Analyzing Land Cover Change Using Remote Sensing and GIS: A Case Study of Gilgit River Basin, North Pakistan

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Abstract: Mountainous areas of northern Pakistan are rich in biodiversity, glaciers and key watershed of Indus River system which provide ecosystem services for their inhabitants. These regions have experienced extensive deforestation and are presently vulnerable by rapid land cover changes, therefore an effective assessment and monitoring is essential to capture such changes. The aim of this study is to analyze the observed changes in land cover over a period of thirty-nine years, divided into three stages (1976-1999, 1999-2008 and 2008-2015). Four images from Landsat 2 Multispectral Scanner System (MSS), Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper and Landsat 8 Operation Land Imager data were obtained to detect land cover change. This study used supervised classification-maximum likelihood algorithm in ERDAS imagine to identify land cover changes perceived in Gilgit River Basin, Pakistan. The result showed that the range land, glaciers, water bodies, built-up/agricultural cover are the major categories that have been altered by the natural and anthropogenic actions. In 1976, built up/agriculture, range land, water bodies and glacier cover was 1.13%, 45.3%, 0.66% and 13.2%, respectively. Whereas in 2015, built up/agriculture, range land, water bodies and glacier cover was 3.25%, 12.7%, 0.91% and 8.2%, respectively. Theses land cover shifts posed acute threat to watershed resources. Therefore, a comprehensive watershed resource management is essential or otherwise, these resources will deplete rapidly and no longer be capable of playing their role in socioeconomic and sustainable environmental development of the area

Keywords: Land cover change, remote sensing, Gilgit watershed.

Introduction

A sound ecosystem covers water, soil, food, climate and other raw materials as well as other cultural services which have direct and indirect impact on human population for associate economic amenities that drive from the environment (Qamer et al., 2016; Erda et al., 2018;). Remote sensing based temporal changes in land cover provide an important understanding regarding dynamics of environment in mountainous area which are related to landscape evolution. Land cover change (LCC) related studies are also helpful for sympathetic observation of the driving factors that control the changes (Nath et al., 2018; Tahir et al., 2013). The rapid population growth leads to overexploitation of natural resources and cause a serious unrest worldwide for future of the world. Therefore, LCC analysis is very important for rational planning, decision making for land cover development, and optimal use of natural resources (Milanova and Telnova, 2007; Beuchle et al., 2015).

Worldwide mountain ecosystems are highly sensitive on earth. The Hindu Kush, Karakoram and Himalayan (HKH) mountain environments are being affected due to many anthropogenic and natural factors such as population growth, urbanization, economic development, tourism and climate change (Coppin et al., 2004; Qamer et al., 2016). Natural landscape degradation through urbanization, agricultural development and exploitation of natural resources as well as natural drivers are the main environmental problems that intensively affect land cover processes. At the same time, KHK regions are highly susceptible to various natural hazards such as glacier lake outburst flooding (GLOF), flash flood, landslide and debris flow, which further degrades mountainous environment (Lasch et al., 2002; Yu et al., 2007; Bajracharya and Shrestha, 2011). Land deterioration in mountainous watershed is a common phenomenon in developing countries because of inadequate planning and misuse of watershed resources. The understanding of land cover dynamics is vital for sustainable environmental, social and economic development. In a scenario, where land and land resources are inadequate due to demographic forces and global climate change, LCC information is very important for planning (Shafiq et al., 2016). In the present study, remote sensing data for the year 1976-1998, 1998-2008 and 2008-2015 are considered for the comprehensive study for the Gilgit river basin in the Karakoram and Hindu Kush mountains of Pakistan.

Sensor	Resolution	Path/Row number	Date of Acquisition
Landsat MSS	57m	162/034,161/035	1976-08-08
Landsat TM	30m	150/034, 150/35	1999-08-16
Landsat ETM	30m	151/35,150/034,150/35	2008-07-05
Landsat OLI-TIRS	30m	150/35, 151/35	2015-08-19

Our objective was to generate information on LCC in order to understand and promote sustainable ecosystem in rapidly growing mountainous areas of northern Pakistan.

Materials and Methods

Study Area

Gilgit watershed is located in the northern part of Hindu Kush and Karakoram mountains of north Pakistan. Gilgit and Ghizer district are located in the study area and Gilgit is the provincial capital of Gilgit-Baltistan (GB). The Gilgit river originates from Shandoor lake, which is situated in between the border of Gilgit Baldistan and Khyber Pakhtunkhwa (KPK) province of Pakistan. Gilgit watershed lies between latitude 35° 46´05 N to 36° 51´ 16´´N and longitude 72° 25´02´´ E to 74° 19´ 25 E (Fig. 1,2). There are 6 valleys in the study area (e.g., Gilgit, Puniyal, Ishkoman, Gupis, Yasin and Phandar. Gilgit is the major river while three small rivers join Gilgit river (e.g., Phandar, Yasin and Ishkoman rivers). The geographical area of the watershed is around 13552sq.km and altitude ranges from 1178 to 7669m. Generally, most of the areas are highly prone to flash floods, glacier lake outburst flood and landslide.

Data Used

In the current study, Landsat and ASTER DEM data were used for the land cover change analysis for the year 1976, 1998, 2008 and 2015. All the Landsat images were processed and corrected in a same coordinate system and images for various years were downloaded for the same month and season in order to reduce the seasonal change in land use and land cover. Landsat multispectral scanner (MSS) images were re-sampled into 30x 30m pixel size. Table 1 shows detailed information of the satellite data, which were pre-processed in Earth Resource Data Analysis System (ERDAS) imagine version-13 for projection transformation, mosaicking, and subsetting of the image on the basis of Area of Interest (AOI). The maximum likelihood algorithm was used for supervised classification of the images. Based on visual analysis, for each land cover type, 150 ground-truth polygons were digitized in order to improve the land cover classification. The accuracy

assessments were performed for classified images of 1976, 1999, 2008, and 2015. The identified five land cover classes comprised of range land, glacier/debris, water bodies, residential/agricultural and barren land (Table 2).
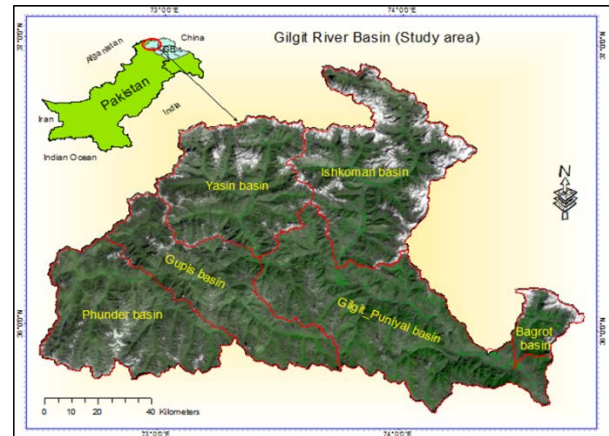

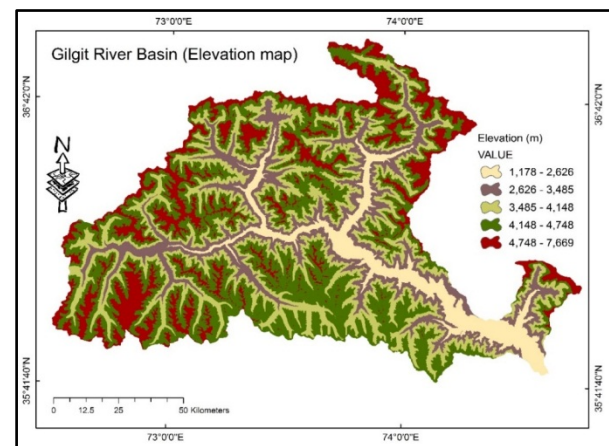Fig. 1 Location of the study area.

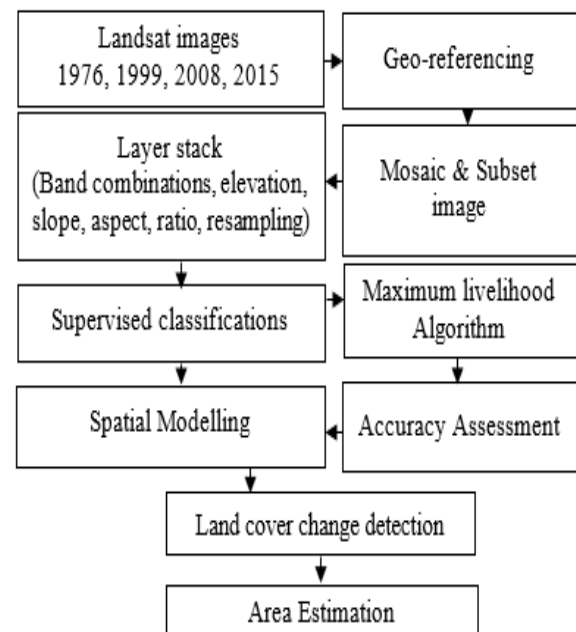Fig. 2 Elevation of the Gilgit river basin.

Fig. 3 Step by step methodological framework of the study.

Table 2. Classes delineated on the basis of supervised classification.

Classes ID	Class Name	Description
1	Residential/agricultural land	Residential (build-up) and agriculture area
2	Rangeland	Grasses, grass-like plants, forbs, or shrubs
3	Water bodies	Rivers, streams, permanent lakes and glacier lakes
4	Glaciers	Clean Ice and debris
5	Rock/soil	Land areas of exposed soil and bare mountains

Results and Discussion

The classified land cover maps of the Gilgit River basin of the year 1976, 1999, 2008 and 2015 are given in Fig.4. The achieved overall classification accuracies were 97%, 96.33%, 96.67% and 92.33%. The achieved overall Kappa statistics for the four images were 0.95%, 0.94%, 0.94% and 0.90% respectively. The area of land cover types in 1976-2015 was represented asrock/soil>rangeland>glaciers>agriculture/residential >water bodies. Apparently considerable changes in land cover have occurred. There was a wide change observed in land cover in the Gilgit River Basin over the past 39 years, which is mainly reflected in rangeland, glaciers, and agriculture land and water bodies (Fig.4).

The findings showed that a major decline took place with respect to area coverage of rangeland and glacier classes, whereas, the area of agriculture/residential, water bodies and rock/soil has rapidly increased. Between 1976 to 2015 the increase in residential/ agricultural class was 1.13% to 3.25% as well as water bodies increased from 0.66% to 0.91% (Table.3) According to AWCI (2009), there are 608 glacier lakes having various sizes and among them 8 glacier lakes are potentially dangerous for the glacier lake outburst flooding. The comparison of each class between 1976-1999, 1999-2008, and 2008-2015 also showed that there has been an intensive land cover change during the three periods. This increasing trend of land cover changes in the basin's area is due to a number of factors such as climate change, increase in population growth, economic developments and lack of implementation of environmental rules and regulations.
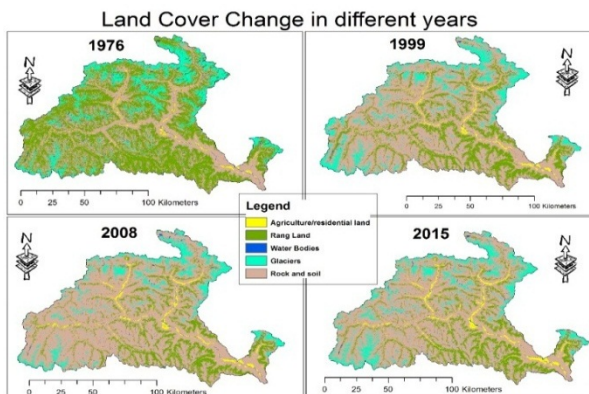

Fig. 4 Land-cover map for the years 1976-1999, 1999-2008 and 2008-2015.

Table 3. Summary of area of classified land covers in the study area for different reference years.

LC Types	1976 Area (km^2)	(%)	1999 Area (km^2)	(%)	2008 Area (km^2)	(%)	2015 Area (km^2)	(%)
Agricultural/ residential areas	139	1.13	214	1.6	327	2.4	413	3.25
Rangeland	6118	45.3	2762	20.4	2002	14.8	1727	12.7
Water bodies	89	0.66	113	0.83	117	0.86	123	0.91
Glaciers	1778	13.2	1405	10.4	1202	8.9	1089	8.1
Rock/soil	5428	40.05	9059	66.8	9904	73.2	10200	74.7

Land cover transformation

Transformation of different land cover types for three periods was analyzed by using the spatial analysis tools in ArcGIS, and the transfer matrix of land cover was attained. The transfer matrix of LCC in three periods is shown in Table.5. Agriculture and residential areas belong to the land use types with greater changes. The transfer-in rate of agricultural and residential area has been rapidly increased in three periods.

The findings show that over the last three periods, rangelands and barren lands transferred into agricultural class. Around the main water bodies (rivers, streams, lakes) land has shifted into agriculture/residential cover. In the first period agricultural/residential class was in the lower areas of the basin, but in the other two periods, it has shifted into the upper areas of the basin or towards the rangeland area. Another important finding was observed in the agricultural class during three periods that rivers and stream areas are transferred into agricultural and residential land. The proportions of rangelands transferring into other land during 1976, 1999, 2008, 2015 were 6118km2 (45.155%), 2761km2 (20.37%), 2002km2 (14.77%) and 1727km2 (12.74%) respectively (Fig. 5). The findings show that during the first two periods, rangelands were very rapidly transferred into barren land and agricultural/residential land. In the Gilgit river basin, the rangelands provide an extensive amount of fuel wood to meet domestic energy needs, fodder for livestock, and medicinal plants for traditional uses and sale purpose. The results show that rangelands are declining very disturbingly and its conservation is now becoming a key issue and challenge in the area.

The transfer-out area of glacier cover decreased gradually over three periods leading up to 2015. The transfer-out rate of glaciers during the years 1976, 1999, 2008, and 2015, the areas were 1778km2 (13.12%), 1405km2 (10.37%), 1202km2 (8.87), and 1089km2 (8.03). Whereas the transfer-out area was larger than transfer-in area (Fig.5). The glacier area of the basin was 13. 2% in 1976, whereas, in 2015, 8.1% area of the basin was covered by glaciers. As in Pakistan the frequency, intensity, as well as duration of heat waves has increased considerably in early summer
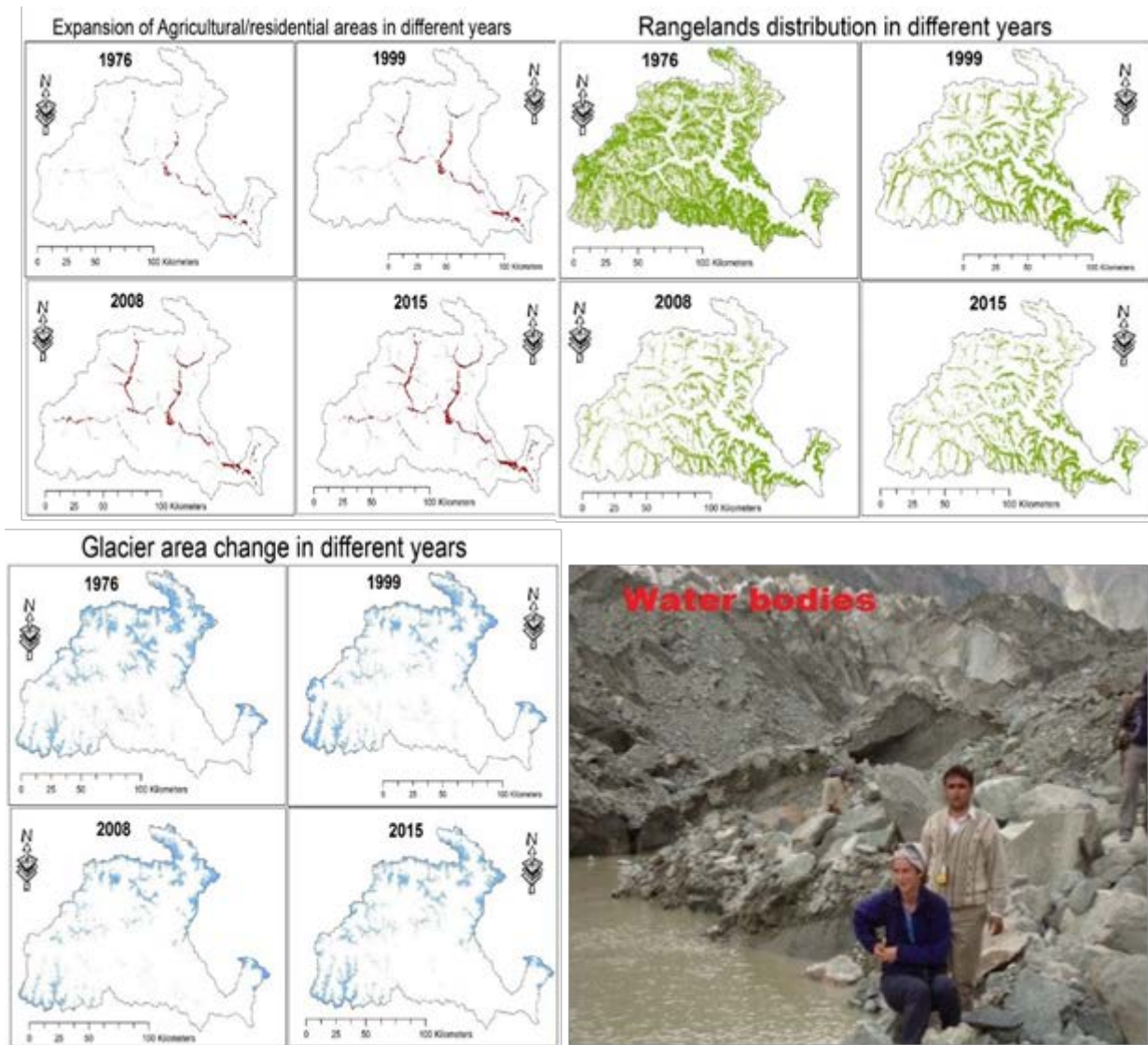
Fig. 5 Land cover changes for each type from 1976 to 2016.

in the mountainous regions of Pakistan. According to ICIMOD, (2011) the total glacier area of the Gilgit river basin was 1053 sq.km. The transfer-in rate of water bodies increased gradually during a three year period. The transfer-in rate of water bodies during the years 1976, 1999, 2008, and 2015, the areas were 89 sq.km (0.66%), 113 sq.km (0.83%), 117 sq.km (0.86%) and 123 sq.km (0.91%) respectively (Fig. 5).

The cross- tabulation matrices (Table 4,5) show the nature of change in different land cover classes. Out of the 413km^2 that was an agriculture and residential area in 1976, 190.4 km^2, 129 km^2 was still agriculture and residential area in 2015 but 93 km^2 was converted to rangeland and water bodies, while the rest into rock and soil. At the same time the increase of agriculture and residential area, from 1976 to 2015, was mainly from rock/soil and range land (256 km^2). Out of the 413km^2 that was an agriculture and residential area in 1976, , 129km^2 was still agriculture and residential area in 2015 but 93km^2 was converted to rangeland and water bodies while the rest into rock and soil. At the same time the increase of agriculture and residential

areas, from 1976 to 2015, was mainly from rock/soil and range land (256km^2).

Table 4. Cross-tabulation of land cover classes between1976 -1999, 1999 - 2008 and 2008 - 2015 (Area in km^2).

1976 / 1999	Agriculture/ residential area	Rangel and	Water bodies	Glaci ers	Rock/S oil
Agriculture/ residential area	112.5	12.0	0.9	0.0	14.0
Rang land	31.0	2163.0	24.0	277.0	3623.0
Water Bodies	0.3	0.7	47.4	5.0	35.3
Glaciers	0.0	9.0	4.0	992.0	773.0
Rock/Soil	70.1	576.0	37.0	131.0	4614.1
1999 / 2008	Agriculture/ residential area	Rangel and	Water bodies	Glaci ers	Rock /Soil
Agriculture/ residential area	208.2	0.9	0.6	0.0	4.3
Rang land	43.7	1781.3	0.7	0.6	934.7
Water bodies	0.3	0.7	62.4	5.0	45.3
Glaciers	0.4	2.7	13.7	1091.4	296.5

Rock/Soil	74.0	216.0	39.7	104.9	8624.0

2008 / 2015	Agriculture/ residential area	Rangeland	Water bodies	Glaciers	Rock/Soil
Agriculture/ residential area	306.1	2.8	2.2	0.0	16.0
Rang land	31.0	1375.0	0.2	0.2	595.2
Water bodies	2.7	0.2	74.5	15.4	24.3
Glaciers	0.1	0.4	1.6	692.6	507.2
Rock/Soil	73.5	348.4	44.9	380.5	9057.0

Table 5. Cross-tabulation of land cover classes between1976 and 2015 (Area in km^2).

1976 / 2015	Agriculture/ residential area	Rangeland	Water Bodies	Glaciers	Rock/Soil	Total Area 1976
Agriculture/ Res	129	3.3	2	0.0	4.3	139
Rang land	85	1471.7	22	261.9	4277	6118
Water Bodies	8.2	12.8	37.7	12	18.6	89.2
Glaciers	0.3	9.3	9.9	689.6	1069	1778
Rock/Soil	190.4	230.4	51.4	125.2	4831	5428.6
Total Area 2015	413	1727	123	1089	10200	**13552**

Driving Forces of Land Cover Dynamics

From the overall characteristics of land cover change and mutual conversion of land use and cover types, inference can be drawn that the spatial patterns of land use and land cover types have great changes. The topography of the Gilgit river basin experiences various types of meteorological conditions, according to elevation, aspect, slope and landforms. However, there are both natural and anthropogenic reasons of land cover dynamics in the Gilgit river basin. The most dominant driving forces of land cover dynamics are the rapid increase in population growth and climate change impacts (Zafar et al., 2009).

According to 1998 Pakistan Bureau of Statistics, the total population of the study area was 240,000, and population growth rate was 2.7%. The growth of population is an important driving force of land cover dynamics in the basin. In the last four decades the increase of population in the basin has worse impacts on rangelands in the form of cutting down of firewood and over-grazing. The number of livestock in GB region, especially goats, sheep, cattle and yaks increased from 0.88 million in 1976 to 2.45 million in 2006 and more than 80% of the livestock was dependent on rangelands. The fourth assessment report of the IPCC (2007) showed that climate change is already happening, and it will lead to a global temperature rise of 2ºC and related increase of extreme weather events. In the last three decades, HKH region has witnessed an increase of 0.15ºC – 0.6ºC per decade. Impact of climate change have been well observed in HKH region, in particular, with respect to the recession of the snowline, formation of glacier lakes and change in biodiversity in the ecosystem (Rasul et al., 2003; Ganasri, and Dwarakish 2015)

Conclusion

This study provides land cover change statistics in Gilgit river basin using GIS and remote sensing techniques and it is concluded that land cover in the study area has substantially changed in the last 39 years. The land cover change in the River basin was evident by the decline in the area of range land and glacier class (45% to 12% and 13% to 8%, respectively) while built-up/agriculture and water bodies increased between 1976-2015 by 1.3% to 3.25% and 0.66% to 0.91%, respectively. The rapid expansion in built-up and agriculture area in the basin was majorly due to mismanagement of natural resources and lack of land use planning. The study reveals that human activities and climate change are the main drivers of land cover change patterns in Gilgit watershed. Furthermore, all these changes in land cover patterns can badly affect environmental quality and it can also enhance the frequency of hydro-meteorological hazards in the region. Additionally, appropriate measures for these resources is needed because without proper management the recovery of these natural resources is very difficult and unable to play its required role in socioeconomic and environmental development of the area. The result of spatial and temporal analysis of land cover change can help in devising land use policies more effectively.

Acknowledgement

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