Temporal and spatial change analysis in Snow cover area in the Panjshir watershed, Afghanistan using MODIS data

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1. Introduction

Snow is one of the most sensitive and vital natural resources, and studying its trend is very important to understand regional climate variations. The Hindukush-Himalaya is counted as the third Polar regions due to its high concentration of snow and ice in the earth after the Arctic and Antarctic (Shrestha et al. 2015). More than half of the area of Afghanistan is situated in the Hindukush-Himalaya rugged mountainous craggy terrain (Singh et al. 2011). These mountain ranges provides major proportion of flow dominated by its snow and glaciers' melt during spring and summer months when the temperature rises. Studies suggest that global warming started affecting glaciers and seasonal snow cover and stream runoff in the Himalayan regions (Immerzeel et al. 2010). Changes in the SCA and snow water equivalence will have long term environmental implications for agriculture, water supply, groundwater recharge, water-based industries and other developments. In order to analyze and mitigate the ill-effects of snow cover changes, the scope of this study has therefore been to assess the spatial and temporal variation of snow cover with a focus on changes that have occurred over a period of (2010 - 2017) in Panjshir watershed of Afghanistan.

2. Study area

The study area is situated in the upper north of Kabul river basin which is a tributary of the Indus river system, the terrain of this watershed consists of steep mountainous valleys within the Hindukush mountain ranges (Figure 1). The total drainage area of this watershed is around 3540 km^2 and its elevation ranges from 1593 m to 5694 m which remains snow covered throughout the year. Snowfall and snow storage in this region is the lifeline for the people living in valleys and downstream areas which deliver water to most of the important irrigated lands in the basin.

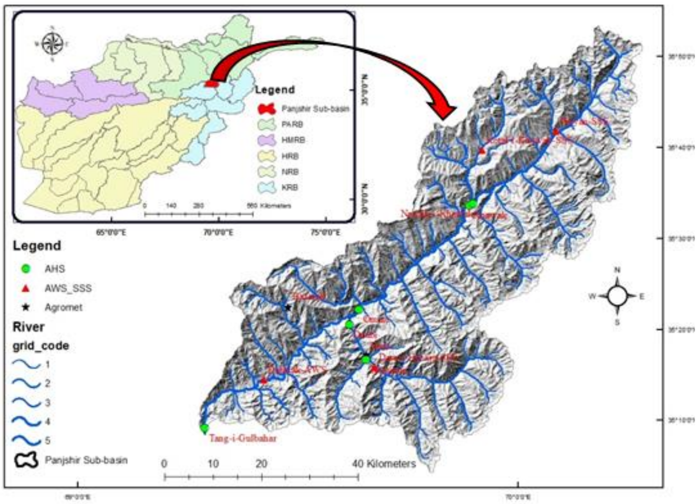

Figure 1. Location map of the study area and installed climate stations

3. Data sources

3.1. Digital elevation model

Topography is an important factor in analyzing the snow cover distribution, snow cover area (SCA) variations between the basin and topographic zonation's. For this purpose, the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) was used. The ASTER GDEM is in GeoTIFF format with geographic lat/long coordinates and a 1 arc-second (30 m) grid of elevation postings. It is referenced to the WGS84/EGM96 geoid (METI and NASA 2009). The basin's elevation range is divided into five elevation zones which were extracted from the ASTER GDEM.

3.2. Snow Cover Data

Remote sensing provides spatially and temporally snow information at various geographic levels. One of the remote sensing derived data, the Moderate Resolution Imaging Spectroradiometer remote sensing cryosphere product, has been widely used which enhances the hydrological predictions in the remote areas. The Improved MODIS snow cover product utilized for the study area is the 8-Day L3 global 500 m grid, an 8-day composite product from both Terra (MOD10A2) and Aqua (MYD10A2) sensors (Gurung et al. 2011).This gives the total maximum area of snow cover over 8 days and is generated by stacking 8 days of daily snow maps together.

Key Words: Hindukush-Himalayan, Snowmelt, Snow cover area, MODIS, DEM

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4. Snow cover area variation

We analyzed the trends considering a period of 2010 – 2017, referred as the short term SCA trend, for the entire basin and in different elevations' belt. Average monthly SCAs spanning an 8-year period were plotted, and variations within individual months were captured with maximum SCA during winter month which is peaks in February; similarly, the lowest SCA is during summer month in August (Figure 2). Inter-annual variability is important for water users like hydropower sector and farming community to understand the changes and adapt accordingly. The linear regression analysis resulted in a positive trend in annual variation, but the results were not significant because of the maximum and minimum SCA in 2015 and 2010 respectively (Figure 3). The elevation zones and the annual mean SCA in various elevation zones are shown in (Figure 5). The annual SCA was high at higher elevation zones and less in lower elevation zones. This indicates that the seasonal snow cover is mostly confined between the elevation 4000 to 5000 m and above. Accumulation (Ac) and Depletion (Dp) of seasonal snow cover varied greatly over the whole accumulation and ablation season. (Figure 6) shows the snow cover area accumulation and depletion curves during the ablation season (March-August) and snow accumulation season (September-February). The snow cover Ac and Dp curves obviously express the impact of temperature variation. A third polynomial regression curve describe for the Ac and Dp period during the year 2010 to 2017 and a high polynomial regression coefficient more than 0.9 was noticed.

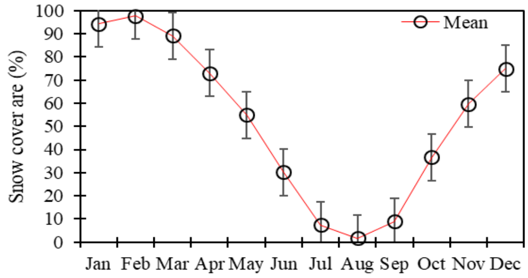

Figure 2. Monthly mean variation in SCA 2010 - 2017

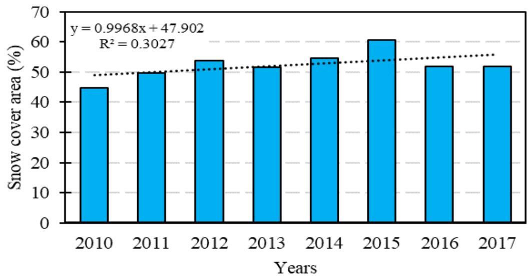

Figure 3. Average annual SCA variation 2010 - 2017

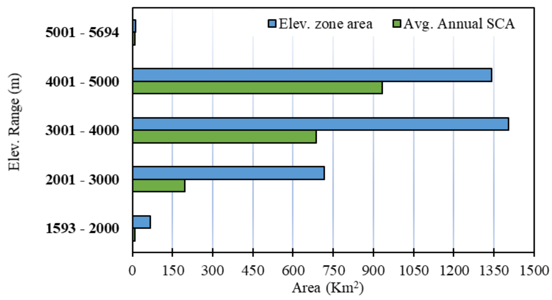

Figure 5. Average annual SCA in various elevation bands

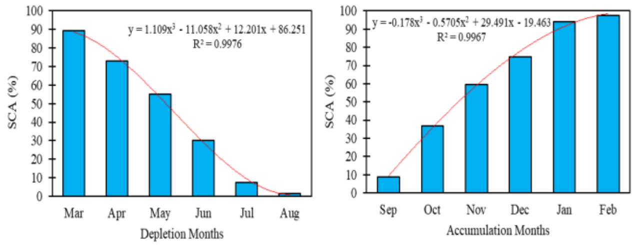

Figure 6. Mean SCA and its variability during Depletion and Accumulation Period

5. Conclusion

Snow cover area statistics of Panjshir watershed were derived from improved MODIS snow product for a period of 2010 to 2017. The annual mean SCA was found to be maximum (i.e. 60.6%) and minimum (i.e. 44.9%) in 2015 and 2010 respectively. The Dp period of snow cover starts from the early spring (i.e. in March) and ends in early September; SCA was largest in the elevation range above 4000 m. Scientific studies indicate that global warming effect on SCA needs more research to evaluate the impacts of climate change in alpine environments using long-term remotes sensing and observed data.

Acknowledgements

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