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EFFECT OF LANDUSE/LANDCOVER CHANGE ON SOILS OF A KASHMIR HIMALAYAN CATCHMENT-SINDH

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ABSTRACT

In the current study, the change in Landuse/Landcover (LULC) in Sindh catchment of Kashmir Himalayan region was examined and its effect on certain soil properties of the catchment was determined. The LULC change over a span of 15 years (1995-2005) was investigated through remote sensing approach using two date satellite images. Post-classification comparison technique was used to detect LULC changes from these images. Soil samples at (0-20cm) depth, were primarily collected from four main LULC types of the catchment namely forests, pastures, cultivated land, and urbanized areas. These soil samples were analyzed for various parameters such as soil pH, electrical conductivity, organic matter, water holding capacity and available nutrients (N, P and K). The results indicated variation of soil characteristics with different LULC types. Land use significantly influenced most soil properties ($p<0.05$). Change in LULC was found to influence most soil properties. The findings of LULC change revealed that the study catchment has experienced decrease in forests and pastural lands with increase in cultivated area and settlements. Deforestation and overgrazing of pasture lands was found to diminish soil quality, while as extensive tillage practices were found to lead to a decrease in soil organic matter content and available nutrients thus degrading soil quality. Concluding, the changes in the properties of the soils may be attributed to the changes in the LULC resulting in the decline of soil productivity. The study emphasizes on a need to consider appropriate land use policy and proper management practices for increasing soil sustainability and productivity.

KEYWORDS *Sindh catchment; Remote sensing; LULC change; Soil properties; Deforestation*

1 INTRODUCTION

Land-use change is one of the main drivers of environmental change being a major issue of global environmental change and an important component in understanding the sequence of changes in the catchment characteristics and the interactions of the human activities with the environment. This change influences the basic resources of land and a variety of natural processes, including the soils which are not static and hence more susceptible to changes in their nutrient and moisture content. The dynamic soil nature describes the condition of a specific soil due to land use and management practices (Karlen et al. 2003). Land use influences soil aggregation, aggregate stability and overall soil health (Castro et al. 2002; Herrick et al. 2001). Land use changes have a great influence on many soil physico-chemical properties mostly soil organic matter affecting its quality attributes and fertility. The impact of LULC change on soil often occurs so creepingly that land managers hardly contemplate initiating ameliorative or counterbalance measures. Land use practices affect the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone (Murty et al. 2002). LULC changes are also known to be important drivers for soil redistribution, by influencing surface runoff, erosion and sedimentation processes. Many researchers have reported that change of land use, implemented locally such as long term cultivation, deforestation, overgrazing and mineral fertilization can cause significant variations in soil properties, terrestrial cycles and reduction of output and that the conversion of natural forests to other forms of land-use can provoke soil erosion and lead to a reduction in soil organic-content, loss of soil quality and modification of soil structure and its stability (Chen et al. 2001; Conant et al. 2003; Hacisalihoglu 2007; Khormali et al. 2009; Saraswathy et al. 2007).

Human activities have pronounced impacts on soil properties. Changing patterns of land use which are most frequently related to human impacts influence the fertility of the soil. These changes in land use alter the fluxes to or from the soil system and/or impose additional stresses on the system. The most significant LULC change affecting soils world over within the past few decades has been decrease in forest cover and agricultural intensification. Cultivation reduces soil carbon content and changes the distribution and stability of soil aggregates (Six et al. 2000). Land use changes, especially cultivation of deforested land may rapidly diminish soil quality; as a result causing severe deterioration in soil quality which may lead to a permanent degradation of land productivity (Islam and Weil 2000). LULC changes such as forest clearing, cultivation and pasture introduction are known to result in changes in soil chemical, physical and biological properties (Houghton et al. 1999), yet the sign and magnitude of these changes varies with land cover and management (Baskin and Binkley 1998; Celik 2005).

We now know that LULC changes have occurred in the Kashmir Himalayan region and are accelerating as well, causing many environmental problems in this region. We also know that these land use changes affect the soil properties. Although few studies on LULC change in Kashmir valley and its impact on various resources of the region especially water (lakes, wetlands) and biodiversity have been carried out (Amin and Fazal 2012; Fazal and Amin 2011; Iqbal et al. 2012; Romshoo et al. 2011), and physico-chemical characterization of certain soils of this region has also been done in some other studies (Ashraf et al. 2012; Verma et al. 1990; Wani et al. 2010), but little information is available on the impact of these changes on the soils of the region. Studies about the interaction between land use and soil fertility are lacking in this environmentally fragile Himalayan region of India which is subjected to accelerated LULC changes. Spatial and temporal effects of land use change and its interaction with soil fertility remain to be investigated. The effects of land use on soil properties need to be studied on a catchment scale (Symeonakis et al. 2007). While LULC changes like deforestation are rampant in the coniferous forests of the Kashmir Himalaya, no information exists on the effect of these changes on soil properties. No systematic link between LULC change and soil fertility has been made. As such, a systematic study linking land use change with the soil properties needs to be undertaken as soil attributes are an important component of LULC change, which if not based on proper scientific investigation affects physical, chemical, and biological properties of soil leading to increased destruction and erosion. The main aim of this study was to investigate the LULC changes in the Sindh catchment of Kashmir Himalaya and analyze their effect on the soils of the region.

2 MATERIALS AND METHODS

2.1 Description of the study area

The present study was undertaken in the Sindh catchment lying in the northeastern part of Kashmir valley (Figure 1.) - a longitudinal depression in the great northwestern complex of the Himalayan ranges constituting an important relief feature of geographic significance. The catchment is located between the geographical coordinates of 34°6' – 34°27' N latitude and 74°40' – 75°35' E longitude and covers approximately 1663.84 Km^2. Sindh, the largest side developed valley of Kashmir begins from Ganderbal and ends near Baltal at the base of Zoji-La pass. The picturesque topography of the catchment is varied exhibiting altitudinal extremes of 1568m to 5236m above mean sea level. Physiographically the area consists of lofty and highly elevated mountain peaks, flat-topped karewas as foothills and valley floor or plains. The karewa formation is a unique physiographic feature of this area. These are lacustrine deposits of the Pleistocene age composed of clays, sands, and silts. The soils in the area are generally of three types, viz., loamy soils, karewa soils and poorly developed mountain soils (Raza et al. 1978).

Sindh catchment belongs to temperate montane valley climate with wet and cold winters and relatively dry and moderately hot summers with an average annual precipitation of 669 mm. Most of the precipitation is received in the form of snow. The study catchment with its high altitudinal variations consists of deep rock girt gorges, glaciers, forests, open grassy meadows and village dotted slopes. However, these natural resources of the beautiful but environmentally fragile valley of Sindh are at present facing tremendous pressure due to varied anthropogenic activities in the region.

2.2 LULC change

The LULC change in Sindh catchment was investigated using geospatial approach. Landsat TM and IRS LISS III remotely sensed images covering the study area for the years 1992 and 2005 respectively were used together with ground measurements to analyze the change in LULC. Additionally, the Survey of India topographic map sheets at a scale of 1:50,000 were used to delineate the catchment boundary and to generate baseline information of the study catchment. Both the images were first pre-processed or geometrically corrected (geo-referenced) in Earth Re-source Data Analysis System (ERDAS) Imagine 9.0 software. The variation in the image characteristics like tone, texture, pattern etc. was used to identify various land use classes or training samples/ sites. Once the training sites were determined, a supervised classification was performed on both the images using Maximum Likelihood algorithm. Both the images were classified independently using this classification technique. Multi-date LULC maps for the year 1992 and 2005 from these remotely sensed images were generated as per the National Natural Resources Management System (NNRMS) standards (ISRO 2005). The LULC map of 2005 was validated in field to determine its accuracy. 150 sample points were choosen for the verification of determination of available nutrients Subbiah and Asija (1956) method was followed for Available Nitrogen (AN), Olsen extraction method (Olsen et al. 1954) for Available Phosphorus (AP) and Jackson's Spectrophotometric Method (1967) was followed for determination of Available Potassium (AK).

The data was expressed as means of the four replications. Statistical analysis was performed using SPSS software (version 16.0 for Windows). Soil properties were grouped according to the the LULC map in the field. Kappa coefficient (Jensen 1996), the robust indicator of the accuracy estimation for the final LULC map was estimated at 0.914. The final LULC maps generated for catchment for both the years, revealed different LULC types. LULC change from these final generated LULC maps was determined using post classification change detection method and the LULC statistics derived from data sets Landsat TM (1992) and IRS LISS III (2005) was computed and compared for quantification of change.

2.3 Soil sampling and statistical analysis

Soil samples were collected from a depth of 0 to 20cm from four different LULC types of the Sindh catchment namely: forests, pastures, cultivated land, and urbanized/built-up areas. These samples were collected as per a completely randomized design with four replications. Within each LULC type 8 to 10 samples were obtained from 0-20cm depth. These were then mixed to form a composite sample. Four replicates from each composite sample were then used for further analysis. The soil samples so collected were then stored in air tight polythene bags for subsequent laboratory investigations. The samples were air-dried, mashed using a pestle and mortar and passed through 2mm sieve before analysis. Soil pH and Electrical Conductivity (EC) were determined by using a Digital pH meter and an EC meter in a 1:2.5 soil/water ratio respectively (Jackson 1967; Page et al. 1986), soil organic carbon by the Rapid Titration Method (Walkley and Black 1934). The percent of Soil Organic Matter (SOM) was calculated by multiplying the percent organic carbon by a factor of 1.724, following the standard practice that organic matter is composed of 58% carbon (Brady 1996). The Water Holding Capacity (WHC) of the soil samples was determined by Keen-Raczkowski Box Method as described by Piper (1966).

LULC type. Statistical differences were tested using one-way analysis of variance (ANOVA) following the General Linear Model (GLM) procedure within SPSS. Duncan's significance test was used for mean separation at 0.05 probability levels.

3 RESULTS

3.1 LULC change

Figure 2. and Figure 3. show the LULC maps of the Sindh catchment for the years 1992 and 2005

respectively. These LULC maps reveal different land use/cover types, which have been grouped into eleven LULC classes namely: aquatic vegetation, bare exposed rock, bare land, built-up/urban areas, cultivated land areas, forests, pastures, plantation, river bed, snow and water. The dominant class in the catchment for both the years was found to forests covering about 26.9% of the catchment area in 1992 and 23.3% in 2005, followed by pastures which covered 26.8% of the catchment in 1992 and 23.1% in 2005. Bare land (0.91%) and built-up areas (0.93%) were found to be the least dominant classes in 1992, while as water was found to be the least dominant class in 2005 covering 14.85Km^2 (0.89%) of the catchment area.

The statistics presented in Table 1 reveal the changes in the LULC pattern of the Sindh catchment that have occurred during the span of 15 years (1992-2005). It's quite apparent that the vegetal cover of the catchment in the form of forests, pastures and plantation has registered a decline, while as impervious land surfaces like built-up areas and bare land have increased. Cultivated land has also increased during this period. In case of forests, western mixed coniferous forests found between elevation of 3000 and 3500 meters cover a substantial portion of the catchment. In these forests are found species of Blue Pine, Sliver birch and Fir. The state of these forests of the catchment from 1992-2005 provides a grim picture. Statistics (Table 1) for this period reveal that the coniferous forests have reduced from 449.22Km^2 in 1992 to 388.65Km^2 in 2005 showing a decline of 60.57Km^2 (13.4%). The pastures found in the region, mainly include moist alpine pastures, which start from tree-line and extend up-to perpetual snowline. Sizable pockets of these pastures found in the steep river bed facing slopes of the study catchment attract shepherds and nomadic tribesmen with their cattle and herds of sheep and goat from far and near for grazing. The results show that these pastures have decreased from 445.93Km^2 in 1992 to 384.78Km^2 in 2005- a decrease of 61.15Km^2 (13.7%). Built-up area consists of anthropogenic land cover features, ranging from small hamlets in rural areas to large cities including residential, commercial, and industrial establishments. This class is mainly confined to the lower plains of the catchment. Built-up which constituted a mere 0.93% (15.62Km^2) of the catchment in 1992 increased by about 15.72Km^2, constituting 1.88% (31.34Km^2) of the catchment in 2005. The increase in spatial extent of this class is mainly reflected in the lower area of the catchment valley floor. Bare land class includes those areas which have no vegetation cover. The area of this class was found to increase from 15.30 Km^2 in 1992 to 50.19 Km^2 in 2005 i.e. an increase of 34.89 Km^2.

Cultivated areas include the land base on which different types of crops, fruits and nuts are raised. Mainly paddy and maize cultivation is prevalent in this catchment. Paddy is cultivated in the flood plains of the region, which are highly productive in terms of rice cultivation. Maize is grown on the long stretches of elevated plateau land mainly in Kandi belts of side valleys of the main catchment. The stretches of elevated land on the northwestern side of catchment are used for raising multiple crops. The fruit crops cultivated in the catchment include apple (*Pyrus malus*), pear (*Pyrus communis*), apricot (*Prunus armenica*), walnut (*Juglans regia*), and in some places mixed plantations of cherry (*Prunus avium*) and plum (*Prunus domestica*). Most of population in the catchment is dependent on this class as it provides a source of employment. The statistics of this class (Table1) reveal that the area under cultivation has increased from 198.35Km^2 in 1992 to 200.85Km^2 in 2005 i.e. an increase of 2.5 Km^2 (1.24% increase).

3.2 Effect of LULC change on soil properties

The changes in soil properties with four different LULC types are presented in Table 2. The mean values (±SD) of comparisons have been presented in this Table. The soil properties were found to vary with different LULC types of the catchment. Soil properties such as pH, SOM content, AN and AK (p=.000) were found to be strongly influenced by the LULC types followed by soil properties WHC, AP and EC, which too were significantly affected by the change in LULC with p=.008, p=.023 and p=.036 respectively (Table 2).

Analysis of pH of soils related to the four different LULC types indicated a significant difference between pH of soils of cultivated areas and of forests and pastures. The mean value of pH of soils in forests, pastures and cultivated areas was found to be 6.61, 6.77 and 7.44 respectively (Table 2). Cultivated areas indicated a higher value of pH than forests. Statistics indicated that soils of forests, pastures and cultivated areas did not differ significantly in terms of their EC. However, the EC of soils of built-up/urbanized areas was found to be significantly different and higher with a mean value of 292.25 µS/cm than all the other LULC types (Table 2).

Comparing the SOM content across the four LULC types –it differed significantly (Table 2). Cultivated areas were found to have significantly lower organic matter of 2.40% than forests and pastures. This parameter had its highest percentage- 5.68% in pastures and lowest 2.40% in cultivated areas. With respect to the WHC –this parameter did not differ significantly in case of pastures, cultivated areas and built-up LULC types. However WHC of forest soils was found to be significantly different from that of cultivated areas (Table 2).

The results (Table 2) showed that land use change significantly affected the available nutrients of soils of the study catchment especially AN and K. AN of soils of forests and pastures differed significantly from that of soils of cultivated areas and built-up having its highest (658.69 Kg/ha) value in pasture soils followed by forest soils (617.28 Kg/ha) and lowest value (364.36 Kg/ha) in soils of cultivated areas. Statistics presented in the table, further reveal that AP of soils of different LULC types did not differ significantly in case of forests, pastures and cultivated areas. In case of AK results indicated that this parameter is significantly affected by change in LULC. AK of forest soils (456.58 Kg/ha) differed significantly from that of cultivated area soils (384.34 Kg/ha) - Table 2.

4 DISCUSSION

4.1 LULC change

LULC change is a dynamic process taking place on the surface of earth and the data on this change has been observed to have potential scientific value for the study of human-environment interactions, aiding in ascertaining the impact of land use on the various natural resources as well as on the amount of pollution of these resources (Tang et al. 2005; Tong and Chen 2002; Tong et al. 2008). The LULC changes observed in the current study during the 15 year time period (1992-2005) i.e. decline in vegetal cover of the catchment in the form of decrease in forests and pasture areas and increase in impervious land surfaces like built-up areas and bare land can largely be attributed to human activities or more specifically, people’s responses to economic opportunities as mediated by institutional factors that drive land use/ cover changes.

Significant change observed in the Sindh catchment is the decrease in forest cover. This decrease is mostly attributed to the large scale clearing/cutting of trees in the forests for various uses such as firewood, timber and clearing for agricultural purposes particularly along the higher reaches. The phenomenon of forest clearing is caused by anthropogenic disturbance (Chowdhury and Schneider 2004). The ecologically and socioeconomically important pasture lands of the catchment too were found to be under tremendous pressure with main reasons for their decline being overgrazing beyond their carrying capacity, biotic interferences and clearing of the grasslands at the low altitudes for cultivation and exploitation for medicinal plants etc. Because of continuous and heavy grazing that too beyond carrying capacity the pasture lands have deteriorated to critical levels (Bhat et al. 2002). The effect of overgrazing on soils is considered destructive because of the reduction of canopy cover, the destruction of topsoil structure, and compaction of soil as a result of trampling (Manzano and Navar 2000). Loss of fine fractions in soils has major influences on such properties as moisture, soil consistence, organic carbon and nutrient presence and availability (Hennessy et al. 1986). With the ever increasing number of cattle and introduction of high yielding varieties of cattle by Animal Husbandry department, the stress on the grasslands of Sindh valley has increased tremendously.

Another significant change observed in LULC pattern of the Sindh catchment in the present study has been increase in area of built-up and bare land classes both at the higher and lower elevations of the catchment. Mainly overgrazed grasslands have paved the way for creation of bare area. Also deforested areas of the catchment have resulted in the creation of bare lands. This is in conformation with the study of Reis (2008) who reported that the lands converted to the bare soil class are mostly forests, agriculture and pasture classes. Increase in built-up is mainly caused by population growth and economic growth (Sudhira et al. 2004; Taubenbock et al. 2008). The retreating of areas covered with forests, pastures and water, while on the other hand expansion of cultivated and building areas mostly residential areas was commonly observed in the study catchment. This indicates the encroachment of built-up towards forest areas, wetlands and other water resources and the conversion of forest and pasture land areas to cultivated areas. The relationships between building areas expansion and the forest decrease have also been reported elsewhere (Fearnside, 2001; Lambin et al. 2003; Velazquez et al. 2003).

4.2 Effect of LULC change on soil properties

Soil is a complex system where in chemical, physical and biochemical factors are held in dynamic equilibrium. The changes in LULC, especially ones in vegetation can cause shifts in the soil properties (Wardle 2006) because individual plants concentrate biomass in soils beneath their canopies and modify biogeochemical processes occurring in the soils (Burke et al. 1989; Schlesinger et al. 1990). From the statistical analysis presented in Table 2 it is clear that LULC changes that have taken place in the study catchment do significantly affect the properties of the soils of the catchment.

The pH of cultivated soils was found to be significantly higher than that of forest and pastural soils. The lower pH values in forests and pastures are mostly attributed to the decomposition of the organic matter which is present in higher amounts in these soils (Arao 1999; Baath and Anderson 2003; Bardgett et al. 2001; Perie and Ouimet 2008). Jiang et al. (2006) too described in his study that continuous agricultural activities cause an increase in pH of soils. In addition Balesdent et al. (2000) states that soil tillage may cause an increase in pH of soils by effecting soil microclimate, natural carbon resources, microorganism activities and soil organisms. Thus, the forest/pasture lands converted to agriculture were found to have higher pH and consequently lower organic matter than native forests. Clear-cut site has slightly higher pH than adjacent forest site (Jehangir et al. 2012). Clear cutting results in the loss of interaction between the above ground vegetation and atmospheric deposition, replaces the continuous flux of litter fall to the soil, disturbs the water influx in the soil and reduces the uptake of nutrients from the soil by trees (Piirainen et al. 2004). So deforestation/clear cutting was found to alter (increase) soil pH and since pH is an important soil property determining the availability of nutrients, microbial activity and physical condition of the soil, disturbing these as well. LULC changes, especially cultivation of deforested land may rapidly diminish soil quality, as ecologically sensitive components of the forest ecosystem are not able to buffer the effects of agricultural practices. As a result, severe deterioration in soil quality may lead to a permanent degradation of land productivity (Islam and Weil 2000).

With respect to EC of soils- built-up areas were found to have significantly higher value. This can be attributed to the location of these areas at the lower elevations of the Sindh catchment, where less leaching of soluble salts takes place hence the higher value. Thus, expansion of these built-up areas especially towards the higher elevations of the catchment can result in altering of EC of the soils by more leaching of the soluble salts.

SOM is a critical component of soil-plant ecosystem and it changes with land use or agricultural management practices (Ghani et al. 2003). In the current study, this parameter of soil was found to be strongly influenced by change in LULC. Cultivated soils were found to have the lowest organic matter content, while as pasture soils were found to have the highest, in the current study. The low organic matter content of cultivated soils is attributed to the fact that cultivation increases aeration of soil which enhances the decomposition of SOM. On the other hand comparatively high percentage of organic matter in pasture and forest soils is ascribed to the fact that these soils are located at high altitudes and at these altitudes due to low temperature and heavy precipitation microbial growth is restricted and rate of mineralization is low as a result accumulation of organic matter is high. These findings are in confirmation with the observations of (Bossuyt et al. 2002; Kharkwal et al. 2009; Kumar et al. 2002; Schindlbacher et al. 2010; Verma et al. 1990). Further, high cattle grazing in pastures may also have contributed to increased SOM levels due to excreta of animals. High organic matter content under pasture lands is attributed mainly to dung from grazing animals and turnover of grass roots (Campbell et al. 1992).

Thus, the change of LULC in the form of conversion of forest/pasture lands to cultivated areas was yet again found to alter (decrease) another most important parameter of soils which plays an important role in enhancing crop production – i.e. the SOM. Land use change has a great influence on many soil quality attributes mostly through its effect on SOM. Structural stability of soils is affected by land use, which in turn is positively associated with total organic carbon content (Khormali et al. 2009). The conversion of native forests and native rangelands into cultivated areas is known to deteriorate soil properties, especially reducing SOM and changing the distribution and stability of soil aggregates. Intensive cultivation degrades the soil structure which is reflected by a decrease in stability of soil aggregates. The lower stability is usually associated with a decrease in SOM content. Soil structural stability and SOM content usually decrease with cultivation (Eynard et al. 2004). A cause of the significant decrease in SOM content in the changed land use type can be related to the decline of plant residues in the soil compared with that in original forest/ pasture lands.

WHC of soils was found to be another factor affected by the change of land use in the catchment. Forests were found to have significantly higher WHC than the other LULC types. This can be attributed to the high percentage of organic matter in these forest soils and more content of clay in them as SOM enhances the available WHC (Gol 2009) and further as this capacity of the soils increases with increase in clay content of the soils (Senjobi and Ogunkunle 2011). Like many other soil properties, WHC too is affected by the organic matter content (Yuksek et al. 2009). Land use changes affect the WHC of soils because of changes produced in infiltration, surface runoff, and evaporation (Demir et al. 2007; Zhai et al. 1990). Soil hydraulic properties and water retention characteristics are strongly influenced by land use and management, vegetation type and quality too have a large influence on the hydraulic property variations of soils (Yuksek et al. 2009).

With regard to the available nutrients- AN has its highest content in pastures followed by forest soils. Significant change has occurred in the AN content of these soils due to the land use change that has taken place in the study catchment i.e. their conversion to cultivated land areas, which maybe the main reason for the reduction of nitrogen content in cultivated area soils. LULC changes in the form of deforestation/rangeland destruction cause a decrease of soil total nitrogen content (Islam and Weil 2000). The reason for nitrogen loss is the removal of natural vegetation. In pastures/forests with good natural vegetation cover, its return into soil is high which increases the SOM content, which in turn increases the total nitrogen content of these soils. In various studies conducted on soils a positive relationship between total nitrogen and total SOM has been observed which has been attributed to the association of nutrient ions by humus complex in soils (Deenik and Yost 2008; Nguyen et al. 2004; Suhadolc et al. 2007; Wang et al. 2009). Disturbing soil surface destroys its natural conditions and leaves negative impacts on soil structure and infiltration rate, increases runoff, and leads to the loss of large amounts of nitrogen from soil surface. Removal of the vegetation cover and disturbance of the soil surface by land use change affect soil temperature and soil moisture and, thereby, accelerate biological decomposition of SOM, increase nitrogen mineralization and, ultimately, reduce the AN. Thus the deterioration of soil fertility due to these LULC changes that have taken place in the Sindh catchment over the years is quite evident, as the soils under various types of cultivated land uses contain less nitrogen and organic matter content than similar soils under natural vegetation.

The results of the present study show that LULC change did not significantly affect the AP. AP of soils of different LULC types did not differ significantly in case of forests, pastures and cultivated areas. In forests and pastures, vegetation cover and its return into soil increases the SOM content, which in turn increases the AP content. Organic matter is the major soil source of phosphorus and sulphur and the primary source of nitrogen (Brady 1996). In case of cultivated areas crops are harvested; so phosphorus is not returned into the soil as a result of phosphorus uptake by crops. However, the concentration of this element increases in these land uses due to phosphorous fertilization during cultivation years; hence, no significant differences are observed in AP content between forests, pastures and cultivated land areas. Further, the results of the study indicate that the LULC change from forests and pastures to cultivation has destroyed the soil and led to the loss of AK. Significantly higher levels of AK in forest soils and pasture lands maybe due to the high ability of vegetation in these soils to absorb potassium from the underlying layers of soil and releasing it by the plant residues to the surface layer. In case of cultivated areas leaching and lessivage of this element to the lower layers leads to the loss of potassium.

5 CONCLUSIONS

The study focused on the effect of LULC change on soils of a Kashmir Himalayan Catchment-Sindh.

The LULC change analysis over the span of 15 years (1995-2005) using remote sensing approach revealed that the most important land conversions that have taken place in the catchment during the said period are deforestation, pasture land destruction, urbanization, and agricultural intensification. These LULC changes have a significant influence on soils of Sindh catchment, affecting many of the soil quality attributes. The study showed that land use change in the form of deforestation, pasture land destruction and long-term cultivation caused decrease of soil organic matter, water holding capacity, available nitrogen and available potassium content, but it caused an increase of pH. This has resulted in the degradation of the quality of soils in this catchment of Kashmir Himalayas. For this reason, the action of converting forestlands and pasture lands into farmlands and urbanized areas should be prevented and use of land resources in the area should be done as per the natural conditions. Appropriate land use policy and proper management practices for increasing soil sustainability and productivity are required.

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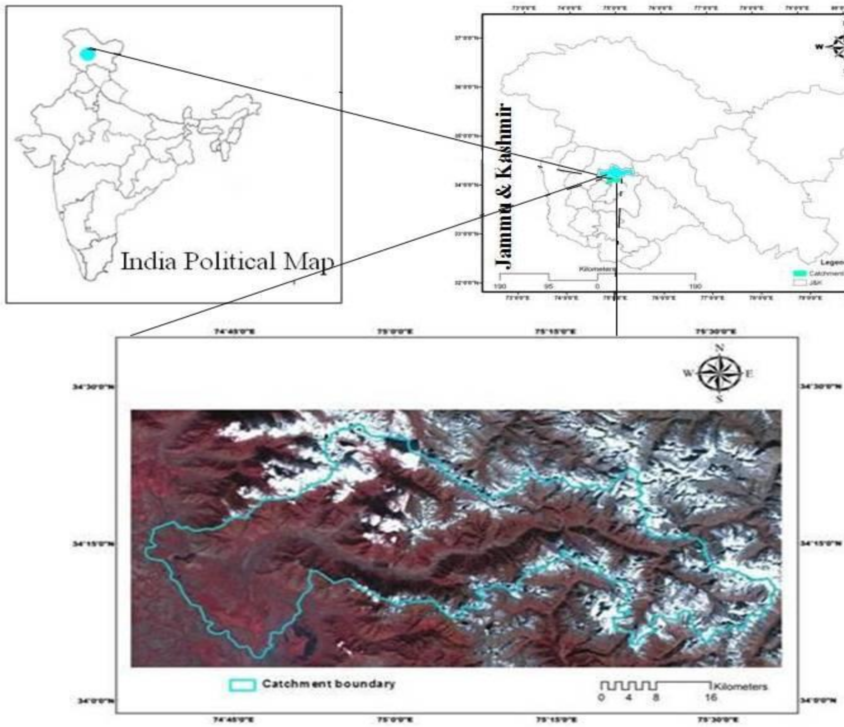

Figure 1. Location of study catchment (Sindh)

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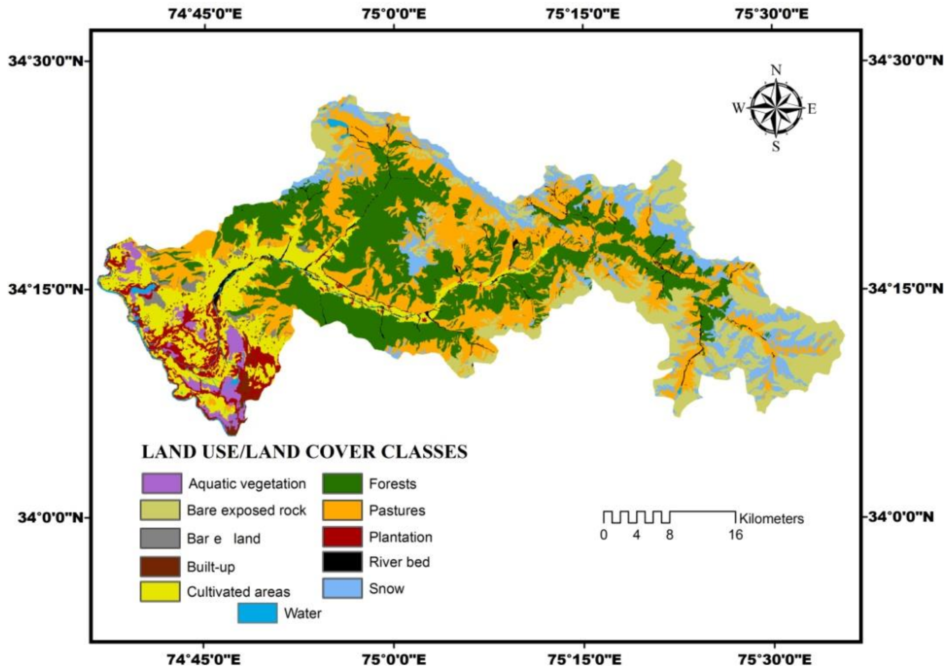

Figure 2. LULC map of Sindh catchment-1992

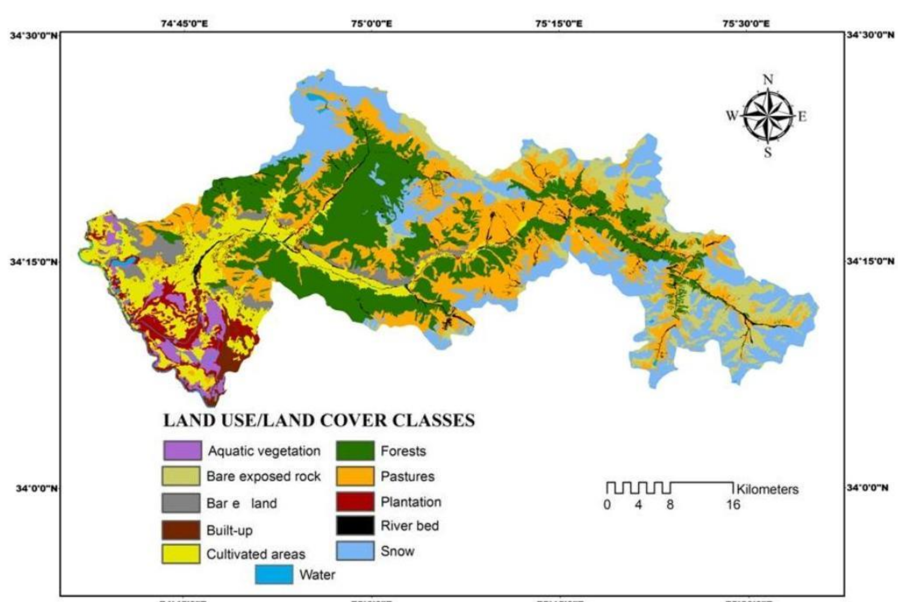

Figure 3. LULC map of Sindh catchment-2005

Table 1. Change in the land use/land cover pattern of Sindh catchment

S.No.	Class Name	Area (Km^2)		Area change (Km^2)	% change
		1992	2005		
1	Aquatic Vegetation	33.05	39.51	+6.46	16.3
2	Bare Exposed Rock	164.50	158.02	-6.48	3.93
3	Bare Land	15.30	50.19	+34.89	69.5
4	Built up	15.62	31.34	+15.72	50.1
5	Cultivated Areas	198.35	200.85	+2.5	1.24
6	Forests	449.22	388.65	-60.57	13.4
7	Pastures	445.93	384.78	-61.15	13.7
8	Plantation	63.10	52.11	-10.99	17.4
9	River Bed	21.45	27.10	+5.65	20.8
10	Snow	239.96	316.44	+76.84	24.16
11	Water	17.36	14.85	-2.51	14.45
	Total	1663.84	1663.84		

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Table 2. Effect of land use/land cover change on soil properties of Sindh catchment

	Land use/cover types				
Soil properties	Forests	Pastures	Cultivated areas	Built-up	Significance
pH	6.61±0.86[a]	6.77±0.34[a]	7.44±0.18[b]	7.16±0.63[b]	0.000
EC (µS/cm)	169.64±5.28[a]	149.42±3.88[a]	154.15±3.98[a]	292.25±28.07	0.036
SOM (%)	3.96±0.26	5.68±0.55	2.40±0.44[a]	2.65±0.38[a]	0.000
WHC (%)	57.87±1.01	49.15±0.59[a]	46.65±2.64[a]	43.92±1.72[a]	0.008
AN (Kg/ha)	617.28±12.99[a]	658.69±47.9[a]	364.36±28.18[b]	378.65±36.0[b]	0.000
AP (Kg/ha)	41.27±7.40[a]	43.26±2.76[a]	36.91±1.31[ab]	31.94±1.80[b]	0.023
AK (Kg/ha)	456.58±9.78[a]	480.30±28.3[a]	384.34±5.51	305.10±5.04	0.000

Values followed by the same letters in a row are not significantly different at $p \leq 0.05$