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Impact Analysis of Glacial Lakes on Land Use Land Cover Dynamics of Karakoram Using Satellite Imagery from 1998-2018

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Abstract

Land use land cover change (LULCC) detection is vital for managing natural resources and monitoring environmental changes. Ishkoman valley being a part of glaciated region is facing the problem of altered land features. Natural disasters triggered by human activities are altering the land cover of the basin. The valley is facing the floods, GLOF and landslides almost every year from glacier melt due to temperature fluctuation.

Present exploration is to identify LULC dynamics in context of the creation of an artificial lake in Ishkoman basin which had blocked the flow of Immit River. GIS and RS techniques were applied for geographic and temporal evaluation of land use modifications in the Ishkoman basin from the year 1998 to 2018. It is identified that barren land and vegetation cover of region declined significantly in twenty years while snow and glacier cover was increased.

1. Introduction

Land is one of the dynamic natural resources hosting all natural and anthropogenic activities. Although Land use and land cover (LULC) are separate features of the earth surface but they are very interrelated. Each parcel of land is distinctive in the cover it possesses (Meyer, 1995). LULC of a region is controlled by natural and socio-economic factors. Natural disasters like drought, rainfall, forest fires, and fluctuations in climate can cause alterations in land cover. The continuous pressure on land to meet the needs of a growing population and several demands driven developmental activities have imposed stress on the earth’s land (Foley et al., 2011; Weinzettel et al., 2013). The changes in the traditional land use pattern caused by growing human population are higher than ever (Hansen et al., 2010). Lack of scientific analysis and evaluation of resources resulted in unsustainable use of land resources. Therefore information on the geographic and temporal allocation of LULC is an important

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prerequisite for management and monitoring programs at the local and regional level (Fan et al., 2007).

The LULC information acquired by GIS and RS for identification of hazard and risk from glacier lakes in the Karakoram must be explored. The purpose of the study is to create LULC classification maps for Ishkoman valley of Gilgit - Baltistan, Pakistan from 1998 to 2018, and to analyze the impacts of glacial lake on LULC dynamics of Ishkoman. Generated data will assist policy makers in updating their planning for Ishkoman Basin.

2. Materials and Methods

2.1 Study Area

Ishkoman is a splendid valley situated at 36.5677° North and 73.7426° East, in north of Ghizer district of Gilgit-Baltistan (Fig. 1). In the Hindu Kush and Karakoram hills, Ishkoman is one of the high mountain valleys, located at an altitude of 7,000 and 12,000 feet.

Figure 1: Map Showing Geographical Location of Ishkoman

At a distance of 140 kilometers from Gilgit, valley is known for beautiful natural lakes, alpine pastures, huge glaciers, and blue ice-cold water. It is a host to several mountain paths and treks from glaciers that makes it a popular tourist destination. The valley includes approximately 25 villages with a population of 30,000 inhabitants. It has a desert climate because it gets little monsoonal rain from June to September. Temperature variation throughout the year is about 26.9 °C. During summer season, many streams increase dramatically, transporting 20 % more water than in winter because of the melting of glaciers and snow.

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2.2 Glacial Lake of a Valley

In Gilgit-Baltistan and Khyber Pakhtoonkhawa, more than 3,044 glacial lakes have already been formed of which 33 are considered hazardous (UNDP estimate). A glacial lake outburst flood (GLOF) event occurred on 17 July 2018, struck Immit, Bilhnaz and Badswat villages of Ishkoman basin (Fig. 2).

Figure 2: The glacial lake image of 26th July 2018 (Source: AKDN).

A lake was formed in Badsawat village and resulted in the destruction of many houses and blocked 10 villages. Two people were killed during the initial rush of floodwaters and more than 1,000 people were evacuated to safer locations before this catastrophic event (Dawn news 20th July 2018). Flooding is one of the severe problems in and around the Ishkoman valley. These particular natural hazards have made Ishkoman subject to flooding.

2.3 Study Method

This research is focused on analyzing the satellite imagery of the Ishkoman watershed. Since the study aims to detect the LULC changes in Ishkoman Basin from year 1998 to 2018, so the Landsat was the best available option.

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Figure 3: The glacial debris image of 26th July 2018 (Source: Pamir Times/Twitter).

Landsat multispectral imageries of valley for said years with a spectral resolution of 30 m were acquired from the earth explorer of United States Geological Survey (2014). Real time data is very important while analyzing remotely sensed data. Therefore field observation was carried out despite of the rough terrain, unusual weather, very cold temperature, and remoteness. In addition, acquiring satellite images for the expected interval of time was a difficult task because of cloud cover. Landsat images of Ishkoman Basin were acquired for September 1998. Selection of this month for acquisition of Landsat images is made due to melting of heavy snow. Snow melting starts from June and continues till August. All the images downloaded were either from the July or early August to keep the analysis free from the impact of seasonal variability.

Two separate images for each year were downloaded to cover the whole basin. Acquired input data was imported to Earth Resources Data Analysis System (ERDAS Imagine 13 software). The different bands were stacked using layer stack in order to generate a false color composite (FCC) image of the acquired tiles of the image. Landsat Satellite images were selected on the basis of the quality of images with low cloud cover (Fig. 4). For georeferencing, World Geodetic System (WGS 84) and the North Coordinate System of the Transverse Mercator Zone 35 were used. Suitable band combinations of Landsat 4-5 and 7-8 were selected. For the Landsat 4 - 5 bands of image display on the channel of red, green, blue and near infrared were used while for Landsat 7-8 band 1,2,3,4,5 were selected. ARCMAP software was used to clip the study area and Histogram equalization has been used as the primary technique in the current research to enhance image contrast.

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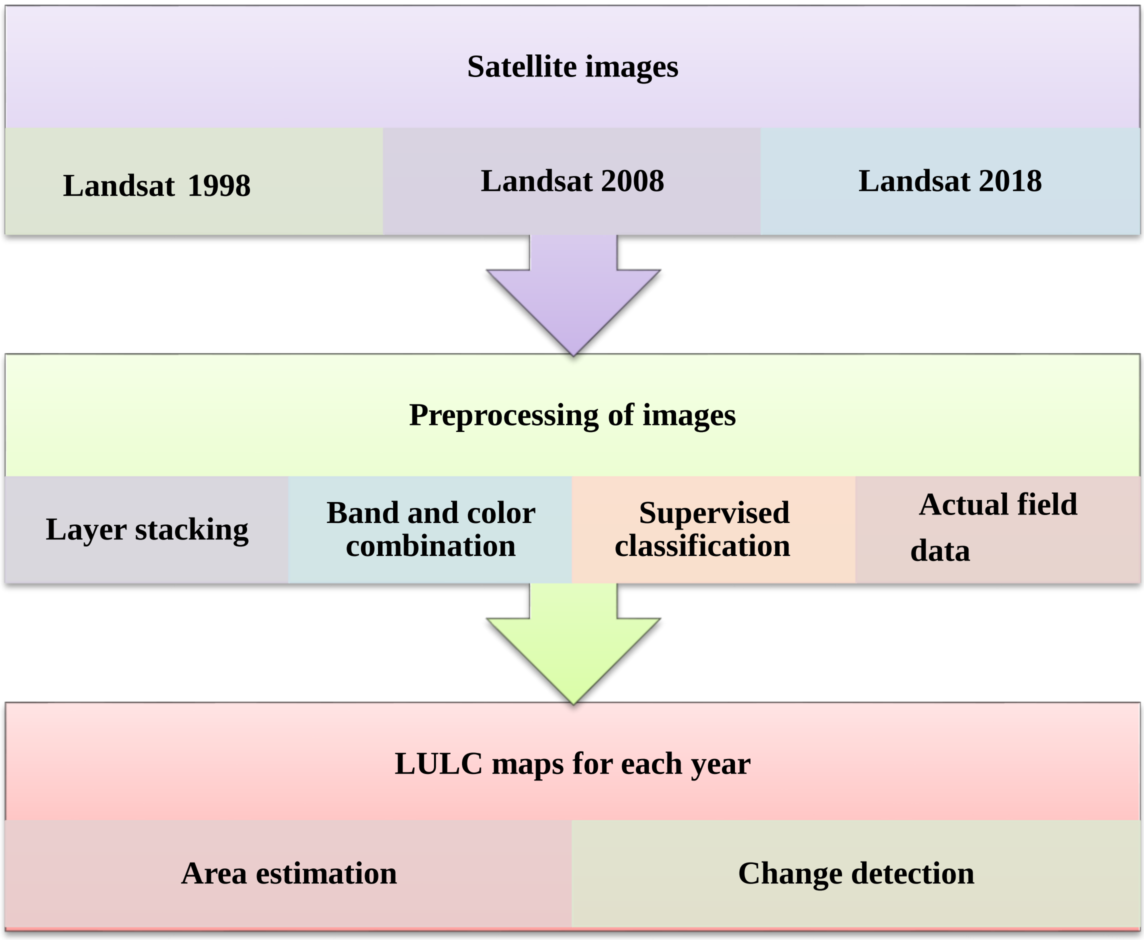

Figure 4: Flow Chart showing the method used in the study

In order to determine the LULC changes supervised classification following the maximum likelihood algorithm was used in ARCMAP software to classify the images of three different time periods. On the basis of the major types of LULC of an area, a classification scheme was thought-out (Table 1). Based on the information from local inhabitants in a field study LULC classes considered are barren land, snow and glacier, vegetation, water bodies, and settlements. Based on the pixel number and total area the area of each LULC class was calculated.

Table 1: Classification Theme for LULC Classes

Elements	Description
Barren land	It comprises bare soil, sand, rocks, strip mines and quarries
Snow &Glacier	It includes glacial lakes, ice and snow

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Vegetation	It covers land under crop fields, fallow, plantation, rangelands, scattered plants, forests, meadows on the mountains
Water bodies	It includes surface water e.g. lakes, canals, ponds, streams, rivers and reservoirs
Settlements	It includes residential area and cattle homes

3. Results and Discussion

3.1 LULC Maps of Ishkoman Valley

Anthropogenic activities and its consequent LULC change have become an important issue for the present time that risks the environmental degradation (Gamble et al., 2003). Ishkoman basin's LULC analysis for past twenty years revealed some important transformations (see Fig. 5).

3.1.1 For the Year 1998

The analysis of 1998 image showed that barren land covered the largest proportion of land in Ishkoman basin covering **68%** of the total land, followed by the snow and glacier (**18%**). The vegetation and settlement constituted **10%** and **3%** respectively while the water bodies showed coverage of **0.7 %**.

3.1.2 For the Year 2008

The assessment of 2008 image revealed the same trend as noted for 1998, that barren land covered about **64%** followed by the snow and glacier which accounts for **19%** of the whole basin. The vegetation constitutes **14%**, while computed values for settlements and water bodies are **3%** and **0. 7% respectively**.

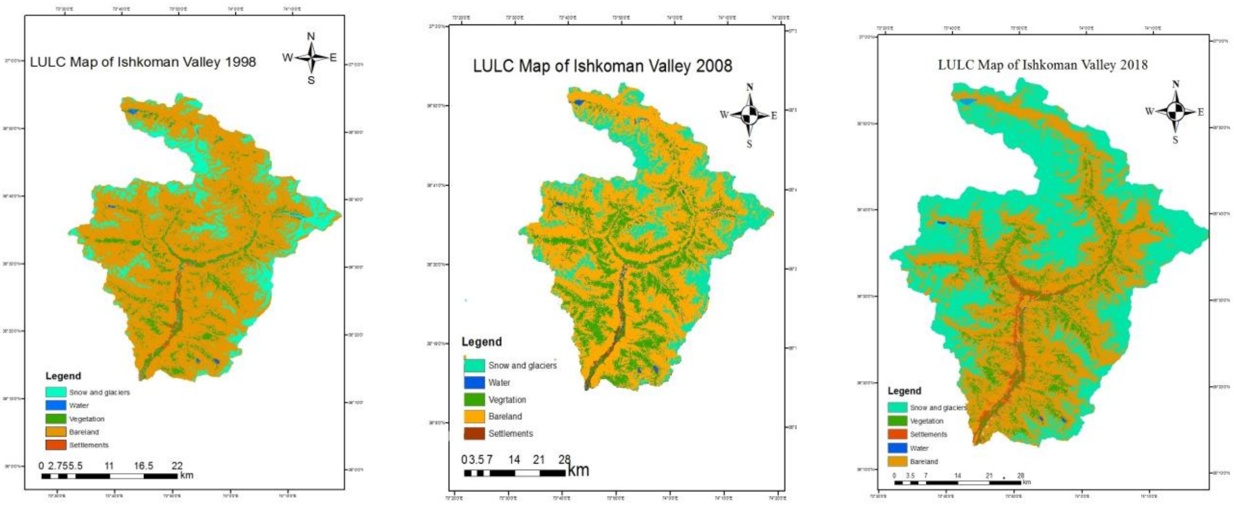

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Figure 5: LULCMaps of Ishkoman valley for the Year 1998, 2008, and 2018

3.1.3 For the Year 2018

The scrutiny of 2018 image showed that Barren land accounted for the **40%** while snow and glacier covered about **38%** of the whole basin. The vegetation constitutes **16%**, while settlement and water bodies showed coverage value of **4%** and **0.8%** respectively.

Table 2: Area Transition for LULC Classes for Years 1998, 2008, and 2018

LULC type	1998		2008		2018	
	Area in Hectares	percentage	Area in Hectares	percentage	Area in Hectares	percentage
Barren land	195383.4	68.15%	182217.1	63.78%	108660.54	40.31%
Snow &Glacier	51436.58	17.94%	53213.33	18.63%	102772.67	38.12%
Vegetation	28200.7	9.84%	39714.78	13.9%	44128.02	16.37%
Water bodies	1909.54	0.67%	1934.39	0.68%	2259.99	0.84%
Settlements	7787.47	2.72%	8625.47	3.02%	9748.80	3.62%

3.2 Dynamics of LULC of Ishkoman Basin

Each class computed from LULC maps is presented in the Table 2.

3.2.1 Barren Land

As the land belongs to the individuals of a specific village in Gilgit-Baltistan, so the people of the village have the privilege of individual ownership and have the rights in areas contiguous to a specific village. In 1978 ownership rights were introduced on barren lands under cultivation. Still districts of Hunza, Ghizer and Diamer are unsettled in comparison to the districts of Gilgit, Astore, Skardu and Khaplu (Bhatti & Ali, 2016). This might be a reason for a larger share of barren land for the basin under analysis.

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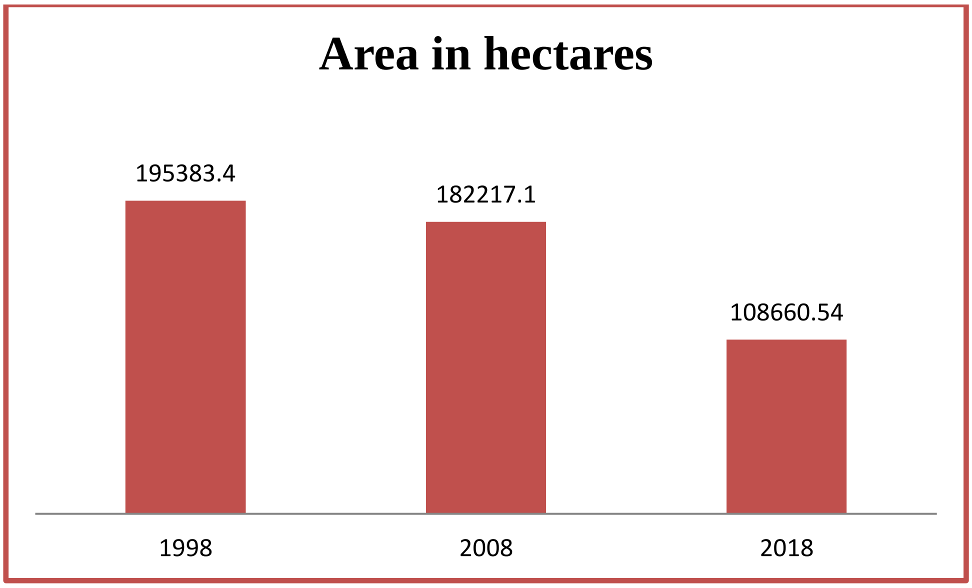

Figure 6: Barren Land Area Distribution of Ishkoman Basin

Continuous decrease in area is figured out for Barren land which was identified as largest in share. The decline is **4**% from 1998 to 2008 while **25**% from 2008 to 2018. Figure (6) reveals decreasing trend, probably caused by encroachment and conversion into other land use and land cover. The current study suggests shift of barren land area with snow and glaciers.

3.2.2 Snow and Glaciers

About **23%** of the Karakoram Range possesses ice reserves of about **2,387** km. Some **2,398** glaciers, including Siachen, Hispar, Biafo, Baltoro and Batura, are among the largest glaciers other than Polar glaciers (Ashraf et al., 2010). In the Karakoram Range, glaciers are stable/stagnant or even growing (Hewitt, 2005).This study also supports the same finding, from the year 1998 to 2018 snow and glacier cover was recognized enhancing from **51437** hectares to **102773** hectares in Ishkoman Basin. The area computed from 2018 map is simply double to the 1998 map. A significant increase of **51336** hectares was estimated for the 2 decades under comparison (Fig. 7).

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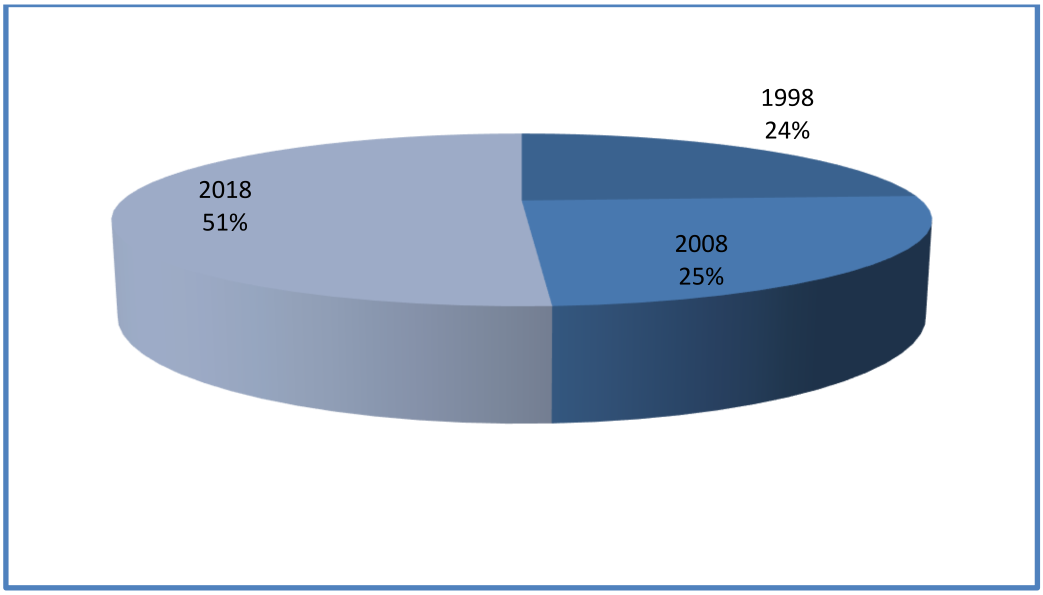

Figure 7: Snow and Glacier Area Distribution of Ishkoman Basin

3.2.3 Vegetation

In Gilgit-Baltistan the vegetation and interface areas constitute the third highest land cover after barren land and snowcapped mountains. It covers **2.34** million hectares of the land (Khan et al., 2013). Vegetation and pasture land of an ecosystem are not only essential for air and water regulation but also a great asset for continuous economic growth. The increase in area under vegetation for the 1st decade was more (**11514** hectares) than the 2nd decade (**4413** hectares). Increasing human population suggests growing need for livelihoods, which put stress on agricultural land and vegetation in terms of production and consumption. The improvement in vegetation cover is probably due to better practice of land ownership which restricts grazing in someone else land. Vegetation expansion was **4 %** from 1998 to 2008 while **2 %** from 2008 to 2018 (Fig. 8). GLOF disaster can change the land cover so that hectares of the agricultural land have been destroyed by GLOF under study. Seasonal crops like wheat, potatoes, and cereals were submerged creating a food shortage. The native people already suffered and this disaster had severely impacted their socioeconomic condition.

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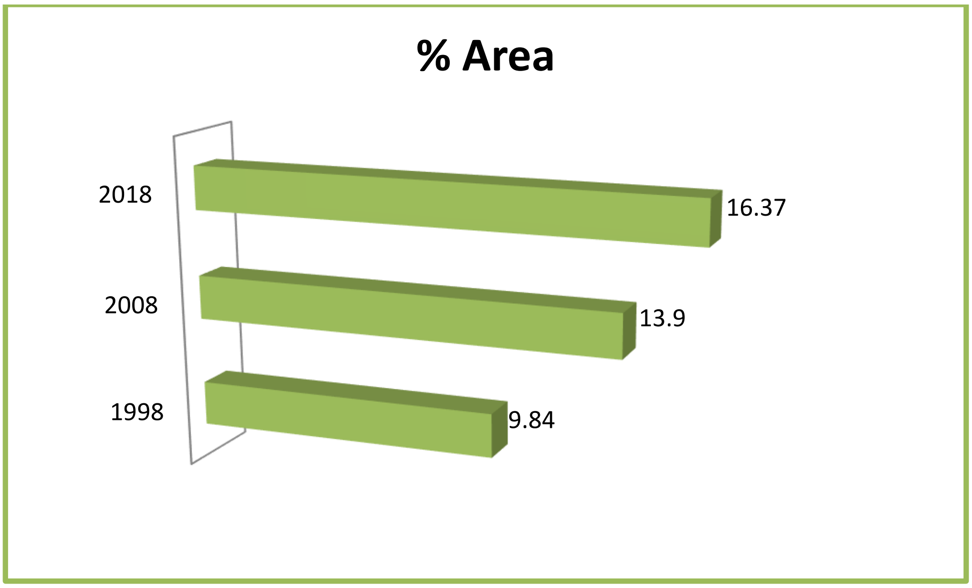

Figure 8: Vegetation Area Distribution of Ishkoman Basin

3.2.4 Settlements

Residential area covered about **7787** hectares in 1998, increased to **8625.47** hectares in 2008 that further increased to **9749** hectares in 2018 of the whole area. The LULC maps generated for settlements have shown an increase from **2.72%** to **3.62%** from 1998 to 2018 respectively. Due to the geographical location a slight increase of **1%** in residence for 2 decades was noted. 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. 1n 1998, residential area was identified in the lower areas of the basin, but in the other two periods, it has shifted to the upper areas of the basin i-e towards the rangeland area. Field visits and responses from local inhabitants helped to reason out this shifting. Wood from the rangeland is the only source of fuel for them so shift to upper areas make collection of wood easier for them. Primarily this relocation of resident to safer places is a potential risk of more damage to downstream population due to GLOF events.

3.2.5 Water Bodies

Ishkoman River is the source of irrigation for the various villages in Ishkoman and Puniyal that drains into the Gilgit River. Water bodies increased from the initial **1910** hectares (1998) to around **1934** hectares (2008) leading in a total rise of **2260** hectares (2018).

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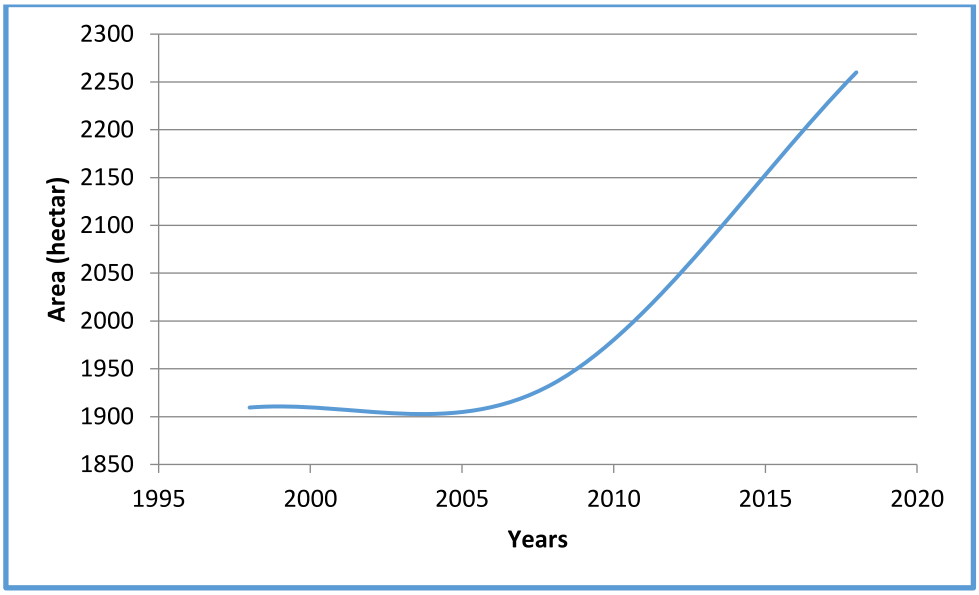

Figure 9: Water Bodies Area Distribution of Ishkoman Basin

3.3 Land Use Land Cover Changes and GLOF

Impact of climate change have been well observed in HKH region, in particular, with respect to the increase of the snowline, formation of glacier lakes and change in biodiversity in the ecosystem (Rasul et al., 2003; Dwarakish & Ganasri, 2015). Global circulation patterns and local topography influences greatly the occurrence of GLOF events. The topography of the Ishkoman river basin experiences various types of meteorological conditions according to elevation, aspect, slope and landforms (Khan et al., 2013). The mechanism for flood generation in the Northern Pakistan depends on extremely different variables. The contributing factors of LULCC for the area under study are natural disasters such as GLOF, rock sliding, avalanches, land slips, earthquakes, climate change, and trampling effects. Potential risk of outburst floods from 8 glacial lakes of hanging nature from Gilgit river basin has been reported by Ashraf et al. (2010). Several GLOF occurrences can be connected with more rainfall leading to rise in river level over the previous few years. In past years temperature and precipitation patterns has changed and directly affected the overall land cover. In the month of April and May, rainfall had occurred in Badsawat, Bilhanz and the other villages of Ishkoman. Due to heavy snowfall in last year's, the percentage of snow and glacier has somehow increased in 2018. The occurrence of any extreme GLOF incidence in the future is very difficult to predict due to rapid dynamics of glacial system. But effective monitoring and planning can reduce impact of natural disasters like GLOF.

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4. Conclusions

The mountainous areas of northern Pakistan are rich in biodiversity, glaciers and key watershed of Indus River system. Effective assessment and monitoring is indispensable to capture land use land cover changes of the region. Present exploration is to identify the reason of land cover dynamics in the Ishkoman basin in context of creation of an artificial lake which had blocked the flow of Immit River. From the overall characteristics of land cover a significant change is measured for Snow and glaciers, vegetation and barren land while settlement and water bodies did not show any major transformation. Snow and glaciers cover were found accelerated along proportionate decrease to barren land and vegetation.

5. Recommendations

In the framework of adjustment to climate change, following are the suggestions to maintain the region's mountain ecosystem and manage land cover:

- As Ishkoman is disaster prone area, there is need to inform people about anticipated disaster hazards and set up an early warning system in Ishkoman
- Special measures are needed first and foremost to secure the built infrastructure of the basin from the impact of climate change,
- Climate resilient building methods must be drawn into account and promoted,
- Maintain an inventory of all significant climate-prone hydrometerological events of region for tracking and formulation of risk assessments,
- Another step forward in protecting and restoring the vegetation would be providing incentives to the local people for guarding the new plantations, and
- A comprehensive watershed resource management is essential for the socioeconomic development of inhabitant in future.

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