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.
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 Baltistan 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, 1999, 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 30x30m 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).

Table 1. Satellite data used in this study.

| 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        | 151/35,150/034,1 | 2008-07-05         |
| Landsat OLI-TIRS | 30m | 150/35, 151/35 | 2015-08-19          |

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.
Overall Kappa statistics for the four images were 97%, 96.33%, 96.67% and 92.33%. The achieved overall classification accuracies for the four images were 97%, 96.33%, 96.67% and 92.33%. The classified land cover maps of 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.

### 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 for the four images 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.

| 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 |

### 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.

| LC Types          | 1976 Area (km²) (%) | 1999 Area (km²) (%) | 2008 Area (km²) (%) | 2015 Area (km²) (%) |
|-------------------|---------------------|---------------------|---------------------|---------------------|
| 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 |

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.
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 413km² that was an agriculture and residential area in 1976, 190.4 km², 129 km² was still agriculture and residential area in 2015 but 93 km² 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 (256km²).

Table 4. Cross-tabulation of land cover classes between1976 -1999, 1999 - 2008 and 2008 - 2015 (Area in km²).

|       | 1976 | 1999 | 2008 | 2015 |
|-------|------|------|------|------|
| Agriculture/residential area | 112.5 | 12.0 | 0.9  | 0.0  |
| Rangeland | 31.0 | 2163.0 | 24.0 | 277.0 |
| Water Bodies | 0.3 | 0.7 | 47.4 | 5.0 |
| Glaciers | 0.0 | 9.0 | 4.0 | 1091.0 |
| Rock/Soil | 70.1 | 576.0 | 37.0 | 4614.1 |

Fig. 5 Land cover changes for each type from 1976 to 2016.
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 2°C and related increase of extreme weather events. In the last three decades, HKH region has witnessed an increase of 0.15°C – 0.6°C 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 Dwarkish 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 watersheds. Furthermore, all these changes in land cover patterns can adversely 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.

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References

AWCI, (2009). Snow, glacier and GLOF and report on demonstration river basin activities, Upper Indus basin. The 5th International Coordination Group (ICG) Meeting GEOSS Asian Water Cycle Initiative Tokyo, Japan, 15-18.

Bajracharya, S.R., Shrestha, B. (2011). The status of glaciers in the Hindu Kush-Himalayan region. Kathmandu, ICIMOD.

Beuchle, R., Grecchi, R.C., Shimabukuro, Y.E., Seliger, R., Eva, H.D., Sano, E., Achard, F. (2015). Land cover changes in the Brazilian Cerrado and Caatinga biomes from 1990 to 2010 based on a systematic remote sensing sampling Approach. Applied Geography, 58, 116 -127.

Coppen, P., Jonckheere, I., Nackaerts, K., Muys, B., Lambin, E. (2004). Digital change detection methods in ecosystem monitoring: a review. Int. J. Remote Sens., 25 (9), 1565–1596.
Erda, L., Wei, X., Hui, J., Yinlong, X., Yue, L., Liping, B., Liyong, X. (2005). Climate change impacts on crop yield and quality with CO2 fertilization in China. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **360** (1463), 2149-2154

Ganasri, B.P., Dwarakish, G.S. (2015). Study of land use/land cover dynamics through classification algorithms for Harangi catchment area, Karnataka State, India. International conference on water resources, coastal and ocean engineering. *Aquatic Procedia*, **4**, 1413 – 1420.

ICIMOD. Livestock, Fodder, Pastures and People, (2001). An integrated study in Karokoram region of Pakistan. *Special Technical Bulletin*. International Centre for Integrated Mountain Development.

IPCC, (2007). Fourth Assessment Report. Intergovernmental Panel on Climate Change Secretariat. Geneva, Switzerland. http://www.ipcc.ch/

Lambin, E.F., Geist, H.J., Lepers, E. (2003). Dynamics of land use and land cover change in tropical regions. *Annu. Rev. Environ. Resource*, **28**, 205–241.

Lasch, P., Lindner, M., Erhard, M., Suckow, F., Wenzel, A. (2002). Regional impact assessment on forest structure and functions under climate change—The Brandenburg case study. *For. Ecol. Manag.*, **162**, 73–86.

Milanova, E. V., Telnova, N.O. (2007). Land-use and land-cover change study in the transboundary zone of Russia–Norway. In Man in the landscape across frontiers: Landscape and land use change in Central European border regions. CD-ROM Conference Proceedings of the IGU/LUCC Central Europe Conference, 123-133.

Nath, T. K., Jashimuddin, M., Kamruzzaman, M., Mazumder, V., Hasan, M. K., Das, S., Dhali, P. K. (2016). Phytosociological characteristics and diversity of trees in a comanaged protected area of Bangladesh: Implications for conservation. *Journal of Sustainable Forestry*, **35** (8), 562-577.

PBS, (1998). Population, Socio-economic and development profile of *Pakistan Bulletin of Pakistan Bureau of Statistics*.

Qamer, F., Shehzad, K., Abbas, S., Murthy, M. S. R., Xi, C., Gilani, H., Bajracharya, B. (2016). Mapping deforestation and forest degradation patterns in western Himalaya, Pakistan. *Remote Sensing*, **8** (5), 385.

Rasul, G., Dahe, Q., Chaudhry, Q.Z. (2003). Global warming and melting glaciers along southern slopes of HKH ranges. *Pak. J. Met.*, **5**(9), 63-76.

Shafiq, M., Ahmad, S., Nasir, A., Ikrarn, M. Z., Aslam, M., Khan, M. (1997). Surface runoff from degraded scrub forest watershed under high rainfall zone. *Journal of Engineering and Applied Sciences*, **16**(1).

Tahir, M., Imam, E., Hussain, T. (2013). Evaluation of land use/land cover changes in Mekelle city, Ethiopia using remote sensing and GIS. *Computational Ecology and Software*, **3**(1), 9.

Yu, H., Joshi, P.K., Das, K.K., Chauniyal, D.D., Melick, D.R., Yang, X. (2007). Land use/cover change and environmental vulnerability analysis in Birahi Ganga sub-watershed of the Garhwal Himalaya, India. *Trop. Ecol.*, **48**, 241–250

Zafar, M., Khan, B., Awan, S., Khan, G., Ali, R. (2009). High-altitude rangelands and their Interfaces in Gilgit-Baltistan, Pakistan: Current status and management strategies. WWF-Pakistan and Gilgit-Baltistan.