



Climate change impact on water resources and glaciers of Upper Kabul River Basins

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Abstract

In general it is obvious that glaciers are receding worldwide. This fits for Afghanistan glaciers as well, mostly the Afghanistan glaciers are spreaded in the high plateau of Pamir and Hindu Kush Mountain in north-eastern Afghanistan. More than 18% reduction of the glacier surface had been discovered in 2016 in area of Afghanistan's glaciers (ICIMOD/WRD Glacier Mapping Team, Ministry of Water and Energy of Afghanistan) On the bases of remote sensing studies. The purpose of this study is to find glaciers' changes in a year time cycle in upper Kabul River Basin by conducting mass balance measurement observations and hydro meteorological data analyses. The Pir Yakh Glacier in Panjshir province of Afghanistan has been chosen as benchmark since 2018. This glacier is under observation yearly base observation by Geo Sceince Facutly of Kabul University and Ministry or Energy and Water (MoEW) of Afghanistan . The study revealed the total accumulated mass of the glacier is 222,791.28 cubic meters w.e. and total ablated mass of the glacier is 1,759,768.70 cubic meters w.e. the overall balance of glacier mass comes with -1,536,977.42 cubic meter w.e./year in a negative rate or 3230 mm w.e. /year. There is no glacier observation from Afghanistan glaciers in the past. Access the glaciers is a challenge since the glaciers are determined in remote areas of cities and insecurity if main one.

Keywords: Climate change, water resources, glacier, Upper Kabul River Basin, Panjshir Afghanistan

1. Introduction

The economics and the livelihoods of most people living within the Hindukush- Himalayan (HKH) countries are extremely water dependent, and agriculture accounts for nearly 90% of all water withdrawals (Shrestha, 2015), Some studies suggest that the water resources in the Indus River Basin (IRB) derived from snow and ice melt contribute about 50 to 80% of the annual flow and come from the western Himalayan ranges (Jeelani, Shrestha, 2015). This dignity of the water tower the mighty Hindu Kush Mountain. The Degree Day Factor DDF values have been studied by a young afghan scholar using in the Panjshir Valley recently that is inline the time period of this study, DDF values change with elevation and the values for the low (1593–3000 m), middle (3001–3500 m) and

high (3501–5694 m) elevation zones were 0.3, 0.6 and 0.9 ($\text{cm } ^\circ\text{C}^{-1} \text{d}^{-1}$) (Abdul Haseeb Azizi1, Yoshihiro Asaoka, 2020). To calculate the DDF for Pir Yakh Glacier the exact daily air temperature is require, the lack of weather station and on the glacier to record the daily air temperature is a barrier, the Ministry of Energy and Water of Afghanistan plan to install an automatic weather station on this glacier to facilitate further researches on this era. This upper Kabul River basin study will serve as a pilot project focusing on climate change impact, including collection of meteorological and hydrological data form five available automatic weather station installed and governed by MoEW within this sub basin , as well as glacier observation data by conducting glacier mass balance measurement, analyzing and interpretation of data with modern technology and tools, this project will fulfill the development objective in Afghanistan with providing efficient and applicable reference to Ministry of Agriculture and Irrigation and livestock and Ministry of Energy and Water for future plans to find a better way to reduce the climate change and drought impact in the Kabul River Basin. The glacier contribution to the UKRB's water resources decreased from almost 8% in 2000 to 6.7% in 2016 (Caleb G. Pan, Ulrich Kamp, Munkhdavaa Munkhjargal, Sarah J. Halvorson, Avirmed Dashtseren, Michael Walther, 2019)

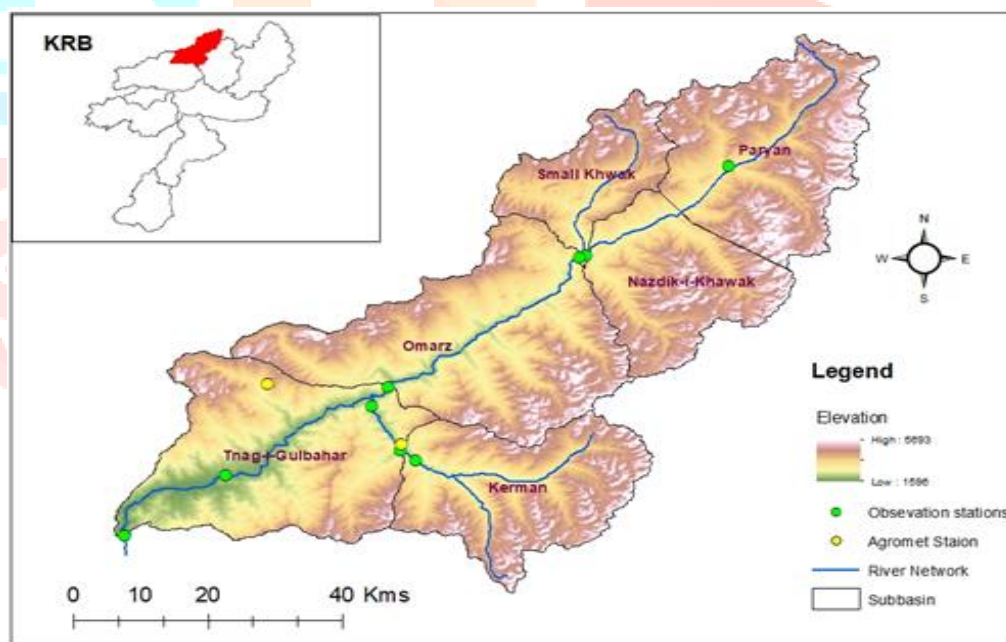


Figure 1. Panshir map & existing Hydro-meteorological stations locations, among the station only the Paryan Hydro-meteorological station is not active, the map is prepared by researcher.

2. Project Aim

The object s for this research was to study fluctuations of hydro-meteorological factors related to climate Change of Kabul river basin, and analyze their possible effects of on Panjshir valley. The analyses are based on yearly Glaciers monitoring to record the climate change impact on the glaciers.

Analyze of hydro-meteorological factors of the Kabul river basin as support will affirm and calibrate the changes, moreover lead the study to predict the relevant hazardous phenomena. besid that it willhelp the related authorities

and agencies of how to mitigate with the Water resources and their scarcity in country. Specific goal of the research is to study fluctuations of hydro-meteorological factors related to climate change of Kabul river basin and analyze the effects of climate change on the study area and find out the glacier behaviors against such changes (Flatt, Victor B 2007).

3. Methodology

3.1. Ablation measurement of glacier

Temperature, precipitation and discharge statistical have been analyzed after the data sorting/organizing, The data passed through several processes such filling the gaps, customizing according to study purpose and finally analyzing (Flatt, Victor B 2007) , (Ministry of Energy and Water Hydro-meteorological Data 2019). The series of 5 existing weather stations' recorded data have been analyzing.

Ablation measurement;- The Pir Yakh glacier is the biggest Glacier in the Panjshir province by 2.1 KM length and 0.8 KM wide, the glacier tongue starts on 4,400 M above the see level and the accumulation zone pique ends on 5,070 M above the see level, the glacier is under the observation since 2017. For the purpose of glacier observation two measurement sticks are installed on the ablation zone, with total length of 4M, the exposed portion of these sticks in the next year represent the glacier melting from its surface.

Table 1. The below table shows the characteristics of installed sticks

No	Name of stick	Elevation	Latitude	Longitude	Date installed	Remarks
1	PY 10	4500 m	E70° 10.802'	N35° 35.932'	24-08-19	
2	PY 20	4600 m	E70° 10.670'	N35° 35.852'	23-08-19	Newly installed in 2019
3	PY 30	4700 m	E 70° 10.452'	N 35° 35.045'	23-08-19	
4	PY 40	4800 m	E70° 10.165'	N35° 35.873'	23-08-19	Newly installed in 2019
5	PY 50	4890 m	E70° 10.760'	N35° 35.670'	23-08-19	Newly installed in 2019

The installation process of the ablation measurement sticks



Figure 2. Stick installation on Pir Yakh Glacier in 2019 by research team, photos by research team.

3.2. Accumulation measurement of glacier

There are small parts in the shadow of the Mir Smer Mountaintop where the zone of accumulation spreads in a narrow belt from 4880m to 4930m above the sea level; Glacier Peak ends in 4930m, however there are hanging glaciers up to 5070m.

On the accumulation zone of the Pir Yakh Glacier at the elevation of 4900m above the sea level snow pit conducted to measure the snow precipitation/accumulation by a measuring barrel diameter with Dim 10 cm with height if 55 cm, The snow density, P is determined by measuring the weight (mass), m_1 , of a snow sample of sample volume, V_1 . (Georg, Kaser, Fountain Andrew, Peter Jansson 2003) .

$$P = m_1 / V_1$$

4. Result

4.1. Glacier

4.1.1 Ablation Zone Measurement

There are 2 measurement sticks installed on the ablation zone from 2018, the first stick (PY-10) had moved 8m to northeast with ablation of 4m and second stick moved 6.5m to east with ablation of 1.8m.

The total ablation area is 588,608.00 sqm, the overall ablation form Aug 2018- Aug 2019 based on measurement is 1,759,768.70 M3. Further details in the below table

Table 2. Ablation Zone Measurement

Ablation Zone Measurement By Sticks									
No.	Name of stick	Elevation Above the see	Latitude	Longitude	reading date	Stick movement	Ablation in M	Area SM	Ablation volume in CM
1	PY 10	4500m	E 70°10.799	N 35°35.926	23-Aug-19	Fully exposed	<4	187,911.00	888,296.25
2	PY 20	4700m	E 70°10.452	N 35°36.045	24-Aug-19	10m to E	1.8	400,697.00	1,067,002.30
total volume CM									1,955,298.55
Density Kg/M3									1,759,768.70

The total accumulation area on the Pir Yakh glacier based on Landsat-8 imagery dated Sep 02. 2019 is 395,020.00 square meter while the thickness is determined by site visit 1.2 meter, the measuring barrel diameter is 10 cm with height if 55 cm. 3 samples were collected in 55, 55 and 10 cm length and weights of 2300, 1870, 345gr accordingly, further details in the following table.

4.1.2 Accumulation Zone Measurement

Table 3. Accumulation Zone Measurement by Snow Pit

Accumulation Zone Measurement by Snow Pit									
Sample No.	Sample Height cm	D cm	□	R ² cm	S cm	M c ³	W gr	P=M/V	
1	55	10	3.14	25	78.5	4317.5	2300	0.53	
2	55	10	3.14	25	78.5	4317.5	1870	0.43	
3	10	10	3.14	25	78.5	785	345	0.44	
Average of 3 Sample KG/M3									0.47
Snow Covered Area measurement									
No.	Total Area SM	Thickness M	volume M ³		Density Kg/M ³ w.e.				
1	395,020.00	1.20	474,024.00		222,791.28				

Since the total accumulated mass is 474,024.00s cubic meters and total ablated mass is 1,955,298.56 cubic meters the overall balance of glacier mass comes with -1,707,752.69 cubic meter water equivalent (w.e.) per year negative as described in below table.

4.1.3 Glacier Mass Balance

Table 4. Glacier Mass Balance

Glacier Mass Balance		
Area	Kg w.e.	M3
Accumulation of the Glacier	222,791.28	247,545.87
Ablation of the Glacier	1,759,768.70	1,955,298.56
Balance	-1,536,977.42	(1,707,752.69)

Map of the glacier surface area calculation by accumulation and ablation zones (Land Viewer 2019)

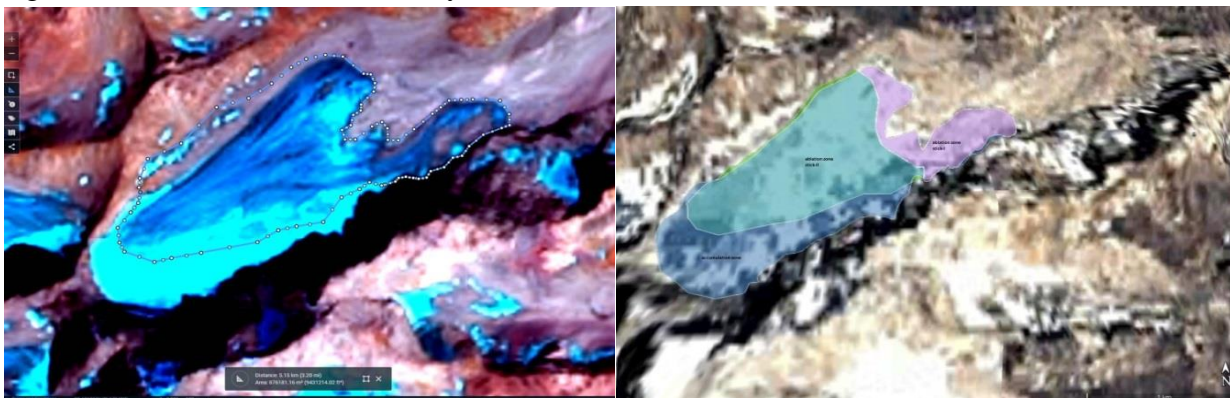


Figure 3. The accumulation and ablation areas calculation by elevation determination, the area calculations are done by Land Viewer using Landsat-8 satellite imagery.



Figure 4. The image shows melting rate in PY-20 stick during one year on the ablation zone, the stick are made of PPR pipe with length of 4 meters. Photo by research team.

4.2 Climate Factors

There are 6 automatic weather station installed by Ministry of Energy and Water Hydro-meteorological Data 2019 in the Panjshir Valley as Tang-i-Gulbahar, Doabi, Keraman, Omarz, Nazdik-i-Khawak, Shamal Khawak, and Paryan, the paryan automatic weather station is inactive since 2015, therefore the available date of the rest 5 stations are analyzed as follow.

4.2.1 Temperature analyses

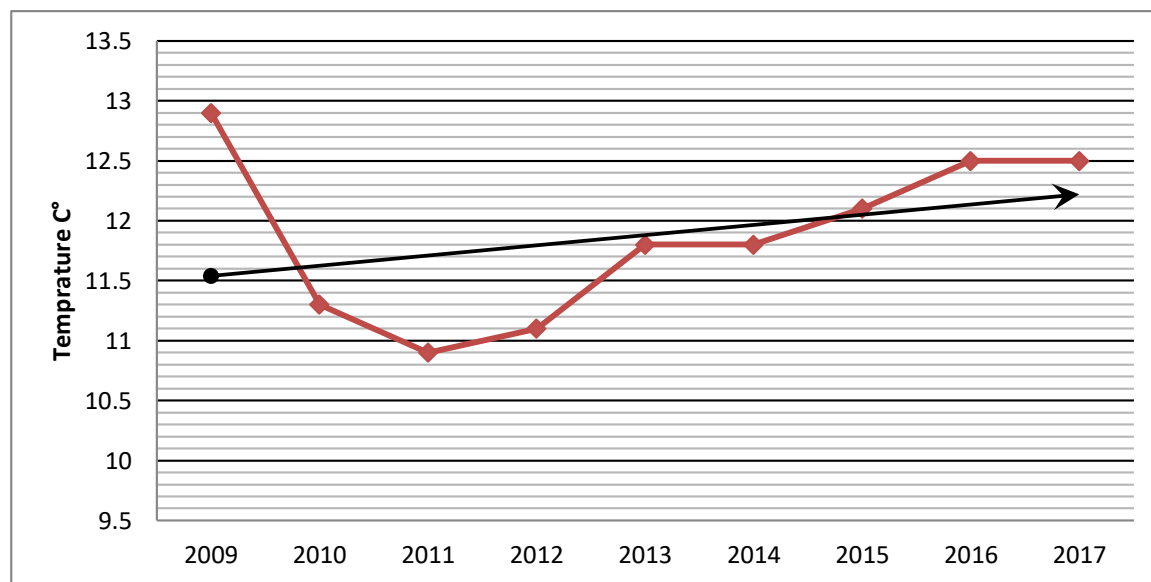


Figure 5. Average of annual temperature data of 5 available hydro-meteorological stations in research area (Panjshir province) from 2009-2017.

The temperature data is available from the period of 2009 to 2017 within the research area. The processed data reveals a positive trend in the Temperature whereas noted a 0.6°C increase, such an increase certainly has positive impact on glacier melting and negative impact on their mass that consequently fed the streams and increases the discharge.

4.2.2 Precipitation analyses

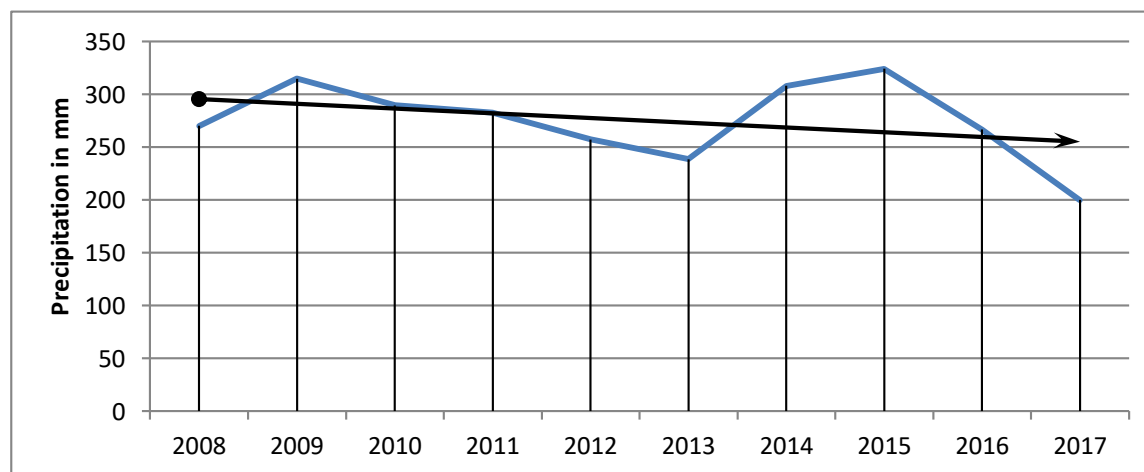


Figure 6. Average of recorded precipitation from 5 hydro-meteorological stations in study area.

The trend of the precipitation discloses a slide decrease in the rainfall trend within the period of 2008 to 2017 where the data is available; the result affirms the changing of precipitation pattern in the region. Considering the precipitation pattern in the past decade there will be less precipitation in the future.

4.2.3 Discharge analyses

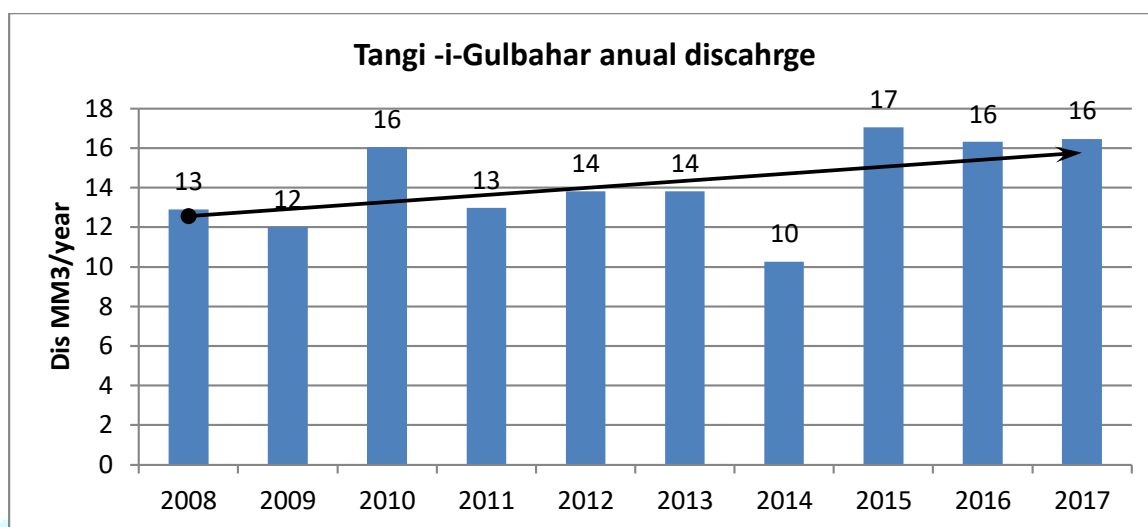


Figure 7. Annual Discharge in Panjshir province

The Tangi –i-Gulbahar station is the last and outlet point for the whole Panjshir valley sub of Kabul River basin and the most reliable point of the discharge measurement, the Tang-i-Gulbahar station share the scenario of increasing of discharge at outlet point.

5 Discussion

The result of temperature increase in region is melt acceleration of the snow and glaciers that consequently lead to more discharge. On the other hand the temperature increase means high evapotranspiration and more water demand in the region. The data disclose the changes occurred within the area and period of the study. While the precipitation decreased since 2008 to 2017 in the same period of time frame discharge increased, the extra discharge supplied by glaciers and losing their mass in this sub-basin, the same story applies to the region.

Since the total accumulated mass of the glacier is 222,791.28 cubic meters w.e. and total ablated mass of the glacier is 1,759,768.70 cubic meters w.e. the overall balance of glacier mass comes with -1,536,977.42 cubic meter w.e./year in a negative rate or 3230 mm w.e. /year. The result is in a bigger scale but in line in with central Asian glacier mass balance report published as Global Glacier Change Bulletin (WGMS Bulletin, No. 2, 2017) the publication reveal a negative balance trend in the history of observation, the Tuyuksu valley glacier in Tien Shan mountain Kazakhstan share quite similarities with studied glacier under this topic. The Tuyuksu glacier reports discloses an average of 750mm water equivalent/year within the period of 2005-2015 where data is available (WGMS Bulletin, No. 2, 2017).

6 Conclusion

There is not precise inventory of the glaciers in Afghanistan particularly in Panjshir Valley where this is study implemented. A negative balance of glacier mass (-1,536,977.42) cubic meter w.e. per year is demonstrator of the single glacier of vast region. To investigate the exact role and percentage of water supply by glaciers in Panshir River, an inclusive study of whole valley's glaciers in a loge period of is required that is applicable at the moment due to lack of data. However this study could be compared with remote sensing studies to simulation the climate

change scenario and its impact on water resources and glacier all over the country.

In summary the climate change affected and increased the temperature, decreased of rainfall and caused faster melting of glaciers in the south Hindu Kush plateau. In the short term there would be plenty of water in the region due to glaciers mass loss but in long term there would be lack of water in warm seasons due glaciers disappearing.

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