INVESTIGATION OF CRYOSPHERE DYNAMICS VARIATIONS IN THE UPPER INDUS BASIN USING REMOTE SENSING AND GIS

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Contents

- Introduction
- Study Area
- Methodology
- Results and Discussions
- Conclusion
- References
1. Introduction

1. The Hindukush, Karakoram, and the Himalayan mountain range accommodate a large number of glaciers and are the major water source for various canals and rivers downstream.

2. The agriculture based economy of Pakistan is dependent on irrigation water supplied by the Indus River and its sub tributaries. Most of the flow abstracted from the Indus River at Tarbela is contributed by snow and glacier melt of the Karakoram, Himalaya, and Hindukush mountains.

3. It is evident from research that glaciers are retreating at a faster rate in many regions of the world (Wang, Siegert et al. 2013). Similarly, climate change is affecting the glaciated locales of Pakistan.

4. The task of monitoring cryosphere dynamics is very challenging. One of the reasons is that most of the glaciers lie in remote mountainous areas and it is very difficult to perform constantly in situ observations and monitoring.
2. Study Area

1. The study area includes the upper Indus Basin in northern Pakistan. Upper Indus Basin regions comprise of the ranges of Karakoram and Hindu Kush. These greatest ranges run from west to east from Northern Pakistan to the Tibet region of China.

2. This region exhibits high topographic relief and climate change variability. Due to climate change, the snow mass balance of this glaciated region gets affected. This is a strong motivation to study snow cover trends in this region.

Figure 1: Study Area showing the location of Upper Indus Basin.
3. Methodology

1. Landsat daily snow cover data is processed to find daily snow cover in the form of percentage and area. Then monthly averages are calculated.
2. Graphs were made for monthly snow cover and average temperature.
3. Landsat data is used for land cover classification and five classes are made.
4. Snowmelt is calculated from the difference of monthly snow cover. Keeping in view that snow melting is equal to water available for irrigation and domestic use; this was compared with the vegetation class of LULC (Land Use Land Cover) classification (Javid 2014).

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**Table 1:** Scenes of Landsat data used
4. Results and Discussions

Supervised classification technique was used to classify all 5 classes for every year in the range (2004-2014). Figure 3a shows supervised classification for the year 2005 and Figure 3b shows supervise classification for the year 2007. Classification was done in ENVI by providing training data for 5 classes as vegetation, water bodies, snow, cloud, and barren land.

Figure 2: (a) Land Cover Classification Map of 2005 and (b) Land Cover Classification Map of 2007.
Figure 3: (a) Snow Area for year 2004 and (b) Comparison of Temperature and Snow Cover for year 2004
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**Table 2:** An overview of snow mass balance calculations for year 2004
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**Table 4:** Estimate of Water reserve from snow mass balance for year 2004
5. Conclusion

1. RS & GIS is an efficient and cost-effective tool for estimating and evaluating spatial-temporal changes using multi-temporal satellite imagery. Availability of the historic data having minimum errors and being free of clouds are of prime importance in the evaluation and estimation of temporal changes and establish the relationship between different land phenomena’s. Climate change would usually have detrimental consequences on the cryosphere.

2. The study has shown a very sharp view of the temperature variations in snow-covered areas. Snow and glacier melt, however, dominates the flow of the Indus River and more investigation is required to absorb glaciers in each mountainous region.

3. Supervised classification technique was used to classify all 5 classes for every year in the range (2004-2014). Classification was done in ENVI by providing training data for 5 classes as vegetation, water bodies, snow, cloud and barren land. Snow mass balance curves reveal that glaciers are regaining their mass balance after losing mass balance in middle of last decade. We got almost similar trend for all eleven years (2004-2014). Snow covers decrease with increase in temperature in June, July and August. Snow cover seems to be recovered in winter season with the start of snowfall. It can be observed that for July and August, snow cover percentage is lowest. Similar results were extracted for other 10 years too. A slide increase in temperature is in 2004 with a small decrease of snow area and large percentage of snow cover is in 2012-13 during extreme low temperature season.
6. Acknowledgment

We want to say our warmest thanks to reviewers for their constructive suggestions and comments for this paper. We also want to acknowledge the USGS and NASA for providing free remote sensing data to make this research work more easy and low costly for us. This paper is a mutual collaboration of students and faculty from Institute of Geographical Information Systems, National University of Sciences Technology, Islamabad, Department of Environmental Engineering, China University of Geosciences Wuhan, China and Wuhan University China. We are thankful to our teachers and lab staff members for their unlimited collaboration during this whole journey.
7. References

谢谢观赏
Thank You
Work Very Hard to get succeed