^2)	(%)	Area (Km^2)	(%)
1	Settlement	987.8276	50.169	1064.244	54.050	1170.767	59.46
2	Vegetation	217.6335	11.053	467.95255	23.766	196.9	10
3	Water	20.4776	1.040	36.3674	1.847	26.9753	1.37
4	Forest	235.1576	11.943	299.7211	15.222	290.8213	14.77
5	Bare land	507.8838	25.794	100.7143	5.115	283.5360	14.4

Higher number of migration to Abbottabad was observed after Earthquake 2005. People from earthquake affected areas moved to the district although it was also hit by the earthquake but the damages were not as severe as they were in other affected areas. Moreover, the higher education institutions in Abbottabad have been expanding rapidly. These institutions include five new medical universities, two engineering universities, and branches of some school chains highly acclaimed in the country.

Forests and vegetation in the area first increased in 2005 and then decreased in 2009, as can be seen in Figure-1. The increase in the forest and vegetation is due to the extensive Shajar Kari Mohim (plantation campaign) conducted in 1998 to improve the forest cover of a certain area. Decrease in the later years is attributed to the increase in the human settlements and the landslides due to 2005 earthquake that eroded much of the green land and left large portions of the land barren. This is evident from the decrease in the bare land in earlier years and then increase in the later years. Whereas, the availability of water body remained almost stable throughout the study period. Figure-2 represents land-use change from 1998 to 2009.

3.2 Analysis of Land-use Classes using Transition Matrix

Transition matrix is an important aspect of land-use change as it clearly shows the direction of the change. Information extracted from transition matrix reveals desirable and undesirable changes overtime and also shows the classes that are relatively stable. Transition matrix of land-use change was calculated using RS software, ENVI 4.7. This helped to demonstrate the conversion among different land-use classes. Figure-3 shows the graph derived from transition matrix and contains information about the rate of transition that took place among different land-use classes.

As seen from Figure-3, there has been a considerable change during 11 years period. Forest and settlement has increased in the area by 2.83 % and 9.3 %, respectively, whereas bare land has decreased significantly by 11.4 %. The GIS-RS analysis further indicated that there was a clear and continuous increase in settlement from 1998 to 2009. Of the area converted to settlement, 34.129 % was bare land and 32.98 % vegetative land. Goa, et al., also found the same trend of land-use change in Manasi oasis of China [7]. There also was simultaneous decrease in the area of bare land with 20.71 % converted to vegetative land. However, 11.43 % of the forest area was converted to bare land, showing the trend of

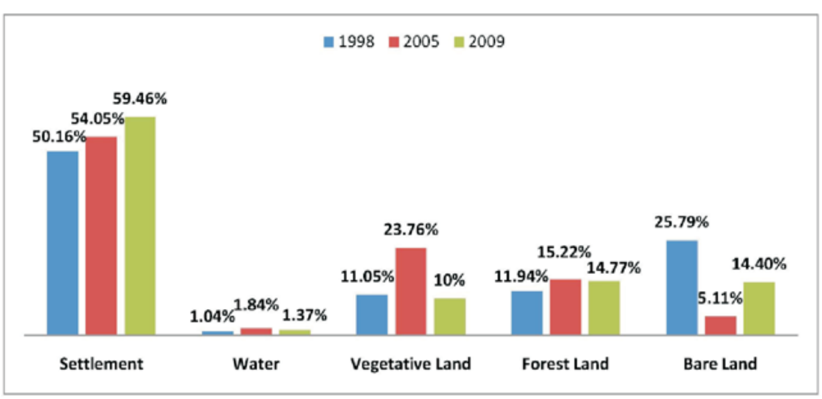

Figure-1: Land use Distribution of District Abbottabad for the years 1998, 2005, and 2009

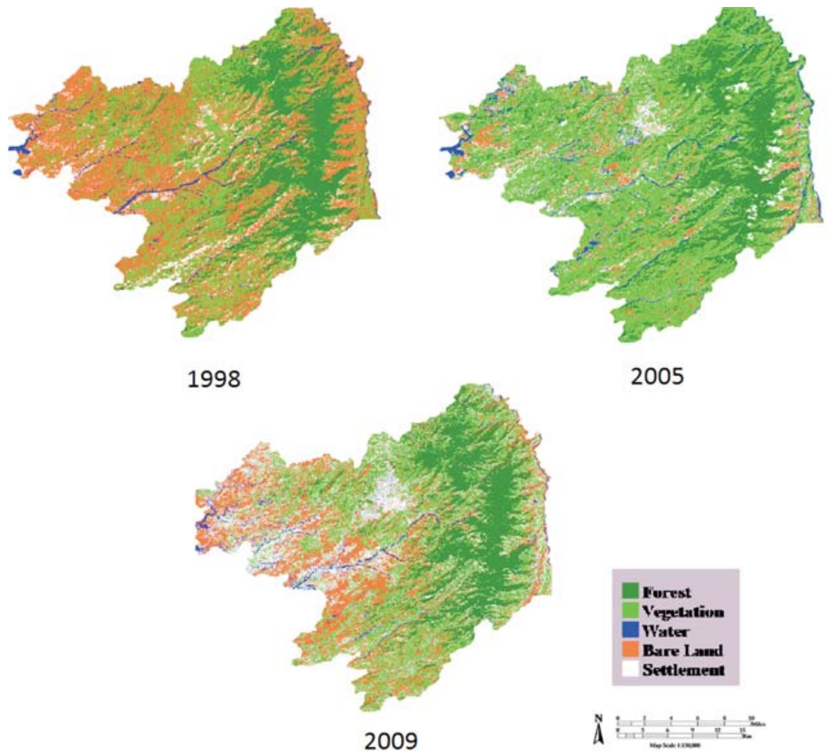

Figure-2: Land-use Pattern of District Abbottabad during 1998-2009

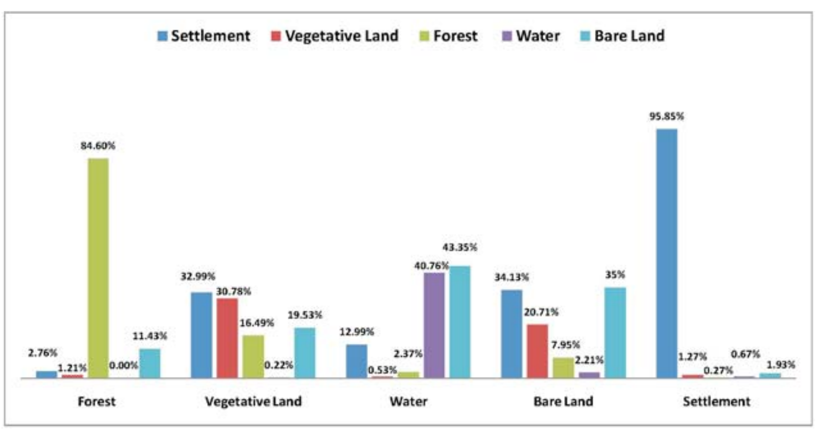

Figure-3: Conversion of Land-use Classes during 1998-2009

deforestation. These figures are useful for examining the relationship between land-use conversion and its socio-economic drivers.

4. CAUSES OF LAND-USE CHANGE

4.1 Natural Forces

Natural events directly influence the pattern of land-use. They cause changes in the natural environment and interact with the human decisions of land-use ultimately causing land-use change. The major natural event in district Abbottabad was 2005 earthquake that has significantly altered the pattern of land-use. After earthquake, in some classes, a reverse change was observed. From 1998-2005 the pattern of land-use change was quite natural and mainly due to human activities. The results in Figure-4 show 3.8 % increase in settlement from 1998-2005 with the simultaneous increase in 12.71 % vegetative land, 0.8 % water, and 3.27 % forest cover. All these land-use changes were desirable as they were positive; the only negative trend observed was in the case of bare land, which showed 20.6 % decrease in the bare land. The other classes were increasing so the bare land converted to other land-use classes as mentioned before. After the earthquake, settlement in the area increased to 5.41 %, which is very obvious because people from the earthquake affected areas migrated to this region and became permanent residents. As far as the situation of other classes is concerned, a negative trend was observed in vegetative land, forest and water with 13.76 %, 0.47 %, and 0.45 % decrease, respectively (Figure-4). Landslides triggered by an earthquake eroded much of the green areas leaving the land barren. Another reason behind the deforestation and decreased vegetative land was the increase in the settlement. Thus, the earthquake caused land-use change in district Abbottabad.

4.2 Demographic Pressure

The changing demographic profile of the population is another major cause of land-use change. According to a census report, in 1998 the population of the district Abbottabad was 880,666, but in 2009 it has risen to 1.2 million [10]. The study shows 9.3 % increase in the settlement from 1998-2009 (Figure-1). Population increase always results in land-use change. It increases the pressure on land resources thus triggering the land-use change. Shelter is a basic need of humans. As evident from the results of this study the settlements have increased tremendously in the last decade. Forests are being converted into residential areas. The naked chalked hills are ready to be converted into a residential area and this has become a common business in the area. The famous Silk Route that runs through the main Abbottabad city now has huge plazas and wide-spread residential colonies and schools, and one can rarely find any tree along the road. Vegetative lands have been converted into residential and commercial areas. This ultimately has environmental impacts. Following are the reasons of increased demographic pressure in the District.

4.3 Establishment of Educational Institutes

In the last 10 years, many higher education institutes have been established in the district. Among the major ones are COMSATS Institute of Information Technology; Women Medical College and University; Frontier Medical College; Hazara University - Abbottabad Campus; University of Engineering and Technology - Abbottabad Campus; Abbottabad International Medical College; National Institute of Medical Sciences; Women Institute of Learning; as well as a number of schools and colleges offering intermediate level education. These institutes have attracted people from different parts of the country and contributed to the population increase of the district. These universities have also raised the value of the land. People started more developmental activities in

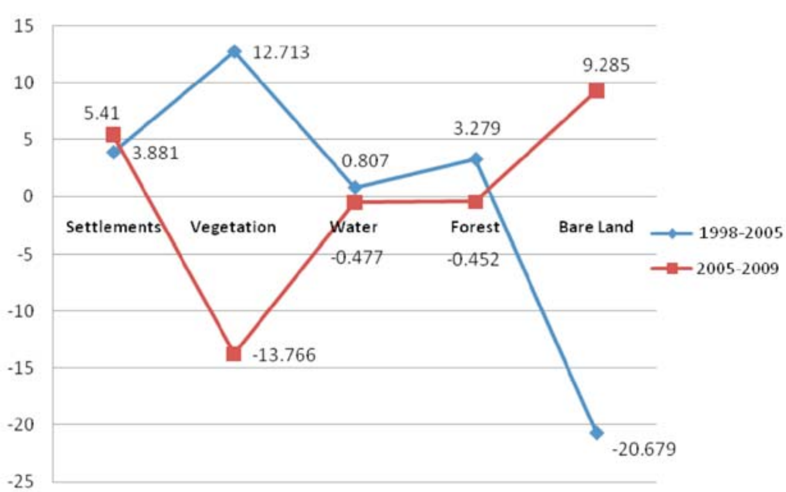

Figure-4: Percentage Change in the Land-Use Type from 1998 to 2009

the areas close to the universities and educational institutes. More residential and commercial buildings have been built, some of them transformed into hostels.

4.4 Pleasant Climatic Conditions and Human Activities

District Abbottabad is famous for its pleasant climatic conditions and breath-taking beauty. It is a hub of tourism in the country and people from all parts of the country visit this area to enjoy its weather and beauty. It has been observed that people prefer to settle in this area after retirement because of its weather, this is particularly true for armed force personnel.

Human activities that alter the land-use are agriculture, livestock raising, urbanization, deforestation, construction, and development, etc. These have some serious implications for sustainable development, climate, and livelihood systems. The study shows 9.3 % increase in settlement in district Abbottabad which is a clear sign of increased urbanization. Urbanization resulting from development, or vice versa, cause land-use change. Many new commercial plazas have been constructed on crop lands and grass lands; the study shows that 32.98 % of the vegetative land in 1998 was converted to settlement in 2009 (Figure-3). 2.75 % (Figure-3) of the forest was converted to settlements, which indicate deforestation that also results in soil erosion, and loss of biodiversity. All of these factors in turn have health, safety, and economic implications.

4.5 Mining

Mining is another cause of land-use change in district Abbottabad as it is a major mining area. According joint report of International Union for the Conservation of Nature and Natural Resources (IUCN) and Sustainable Development Policy Institute (SDPI) quarrying and mining is carried out in 108 villages, covering 4.8 % of the total land area of District Abbottabad. About 20 different minerals are excavated. A total of 308 mining licenses have been issued, of which 206 were for industrial rock and minerals (barite, clay minerals, dolomite, feldspar, graphite, gypsum, iron laterite, limestone, magnesite, phosphate, rock salt, silica sand and soapstone), 66 for dimension stone (granite, marble, serpentine), 19 for metallic minerals, 9 for gemstones and 8 for coal. About 73 % of the mines in the district are situated in hilly areas, while the remaining are on flat land. All are at a distance of less than 2 km from the water body, with the result that mine residues are polluting drinking water sources. About 18 % of these mines are located in landslide zones, posing a risk not only to the environment, but also to the safety of the local communities [17].

4.6 Cultural Changes

Cultural changes also drive land-use change. In district Abbottabad, people used to live in joint families, i.e. five to six families, live under one roof. However, due to some modern influences the trend has been changing. The extended families have been breaking down into multiple nuclear families, thus resulting in an increase in settlement area.

5. IMPACTS OF LAND-USE CHANGE IN ABBOTTABAD

The changes of land-use patterns certainly provide many social and economic benefits. However, they also come at a cost to the natural environment. In this section, the major impacts of land-use change pattern on natural environment of district Abbottabad are discussed providing key inputs to the decision-makers to make informed decisions and enforce policies to mitigate the effects of land-use change in district Abbottabad. The predicted impacts may be helpful if planning of the city is considered important to preserve the natural beauty of the district Abbottabad.

5.1 Climate Change

In district Abbottabad the settlement increase since 1998 has been 9.29 %, indicating population increase which has increased pressure on the district s natural resource; resulted in 1.94 % decrease in vegetative land; and 11.39 % decrease in bare land. The increase in population is also connected to more use of fuel in cooking, heating, and transportation. The burning of the fuel releases carbon dioxide into the atmosphere, which is resulting in increased atmospheric temperature. In the past, there were significant snowfalls in Abbottabad, but now due to increased urbanization, transportation and burning of fossil fuels, it has gradually decreased. However, the surrounding mountains are still getting enough snowfall, which has a pleasant effect on the overall temperature of the city during summers. Mining in Abbottabad is becoming very common and has resulted in complete disappearance of hills in Ghomanvan and Thandiani areas having adverse impacts on the landscape of the district and added amounts of particulates into the atmosphere. The particulates absorb radiation from the sun and then release the absorbed energy into the atmosphere, increasing atmospheric temperatures and adversely affecting human health.

5.2 Landslides

Deforestation and removal of vegetation make soil vulnerable to soil erosion due to which landslides are more recurrent now in Abbottabad. This study shows that since 1998, 1.05 % of vegetative land has decreased due to land-use change. One additional factor contributing to landslides is agriculture practices on steep terrain, which make the soil unstable and vulnerable to erosion. Mining, which is becoming very common in district Abbottabad, also contributes to soil erosion.

5.3 Water Pollution

One of the major direct environmental impacts of land-use change resulting from urbanization is the degradation of water resources and water quality. The study shows that from 1998-2009, 9.29 % increase in the settlement has 32.98 % vegetative land, 2.75 % forest, 13 % water body, and 34.12 % bare land (Figure-3). This conversion results in increase in impervious surface, which alters the natural hydrologic condition of an area. It is well understood that the outcome of this alteration is typically reflected in increases in the volume and rate of surface runoff during heavy rainfall, and decrease in ground water recharge which is quite evident in district Abbottabad. The events of roads filled with water due to blocked drains are very commonly seen during rainy season. These eventually lead to larger and more frequent incidents of local flooding during heavy rainfall, and reduced residential and municipal water supplies. Impervious surfaces collect pollutants either dissolved in runoff or associated with sediment, such as nutrients, heavy metals, sediment, oil and grease, pesticides, and fecal coliform bacteria. These pollutants are washed off and delivered to aquatic systems by rainfall and sometimes make their way to the drinking water supplies and results in health problems. Typhoid fever and water-borne diseases are common in Abbottabad. This is because the sewage pipes and the drinking water pipes run side by side and a small leakage in the former can have adverse health impacts on the water quality.

Heavy metals are major water and sediment contaminants. The potential major urban non-point source (NPS) pollutants include fertilizer and animal waste for nutrients, roads and paints for heavy metals, and motor oil for oil and grease. These NPS pollutants make their way into water body, and underground water and deteriorate the water quality. Open drains is another problem commonly seen in the region.

Mining which is common in district Abbottabad also pose threat to the water quality. All mines are at a distance of less than 2 km from a water body, with the result that mine residues pollute drinking water sources [9].

5.4 Air Pollution

Increase in the settlement (9.29 % from 1998 to 2009) is directly linked with increase in vehicles and more fuel combustion. This eventually has adverse impacts on air quality. Vehicles are mobile source of pollution and fuel combustion in stationary sources, including residential, commercial, and industrial heating and cooling also release air pollutants. Mining releases dust particles into the atmosphere which also deteriorate the air quality. Air pollutants and particulates can penetrate deep into lungs and have adverse health effects. In Abbottabad, the situation of transport is worse. The number of vehicles has increased due to increase in population but the existing road infrastructure cannot meet the needs of the growing population which adds to the pollution caused by vehicles. In summers, a number of vehicles increase as the people from other parts of the country visit this area for recreation. Unplanned and unmonitored land-use change can make the situation worse in the coming years if necessary attention it goes unchecked. It is of great importance to deal with the present impacts of land-use change and predict the future status in an effort to restore the environmental quality of the district Abbottabad.

6. CONCLUSION

Land-use change during the last 10 years of the district Abbottabad was studied by taking advantage of GIS and RS analysis. The study showed that the region has undergone a noticeable land-use change due various factors, including demographic, anthropogenic and environmental factors. The Earthquake 2005 played a major role in land-use change. From 1998 to 2009, the vegetative and bare land decreased while the areas of settlement, forest, and water areas were observed to have increased. The vegetative land decreased by 1.053 %, bare land by 1.394 %, settlement, forest and water area increased by 9.29 %, 2.82 %, and 0.33 %, respectively. Major portion of the vegetative land and bare land have been converted into settlements.

Most of the study results showed uneven and unchecked land-use change that has adverse impacts on the air and water quality, as well as climatic conditions of the region. This poses a risk to the health of local community. Problems of water availability, water contamination, and overall management of the region were quite apparent and on increase. This study can help in the selection, planning, and implementation of the land-use schemes to deal with the problems arising from land-use change. It can also help in monitoring the dynamics of land-use due to changing demands of increasing population, in order to ensure the environmental sustainability of the district Abbottabad.

REFERENCES

1. SMEDA, 2009. District profile Abbottabad. Small and Medium Enterprises Development Authority, Government of Industries and Production.
2. Pastakia and Firuza, 2004. Abbottabad - State of the Environment and Development. IUCN Pakistan, P.135
3. Fujiwara, S., Tobita, M., Sato, H.P., et al., 2006. Satellite Data Gives Snapshot of the 2005 Pakistan Earthquake. EOS, Transactions American Geophysical Union, 87(7), 73-77
4. Michalak, W.Z., 1993. GIS in land-use Change Analysis: Integration of Remotely Sensed Data into GIS. Applied Geography, 13(1), 28-44.
5. Green, K., Kempka, D., and Lackey, L., 1994. Using Remote Sensing to Detect and Monitor Land-Cover and Land-use Change. Photogrammetric Engineering and Remote Sensing, 60(3), 331-337.
6. Chang, K., 2004. Introduction to Geographic Information Systems. New York, NY 100206.
7. Walter, V., 2004. Object-based Classification of Remote Sensing Data for Change Detection. ISPRS Journal of Photogrammetry and Remote Sensing, 58(3), pp. 225 238.
8. Pijanowski, B.C., Brown, D.G., Shellito, B.A., and Manik, G.A., 2002. Using Neural Networks and GIS to Forecast Land-use Changes: A Land Transformation Model. Computers, Environment and Urban Systems, 26, pp.553 575.
9. US Geological Survey, 2010. <http://glovis.usgs.gov/.> Retrieved April 6, 2010
10. GoP. 1998. <http://www.statpak.gov.pk/> depts/pco/index.html. Retrieved 01 June 2010.
11. Mapper, Global. 2010. Global mapper llc. <www.globalmapper.com.>
12. ESRI. 2010. Arcview. www.esri.com/software/arcview/index.html.
13. ITT 2010. ITT Visual Information Solutions. Envi 4.7. <www.ittvis.com/ProductServices/ENVI.aspx.>
14. Hill, J., Sturm, B., 1991,Radiometric correction of multi-temporal Thematic Mapper data for use in agricultural land-cover classification and vegetation monitoring. International Journal of Remote Sensing, 12(7), pp.1471-1491.
15. Franklin, S.E., Giles, P.T., 1995, Radiometric processing of aerial and satellite remote-sensing imagery. Computers & Geosciences, 21(3), pp. 413--423
16. Paola, J. D., Schowengerdt, R.A., 1995, A detailed comparison of back propagation neural network and maximum-likelihood classifiers for urban land-use classification. Geoscience and Remote Sensing, 33(4), pp.981-996
17. IUCN and SDPI. 2006. Environmental fiscal reform in Abbottabad, mining and quarrying. IUCN-Pakistan.