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HYDROLOGIC IMPACT OF CLIMATE CHANGE ON PLANNED HYDRO DAMS IN SWAT RIVER BASIN

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By

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Abstract.

Abstract. In Pakistan, there exists already a rather high awareness on the threats that climate change might pose on water resources. Khyber Pakhtunkhwa province of Pakistan in particular Swat basin has experienced several disastrous floods during recent past. There is large potential of hydropower development in the basin and many projects are planned to be constructed in the coming years. Mohmand Dam, largest multipurpose storage dam in Swat basin is being constructed in the basin. Therefore, it is pertinent to investigate the impact of climate change in this basin. A hydrological model Soil and Water Assessment Tool (SWAT) is coupled with regional circulation models (RCMs) to assess the potential water resources and other water budget components of the future under the changing climate. The hydrologic model was calibrated and validated against the measured stream flow data using observed weather data and inputs from the global SWAT database. The SWAT and RCM performed well, especially on an annual basis. Climate change impacts on hydrology were then quantified by driving SWAT with the existing and future climate scenarios. Results of analysis depict an increase in temperature in the future, causing early snowmelt and shifting peak discharge from summer to spring. An overall increase of 1.3 to 2.2 OC is projected to increase in 2011-2099 under RCP 4.5 and 2.3 to 3.75oC under RCP 8.5 (RCP = Representative Concentration Pathway). Future precipitation is likely to change from 16% to 23% under RCP 4.5 and -20% to 13.8% under RCP 8.5.

The overall discharge in the Swat river basin is expected to rise in future, with higher rate of increase from November to May with respect to the baseline period whereas it is expected to decrease from June to October. The change in future precipitation simulated by the RCM produced 18% increase in surface runoff, and 24% decrease in base flow and 20% increase in evapotranspiration in the Swat River Basin on an annual basis.

Keywords. Climate change; stream flows; water budget; Swat river basin; Pakistan

1. Introduction

After the industrialization started in the seventeenth century, a new era of development started that was attained at the price of excessive greenhouse gas emissions. The energy balance of climate system of the Earth has changed significantly. Geographic location, dense population, and poverty have made countries of South Asia, including Pakistan, highly vulnerable to climate change. Pakistan experienced damages worth an estimated US $ 10 billion as a result of the floods of 2010 (ADB, 2010). IFPRI (IFPRI = International Food Policy Research Institute) predicts that global warming will also decrease agricultural production by 16 percent by the year 2020 with developing countries suffering much more than the developed ones. Due to low technological and scientific base of agriculture and lack of adequate monitoring systems that predict the occurrence of extreme weather events in a timely manner in Pakistan, there is low

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capacity to adapt to changes related to climate change. In July 2010 Pakistan was hit by the worst floods in its history. Twenty million people across an area of over 100,000 km2 were affected, and there was widespread damage to property and infrastructure. The flood situation in the study area was also very critical.

The Swat catchment received historic extreme rainfalls which created high flood flows in the Swat and Kabul Rivers. Instantaneous flood peaks of 9,900 m3/s, 4,200 m3/s, 1,190 m3/s and 12,700 m3/s respectively were recorded at Munda Headworks, Warsak dam, Jindi Nullah and Nowshera water gauge stations (Figure 1). The situation was further worsened due to the back water effects of Indus River, which was also flowing very high at that time. As a result, the study area was subject to severe inundation, causing many casualties and countless damages to the standing crops, houses, roads, hydraulic structures, etc. Mohmand Dam Hydropower Project (MDHP) is proposed on the Swat River about 37 km north of Peshawar in Khyber Pakhtunkhwa (KPK) Province of Pakistan. The dam site is located about 5 km upstream from the existing Munda weir, which will continue to function. The dam type will be a Concrete Face Rockfill Dam (CFRD), about 213m high with a crest length of only 760m (MDC, 2017).

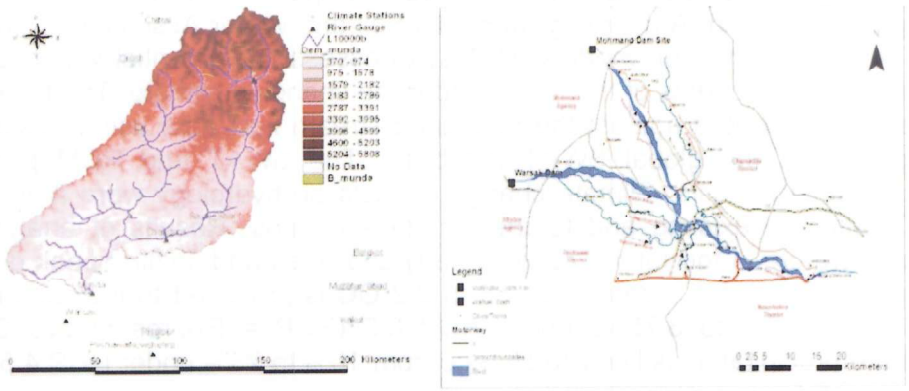


Figure-1: Physiography Features of the Swat watershed

2. Climate change assessment and forecast

Climate Change is a natural phenomenon that has happened on earth throughout its existence. During ancient times the climate has been warmer as well as cooler as compared to today. Climate Change is happening on a global scale with locally varying magnitude and is driven by physical processes. During the last century, for which detailed climate observations are available, an increasing trend has been recorded, indicating that we are in a warming phase. Next to natural drivers the warming is driven by anthropogenic activities, mainly the combustion of fossil fuels and respective release of "greenhouse" gases into the atmosphere. The "greenhouse" gases are promoting atmospheric warming by reducing thermal losses into space.

Most visible impacts of climate change are increasing variability in rainfall leading to more extreme events – floods and droughts, as well as increasing temperatures with respective impacts on evapotranspiration and respective agricultural impacts as well as impacts on snow and ice covers resulting in glacier melt, changes in the snow line and respective freshwater availability changes in space and time in many regions. Glacial retreat caused by climate change may initially lead to excess water. However, with glacier depletion, this may result in dramatic decreases in river flow, potentially 30% to 40% in 100 years (Briscoe & Qamar, 2006).

Climate change projections for the foreseen location of the Project are constructed using Coupled Model Intercomparison Project Phase 5 (CMIP5) and across two of the four greenhouse gas emissions scenarios known as Representative Concentration Pathways

(RCPs). The CMIP5 RCM runs were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The dataset includes downscaled projections for RCP 4.5 and RCP 8.5 from the models and scenarios for which daily scenarios were produced and distributed under CMIP5. Each of the climate projections includes daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100.

2.1 Analysis of temperature and precipitation

Higher temperatures could increase evaporation leading to drier soils. Moreover, the shift in rainfall patterns will reduce water availability in the winter season. As a result of climate change, rainfall events are expected to occur more frequently in the future. In addition to the potential for more frequent flooding, this shift in the characteristics of rainfall events is also expected to increase runoff and associated pollutants, increase soil erosion, impact the vegetation cover which provides soil stability as well as impact the waterways and biodiversity.

The projected future climate is subjected to considerable uncertainty. Therefore, a combination of three RCMs with two emission scenarios is taken in this study, to obtain a range of probable future climate. RCP 4.5 and RCP 8.5 are taken to obtain future climate data corresponding low and high bound of uncertainty range.

Higher annual mean temperature are projected within the project area. Table 1 shows the change in mean annual temperature within the Swat river basin for the current climate for the 2020s, 2050s and 2080s timeframes using 3 RCMs for RCP 4.5 and 8.5.

Table-1: Average increase in temperature (°C) with respect to baseline temperature in Swat region under 3 RCMs

	RCMs	Average temperature increase under RCP 4.5 (°C)	Average temperature increase under RCP 8.5 (°C)
2020s	REMO	1.08	2.30
	CNRM	0.60	0.65
	MPI	0.90	1.15
2050s	REMO	2.40	3.30
	CNRM	1.20	1.95
	MPI	1.70	2.85
2080s	REMO	3.20	5.65
	CNRM	2.05	4.30
	MPI	2.25	5.60

The change in precipitation with respect to baseline precipitation, shown in Figure 2, suggest a rise in future precipitation by two RCMs and decrease in future precipitation by one RCM. RCP 4.5 is showing higher increase in the future precipitation than the RCP 8.5 scenario. The overall results indicate up to -28%(decrease) to 34%(increase) in the future precipitation. All the three RCMs show a percentage change of more than 10% in the precipitation with respect to the baseline precipitation.

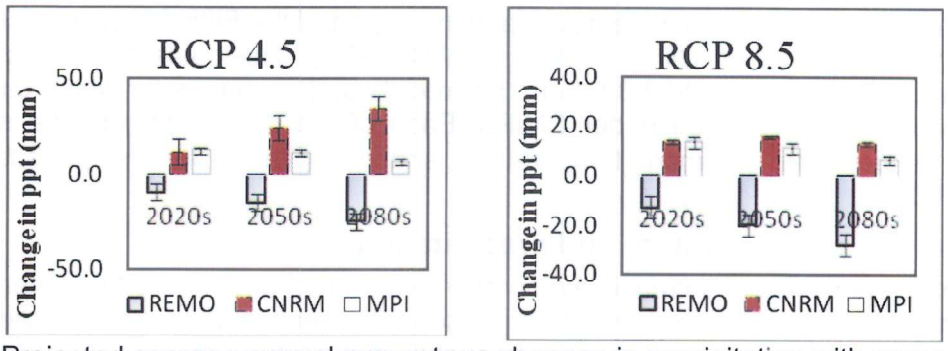


Figure-2: Projected average annual percentage changes in precipitation with respect to the baseline period under RCPs 4.5&8.5 in Swat river basin

3. Impact of Climate Change

Changes in temperature and precipitation have an impact on vegetation and resilience against erosion. The climate change assessment indicated a significant increase of temperature, which has both a positive and a negative effect:

3.1 Impact of climate change on stream flows

The monthly average flows of the three time periods 2020s, 2050s and 2080s is plotted for one RCM under RCP scenarios 4.5 and 8.5 (Figure 3) to examine the temporal shifting of the flows. It can be seen from the figure that the results of future projection of streamflows show two peaks of flow, one in March and one in May. The peak in the March may be as a result of snowfall an immediate melting of the snow. The peak in the May might be due to increased rainfall in spring and the melting of glaciers. The flows from July to October is projected to decrease under all scenarios. This might be attributed to early snowmelt, more temperature and high evaporation losses. Increase in discharge in winter (Dec-Feb) and early spring (March-May) can also be seen. The discharge is more in the spring (Mar-May) but the change in discharge is more in summer from June to August (negative change).

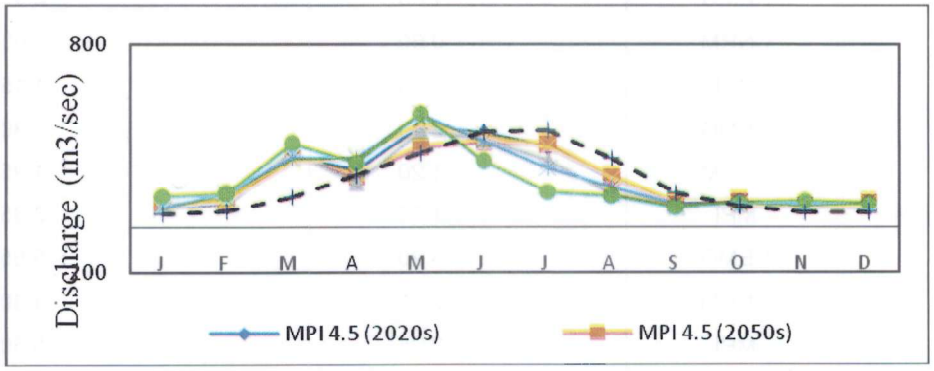


Figure-3: Projected monthly average discharge (%) relative to baseline period

3.2 Relationship between precipitation and stream flows

Discharge is mainly driven by rainfall and snowmelt. The snowmelt depends on the temperature patterns. The relationship between percentage change in the discharge and percentage change in precipitation by the three RCMs under the RCP 4.5 and 8.5 scenarios for the three time slices (2020s, 2050s and 2080s) is given in the Figure 4. The figure shows that there is a direct relation between precipitation and runoff.

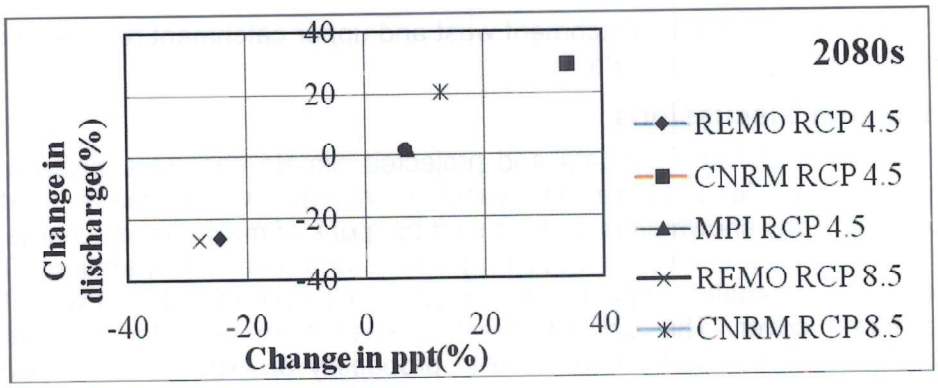


Figure-4: Relationship between percentage change in precipitation and percentage change in discharge (w.r.t baseline data) in Swat river basin.

The check for water balance for annual average flows for the baseline period was done using the observed climatic data. The processes which contribute the most to the hydrology of an area, i.e., precipitation, surface runoff, baseflow and evapotranspiration were considered and compared for the future scenarios to see the impact of climate change on the distribution of water in the watershed in the future. The results indicate that for the existing climate, 37% of the precipitation contributes to surface runoff, 40% contributes to the baseflow, 19.6% goes as evapotranspiration and the rest goes as deep aquifer recharge, sublimation and other losses. Simulation of annual average water balance for the future scenarios show that more percentage of precipitation is going to be converted to surface runoff in the future and baseflow is projected to decrease in percentage as shown in Figure 5.

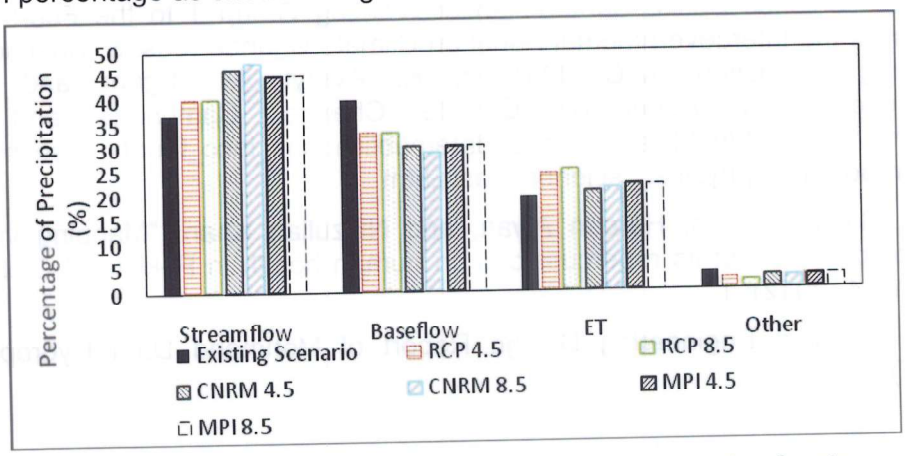


Figure-5: Percentage of precipitation converted to components of water cycle for future climate scenarios

3.3 Impact of climate change on extreme flood events

The available precipitation projections deliver only monthly data on rainfall and no daily figures. This makes predictions on future floods difficult, as the planned rainfall runoff model (which would resample monthly data into daily data) could not be completed during the time of the study. However, the following quantitative statements are possible: Floods in spring will become less. In the past, spring floods were caused by heavy rains during the melting process. Although the melting may be accelerated in future, extreme rainfall events during that period will become less. Floods during monsoon will increase, as indicated by the increase of extreme precipitation months during monsoon in the irrigation zone and the middle catchment east. However, it must be mentioned here, that the phenomenon causing the flood in year 2010 (where the complete

catchment, particularly the middle catchment west and upper catchment received heavy rainfall) are not indicated by the projected data.

4. Results and Discussions

Long term analysis of stream flow data and projected climate change analysis indicates that projected change in temperature in summer month will increase snowmelt and evapotranspiration. Early snowmelt is likely to shift the peak of maximum discharge from July to March which will require a change in cropping patterns and reservoir operations. The increase in streamflow will have negative impact on the vegetation in un irrigated area when they lack the protection of forest cover. The biggest threat is seen from projected increase in rainfall especially in monsoon months with increase in probability of extreme rainfall events, as the main inflow of sediments take place during rather short periods of high floods. The frequent extreme rainfall events due to climate change in the basin will increase in the probability of landslides and mud flows and it is likely that this will fall in the reservoir area (particular when there is no protection by natural vegetation).

5. References

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