Ensemble GCMs Climate Change Projections for Kabul River Basin, Afghanistan under Representative Concentration Pathways

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Abstract

The aim of study is to project the future climate of the Kabul River Basin of Afghanistan under the recent IPCC AR5 data set. The SimCLIM model was applied for climate modeling. A multi- model ensemble was used for best representation of future climate under the selected RCP4.5 and 8.5 pathways with time span of 2021-2040 (2030s), 2051-2070 (2060s) and 2081-2100 (2090s) with respect to baseline of 1961-2010. The output of multi-model ensemble climate modeling illustrated a considerable change in temperature and precipitation of the basin. The potential seasonal change of Tmax under RCP 4.5 and 8.5 pathways demonstrated peek rise in the winter season and lowest increases in the summer months, the change not exceed from 4.49˚C in winter and 3.96˚C in the summer by end of the century. In addition, under both pathways RCP4.5 and 8.5 the future Tmin depicted high rise at winter and lowest increase at the spring months, under the high emission scenario RCP8.5 the Tmin projected to increase by 4.53˚C and 3.49˚C at winter and spring respectively by the end of this century. However, the overall multi-model ensemble results of future seasonal precipitation pattern showed both downtrend and upward trend in spring and summer at all three periods, under RCP 8.5 the percentage of downtrend and upward projected (-5.02%) in autumn and (+1.55%) in winter by end of the century with respect to baseline, under this pathway the overall annual precipitation pattern simulated to decrease (-2.18%) by end this century.
Keywords- GCMs, RCPs, Climate change, ensemble, Kabul River Basin

I. INTRODUCTION

Global population are increasing, this associated with industrial development and urbanization over the globe. The human activities intensifying production of atmospheric greenhouse gases. Now we are reaching to over 400ppm of CO2 on the earth's atmosphere. [1]. The ongoing emission of CO2 leads global warming, the global surface temperature increased by 0.74˚C in twentieth century and 0.85 since 1880, the significant warming happened since industrial development with the successive warming in last decade [2,3]

The Paris climate conference (COP21 in 30 Nov to 13 Dec, 2015), started negotiation to achieve a legally mandatory worldwide climate agreement to keep global temperature warming since 1800 well below 2.0C by 2100. The global financial support of 100 billion USD per year proposed by developed countries for investing on carbon dioxide reduction solutions [4,5]. All participated countries agreed to reduce the carbon dioxide emission but the both developed and developing countries not interested to commit the reduction polices for itself [6]. However, the Marrakesh climate conference (COP22, 7-18 Nov 2016) the parties reaffirms their commitment to implementing the Paris Agreement and called on all non-state actors to join us for immediate and ambitious action and mobilization, building on their important achievements. A group of climate valuable forum involved of 48 developing countries, declared their intention to switch to 100 % renewable energy between 2030 and 2050. Canada, Germany, Mexico, and the USA laid out strategies for decarbonizing their economies by 2050, however, the major obstacle to reduce emissions, for developing counties is lack of financial investment to design and implanting effective decarbonization policies to have climate friendly development [7].

Climate change is a change in state or property of climate parameters such as temperature, precipitation or extreme climate indices. However, change in quantity of temperature and precipitation may lead drought and flooding or may affect both the long-term availability and the short-term variability of water resources in many regions [8]. The climate change will change the world of the present situation of the hydrologic cycle, and cause the redistribution of water resources in time and space [9].

In context of Afghanistan, where the rural community relaying directly to natural resources which make them vulnerable into negative impacts global climate change. More than 80 per cent of the country's water resources have their origin in the

Hindukush mountain ranges which function as a natural storage of water in form of snow during winter and thus support perennial flow in all major rivers by snow melt during summer. Recent estimates indicate that the country has 75 billion cubic meters (BCM) of potential water resources of which 55-57 BCM is surface water and around the 18-20 BCM is groundwater resources [10]. The average renewable water availability in Afghanistan is about 2280m3/year per capita, but this strongly vary in temporal and spatial distribution of water within the basin as well as country level [11].

The Kabul River Basin covers 12 percent of national land of the country and total water flow is about 22 BMC which is 26 percent of total annual water flow of Afghanistan [12]. However, this river has many irrigation and hydropower dam constructed on this river basin. Therefore, climate change is big problem for local communities' economy and development of Afghanistan. Hence the Kabul Basin plays major role socio-economic development of country. One fourth population of the country living within this basin. Additionally, Kabul populated city the capital of country located within this basin. Obviously, water demand for different use sectors are increasing by growth of population, urban development, food production and industrial development.

The high dependency on agriculture sector and natural resources, the low of water management policies, options and lack of dam, storage infrastructure and ongoing land degradation in Afghanistan particularly sensitive to the effects severe floods and drought. On the other hand, Population growth, economic development and improving of life style will be the main drivers of water shortage in coming decades. Parallel with economic growth, the demand for water for domestic uses, agriculture and industry will increase. On the top of these drivers the climate change is major challenge for environment and water resources of the Kabul river basin as well as country level. To assess the current climatology of Kabul River Basin and future temperature and precipitation required to use the global supplementary dataset and Global Circulation Model (GCM) outputs. The main objective of this paper was; translated GCMs outputs into station points in basin level; to generate a multi-model ensemble climate change projection under RCP 4.5 and 8.5 pathways and; Assess the potential change of temperature and precipitation over Kabul River Basin based on CMIP5 projected climate change.

II. Material and Methodology

A. Area of the Study

Kabul River Basin located in eastern part of Afghanistan. The basin is trans-boundary river that is share between Afghanistan and Pakistan. The basin located in the eastern part of Afghanistan and some parts of Pakistan. It lies between 33.8º- 36.3º N latitudes and 67.8º-71.5º E longitudes as shown in fig.1 with the drainage area of 53832.8 km2. This basin covers 10 provinces of the country, including Kabul capital located in this drainage area. Kabul city is the most populated city within the country. However, growth of population may need more water for drinking, food production as well as industrial development issues.

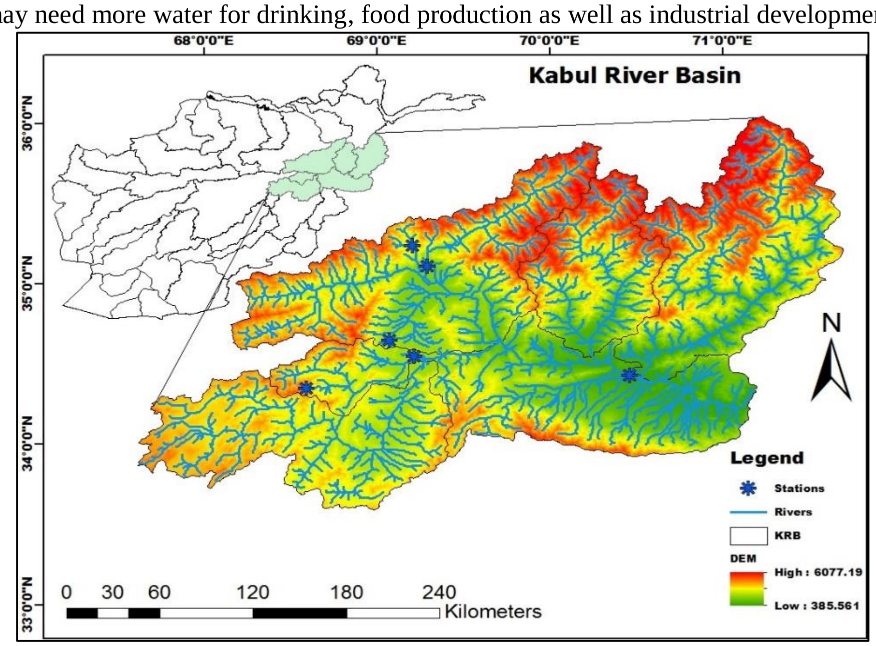

Fig. 1: Location Map of the Study Area

The Kabul river basin is divided into five distinct watersheds [12]; 1- Kabul watershed which is include of Kabul city, Kabul river stream starts from Paghman mountain and cross the city through the Mahipar area and then the Logar stream joins to the Kabul river, 2-the Maidan-Logar - Kabul catchment that drain from Maidan to Logar and Kabul city, 3- the Ghorband- Panjshir watershed contain three tributaries such as, Ghorband, Salang and Panjshir rivers. However, these two branch are joining at the Shukhi area of make greater Kabul River, 4- Alishang and Alinigar watershed which is contain Alishang and Alinigar rivers and joins at Surobi area to the Kabul river, 5- Kunar watershed which is share watershed with Pakistan. Kunar River originate from.

Chatral valley of Pakistan and entering of the Kunar province of Afghanistan flowing until Darunta area of Jalalabad province. Finally, the river pass the border throughout the Pakistan territory.

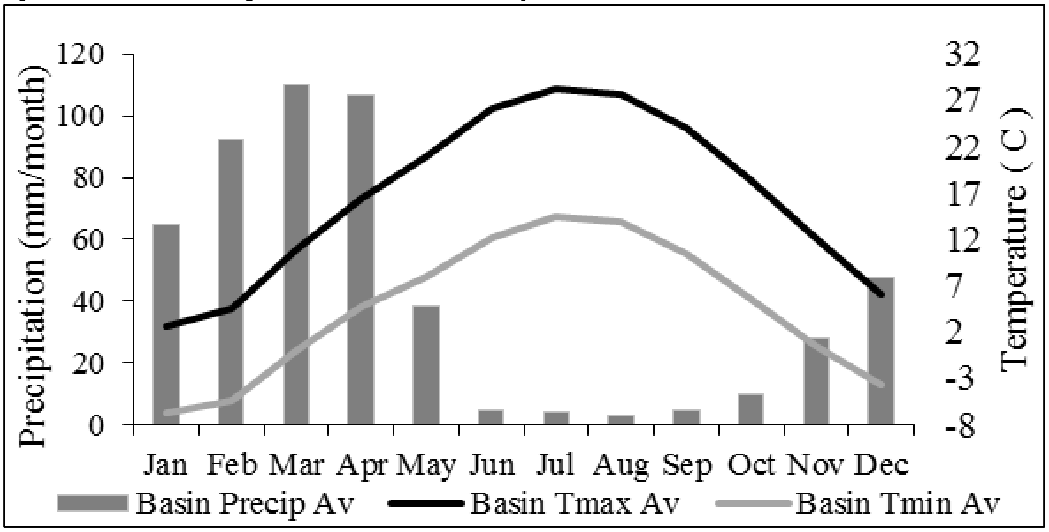

Fig. 2: Average Monthly Temperature and Precipitation in Kabul River Basin

Analysis of average monthly temperature depicted that July is warmest month and January is coldest months with range of 28.22 ˚C and -6.62˚C respectively at the entire of the year. In the other word, the from seasonal perspective the summer month's experience hot and winter months are coldest time at the whole basin. In addition, distribution of monthly precipitation of Kabul River Basin illustrated in the fig.2. Simply, the average monthly statistic of precipitation shows highest values at months of spring and lowest values at summer months. For example, the average precipitation at the month March recorded 110 mm per month and the lowest record of precipitation at August 3.23 mm per month. Moreover, the higher elevation receives more precipitation rather than lower area of the basin.

B. Dataset of the study

The monthly temperature and precipitation time series of 6 meteorological stations were collected from Afghanistan Meteorological Authority (AMA) [13]. There was big missing in observed data records. Because during the civil war in Afghanistan there was no any records in the weather stations. The collected the observed data recorded from 1961-1978 and 2003-2010 time periods. The detail information about the weather station are listed in the table.1a, and the geographic location of stations mentioned too. In addition, supplementary data for filing the gaps were downloaded from Climate Research Unit (CRU) University of East Anglia. The climate research unit constructed high spatial resolution at the 0.5˚x0.5˚ grids degree for the globe with period of Jan. 1901 - Dec. 2012 without the future scenarios [14]. Afterwards, the data format visualized in (x,y) coordinates by using ArcGIS10.1 which is the grid data of (x,y) coordinates matches with the each location of observed stations.

Table 1: The Collected Data for Current Study

Observed dataset from Afghanistan						
Stations	*Lat(D)*	*Long(D)*	*Alt (m)*	*past*	*new record*	*Total*
Jabulsaraj	*35.11*	*69.29*	*1630*	*1962-1978*	*2003-2013*	*26*
Kabul	*34.91*	*63.42*	*1791*	*1961-1978*	*2003-2013*	*28*
Karizmir	*34.91*	*63.07*	*1905*	*1961-1977*	*2003-2013*	*27*
Paghman	*32.21*	*66.97*	*2114*	*1967-1977*	*2003-2013*	*20*
Salang South	*45.324*	*69.02*	*3172*	*1962-1977*	*-*	*18*
Jalalabad	*34.43*	*70.46*	*580*	*-*	*2003-2012*	*10*
Global datasets						
Name	*Grid resolution*		*Source institute*			
	Lat(D)	*Long(D)*			*source link*	
CRU	*0.5*	*0.5*	*University of East Anglia*		*http://www.cgiar-csi.org/data*	
GCMs dataset						
Name	*Grid Resolution*		*Country*	*Developer/ Research Institute*	*Pathways*	
	Lat(D)	*Long(D)*			*RCP4.5*	*RCP8.5*
BCC-CSM1-1	*2.81*	*2.81*	*China*	*Beijing Climate center*	√	√
CanESM2	*2.81*	*2.81*	*Canada*	*Canada Center for Climate modeling & Analysis*	√	√
CSIRO-MK3-6-0	*1.87*	*1.86*	*Australia*	*Commonwealth Scientific & Industrial Research Organization*	√	√
GFDL-CM3	*2*	*2.5*	*USA*	*Geophysical Dynamic Fluid Lab*	√	√

CCSM4	0.93	1.25	USA	National Center for Atmospheric Research	√	√
IPSL-CM5A-MR	1.3	2.5	France	Institute Pierre-Simon Laplace	√	√
MIROC5	1.41	1.41	Japan	Atmosphere and Ocean Research Institute	√	√
MIROC-ESM	2.81	2.81	Japan	Atmosphere and Ocean Research Institute	√	√
MPI-ESM-LR	1.9	1.9	Germany	Max Plank Institute for Meteorology	√	√
MRI-CGCM3	2.81	2.81	Japan	Meteorological Research Institute	√	√

Digital elevation model (DEM) map represent the elevation of study area was downloaded from USGS public geoportal database with 90-meter resolution [15]. The DEM map of the study area clipped by ArcGIS 10.1 Clipping tool. DEM shows range of elevation between 6078.94 to 307.5 above the mean sea level figure1.

In addition, for future projection new data set of CMIP5 of IPCC fifth assessment used table 1b. The Representative Concentration Pathways (RCPs), stands on; Representative signifies that each trajectory provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics [16]. The Concentration instead of emissions also emphasizes that concentration of the greenhouse gases and chemically active gases, as well as forests and land use change used as the primary input to climate models [17]. The term Pathway stands for trajectory taken over time to reach that outcome based on level of greenhouse gases concentration [16]. There are four scenarios; RCP2.6, RCP4.5, RCP6.0 and RCP8.5 which is represent range of radiative forcing 2.6 W/m2, 4.5 W/m2, 6W/m2 and 8.5W/m2 by 2100. Out of four scenarios, the RCP4.5 and RCP8.5 was used; the RCP4.5 is a stabilization scenario where total radiative forcing is stabilized before 2100 by employing a range of technologies and strategies for reducing greenhouse gas emissions, the RCP8.5 is characterized by increasing greenhouse gas emissions over time representative of scenarios and leading to high greenhouse gas concentration levels [16, 17].

C. Simple Climate Model (SimCLIM)

The SmiCLIM model was applied for future climate projection. In this model the climatic data can be divided into two periods as baseline and future climate change periods. During constructing of future scenario, SimCLIM model follows IPCC, Fifth Assessment Report. However, the future changes are representing climate for the year of interest until 2100 which defined by user [18, 19]. In SimCLIM model site scenario generation follows this formula:

Future temp = present temp + (MAGICC value* standardized GCM pattern of temp change in ˚C)

Future precip = present precip + (MAGICC value* standardized GCM pattern precip change in %)

D. Ensemble GCMs Approach under RCPs

There are many Global Circulation Model which project future temperature and precipitation at globe or regional level. The GCMs criteria is based performance of its vintage, resolution, validity and representation of outputs with new knowledge and feedbacks which is widely used [20]. However, there are some uncertainties such formulating of climate variables, sensitivity of temperature and precipitation due to modeling process, concentration of greenhouse gases, scenario generation uncertainty due to radiative forcing [21]. Hence, with consideration of all aspects, scientific community argued for doing comprehensive impact analysis upon different development sectors, it would be best to transform the single GCMs outputs into averaged as ensemble format which is provide robust estimate of the climate and possible change. Finally, multi-model ensemble approach is used which is reliable and superior to single model scenario [22, 23]. In this study, a total 10 GCMs ensemble have been selected based on the simulation of surface air temperature and precipitation under RCP4.5 and 8.5 scenarios.

RCP	Description	Developed organization
RCP2.6	Its radiative forcing level first reaches a value around 3.1 W/m2 mid-century, returning to 2.6 W/m2 by 2100.	IMAGE modelling team of the Netherlands Environmental Assessment Agency
RCP4.5	A stabilization scenario where total radiative forcing is stabilized before 2100 by employing a range of technologies and strategies for reducing of emissions.	MiniCAM modelling team of Pacific Northwest National Laboratory’s Joint Global Change Research Institute
RCP6.0	A stabilization scenario, total radiative forcing is stabilized after 2100 without overshoot by employing a range of technologies and strategies for reducing GHGs emissions.	AIM modelling team at the National Institute for Environmental Studies), Japan.
RCP8.5	It is characterized by increasing greenhouse gas emissions over time, in the literature leading to high greenhouse gas concentration levels.	MESSAGE modelling team of International Institute for Applied Systems Analysis (IIASA), Austria.

III. RESULTS AND DISCUSSION

In this study, the period of 1961-2010 has been used as the climatological baseline which important for adjusting and construction of future climate projection. The GCMs simulates or construct a scenario based on averaged observation period. the difference between simulated temperature and the ratio of projected precipitation from the observed baseline are known change condition. To examine the potential change in monthly, seasonal and annual of temperature (Tmax and Tmin) and precipitation in the Kabul River Basin, using the multi-model for the future period of 2021-2100 with refracted to 2961-2010.

A. Analysis of Temperature

The current study is focuses on the temperature and precipitation as two important parameters of future climate. The future projection carried out for three-time series such (2021-2040), (2051-2070) and (2081-2100) and here addressed early as 2030s, mid as 2060s and late as 2090s projection respectively. A 50-year (1961-2010) time scale used for baseline period for future projection.

The multi-model ensemble projection of Tmax and Tmin carried out under the both RCP4.5 and RCP8.5 pathways in the station table 2a.b, the compression of simulated and observed data set illustrated significant rise of temperature in the basin and the stations located in higher elevation demonstrated to get warmer than the low elevation stations but the difference between simulated outputs not higher within the stations. For example, Jabulsaraj, Paghman and south Salang stations getting warmer rather than Karizmer, Kabul and Jalalabad stations by end this century.

Table 2a: Future Projected Increase of Tmax under Selected RCPs

Stations	Baseline	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jabulsaraj	20.01	20.90	21.44	21.69	21.04	22.47	24.19
Kabul	20.08	20.96	21.50	21.75	21.11	22.53	24.23
Karizmir	18.70	19.59	20.13	20.39	19.73	21.16	22.88
Paghman	17.22	18.12	18.66	18.91	18.26	19.69	21.41
Salang South	6.42	7.31	7.85	8.10	7.45	8.88	10.60
Jalalabad	30.48	30.62	31.01	31.26	30.62	32.01	33.68

Table 2b: Future Projected Increase of Tmin under Selected RCPs

Stations	Baseline	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jabulsaraj	10.79	11.61	12.11	12.34	11.74	13.05	14.63
Kabul	5.21	6.03	6.53	6.76	6.17	7.49	9.07
Karizmir	3.43	4.25	4.75	4.99	4.38	5.70	7.29
Paghman	3.18	4.01	4.51	4.75	4.14	5.47	7.07
Salang South	-0.11	0.71	1.20	1.43	0.84	2.14	3.71
Jalalabad	15.61	16.42	16.91	17.14	16.55	17.84	19.40

In this study, the future simulated scenarios monthly of Tmax singled increase in the three study periods. The monthly variation exhibited peak increase in the month of January and low increase in the month of November entire the basin. For example, under RCP4.5 the future of Tmax simulated to be 5.52˚C, 6.13˚C and 6.42˚C by early, mid and late century respectively relative to baseline recorded temperature 4.52˚C at 1995. Similarly, under RCP8.5 the future Tmax expected to be 5.68˚C, 7.29˚C and 9.23˚C at the early, mid and late century with comparison to baseline maximum temperature in this month. However, the lowest increase of Tmax simulated in the November. For instance, under RCP4.5 the Tmax expected to be 12.89˚C,13.38˚C and 13,61˚C by period of 2030s, 2060s and 2090s respectively with respect to baseline temperature. In same manner, under RCP8.5 future Tmax anticipated to be 13.02˚C, 14.30˚C and 15.84˚C with comparison to the baseline observed Tmax 12. 10˚C in the Kabul River Basin. However, summer months getting moderate warming for current century table (3a).

In the whole Basin, the future monthly minimum temperature (Tmin) anticipated to peak rise in the month of January and low increase in the month of November at all three selected periods. For example, under RCP4.5 the future of Tmin simulated to be (-6.78˚C, -4.99˚C and -4.70˚C) by 2030s, 2060s and 2090s respectively with comparison the baseline recorded temperature (-7.80˚C). In addition, under RCP8.5 the future Tmin forecasted (-6.62˚C, -3.31˚C and -1.85˚C) in the early, mid and late century with comparison to baseline Tmin. However, the lowest increase of Tmin predicted in the November. For instance, under RCP4.5 the future Tmin predicted to be 1.73˚C,1.95˚C and 2.37˚C by early, mid and late time of the century respectively with respect to recorded Tmin in this month 1.67˚C. In addition, under the RCP8.5 the Tmin forecasted to be 2.31˚C, 2.48˚C, and 3.59˚C by 2030s, 2060s and 2090s respectively with comparison to observed Tmin 1.69˚C, the detail is in table 3b.

Table 3a: Monthly Projection of Tmax under RCP Scenarios

Months	baseline	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jan	2.61	3.54	4.11	4.37	3.69	5.19	6.99
Feb	4.52	5.52	6.13	6.42	5.68	7.29	9.23
Mar	10.82	11.77	12.35	12.62	11.92	13.45	15.29
Apr	16.36	17.26	17.81	18.07	17.41	18.87	20.61
May	21.06	21.86	22.35	22.58	21.99	23.28	24.83
Jun	26.10	26.97	27.50	27.75	27.11	28.51	30.20
Jul	28.22	29.05	29.56	29.79	29.19	30.52	32.12
Aug	27.68	28.56	29.10	29.35	28.70	30.12	31.82
Sep	23.98	24.85	25.38	25.63	24.99	26.40	28.08

Oct	*18.33*	*19.22*	*19.76*	*20.01*	*19.36*	*20.79*	*22.51*
Nov	*12.10*	*12.89*	*13.38*	*13.61*	*13.02*	*14.30*	*15.84*
Dec	*6.04*	*6.98*	*7.54*	*7.81*	*7.13*	*8.63*	*10.44*

Table 3b: Monthly Projection of Tmin under RCP Scenarios

Months	*baseline*	*RCP4.5*			*RCP8.5*		
		2030s	*2060s*	*2090s*	*2030s*	*2060s*	*2090s*
Jan	*-7.80*	*-6.78*	*-4.99*	*-4.70*	*-6.62*	*-3.81*	*-1.85*
Feb	*-5.80*	*-4.78*	*-3.75*	*-3.46*	*-4.61*	*-2.55*	*-0.55*
Mar	*-1.04*	*-0.17*	*1.25*	*1.48*	*-0.03*	*2.19*	*3.76*
Apr	*3.81*	*4.53*	*5.90*	*6.09*	*4.64*	*6.70*	*8.04*
May	*7.11*	*7.82*	*9.16*	*9.37*	*7.94*	*9.99*	*11.37*
Jun	*11.08*	*11.86*	*13.44*	*13.66*	*11.99*	*14.36*	*15.90*
Jul	*14.01*	*14.80*	*15.78*	*16.01*	*14.92*	*16.70*	*18.22*
Aug	*14.12*	*14.94*	*15.33*	*15.57*	*15.08*	*16.30*	*17.92*
Sep	*11.10*	*11.96*	*11.77*	*12.01*	*12.10*	*12.76*	*14.41*
Oct	*6.52*	*7.29*	*6.70*	*6.91*	*7.41*	*7.56*	*8.99*
Nov	*1.69*	*1.73*	*1.95*	*2.37*	*2.31*	*2.48*	*3.59*
Dec	*-2.70*	*-1.87*	*-2.29*	*-2.03*	*-1.73*	*-1.26*	*0.45*

From scientific and policy planning communities point of view, calculation of seasonal analysis of climate parameters are key measures to understand the seasonal changes and designing proper policies regarding to this change hand have coping strategies to adapt with possible seasonal variation. In this study, all months have been divided into four distinguished season such as spring (March, April, May), Summer (June, July, August) Fall (September, October, November) and Winter (December, January, February). Therefore, under the selected scenarios, seasonal Tmax showed increase from the baseline but the most significant rise projected in winter and low increase simulated fall season. For example, under the RCP 4.5 the rate of rise projected 0.96˚C, 1.54˚C and 1.81˚C by period of early, mid and late century respectively. Meanwhile, under RCP8.5 pathway the rise of Tmax projected 1.11˚C, 2.65˚C and 4.49˚C in period of 2030s, 2060s and 2090s respectively relative to baseline period. On the other hand, the lowest increase Tmax predicted in fall season. Under the RCP4.5 the increase is 0.85˚C, 1.37˚C and 1.61˚C during the early, mid and late century respectively. At the same time, under worst case scenario RCP8.5 the rise of Tmax simulated 0.99˚C, 2.36˚C and 4.01˚C by period of 2030s, 2060s and 2090s respectively from the baseline period figure 3a.

In the Kabul River Basin, under the selected scenarios anticipated the future Tmin will rise. The total image of changes following the maximum temperature. However, peak rise projected for winter season and steep low increase are projected in spring months. The detail of variation illustrated in the figure 3b. As can be seen, under the RCP 4.5 the rate of increase projected 0.98˚C, 1.54˚C and 1.85˚C at time of 2030s, 2060s and 2090s respectively. At the same study period, under RCP8.5 pathway the level of Tmin rise predicted 1.14˚C, 2.71˚C and 4.60˚C with respect to baseline period. However, the lowest increase of Tmin projected in the spring, this change under the RCP4.5 pathway simulated 0.74˚C,1.43˚C and 1.41˚C by all three periods as early, mid and late century respectively, Meanwhile, under RCP8.5 pathway Tmin predicated to rise 0.86˚C, 2.05˚C and 3.48˚C by 2030s, 2060s and 2090s respectively from the base line.

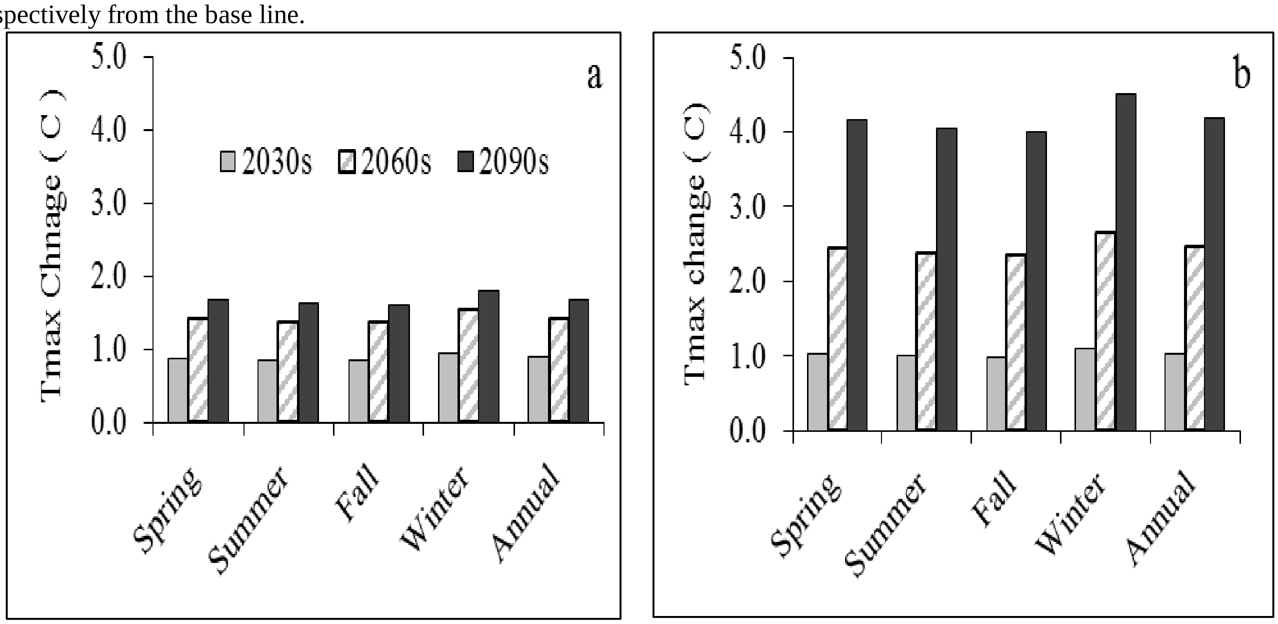

Fig. 3a, b: Seasonal Projected Increase Tmax under RCP4.5 and 8.5 in Kabul River Basin

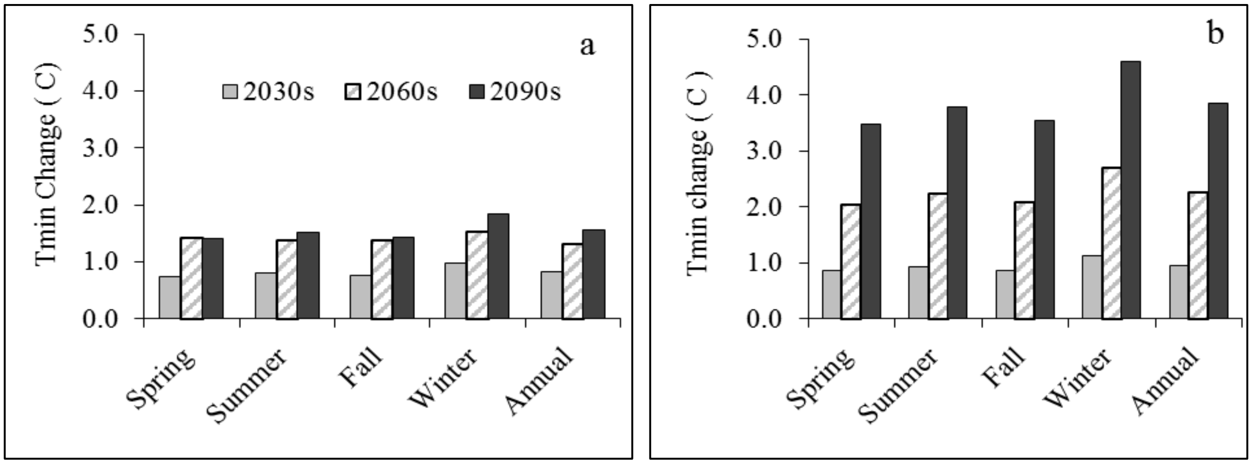

Fig. 3b: Seasonal Projected Increase Tmin under RCPs (4.5 and 8.5) in Kabul River Basin

Finally, as can be seen in the figures 4a. The future annual Tmax depicted change under the two selected scenarios. For instance, under the scenario RCP4.5 the future increase predicted 0.89˚C,1.43˚C, 1.68˚C by early, mid and late time of the century. Meanwhile, based on RCP8.5 the Tmax forecasted 1.03˚C, 2.46˚C, 4.18˚C at the period of 2030s, 2060s and 2090s respectively relative to baseline. Furthermore, as shown fig.4b demonstrate gradually rise of annual Tmin under the both distinguished scenarios. For example, under the RCP4.5 the annual increase projected 0.82˚C,1.32˚C, 1.55˚C by early, mid and late period respectively, and under the RCP8.5 path the change predicted 0.95˚C, 2.27˚C, 3.85˚C by 2030s, 2060s and 2090s respectively relative to baseline.

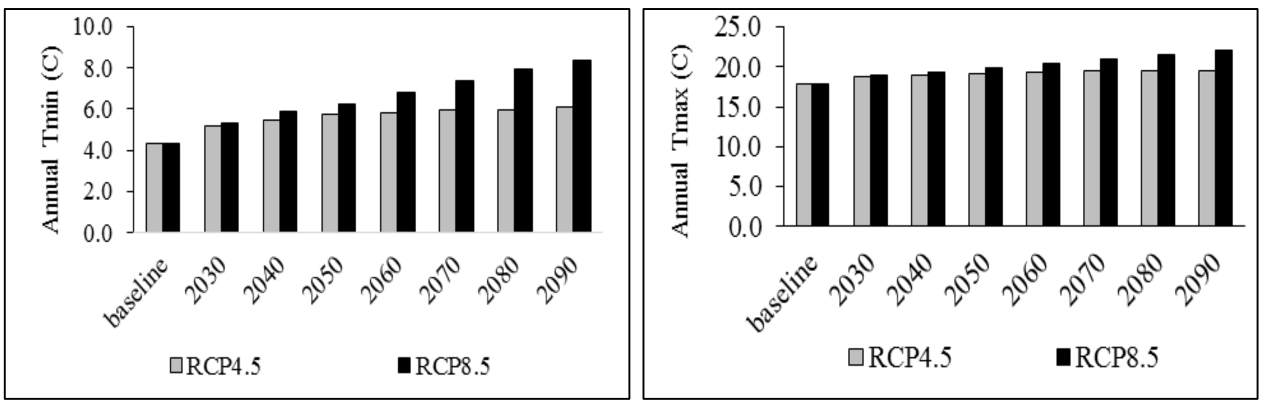

Fig. 4 a, b: Projected Trend of Annual Tmax and Tmin over Kabul River Basin

B. Analysis of precipitation

As global warming, may alter the precipitation pattern of a specific region or it can be influence on the intensity, extreme or simply amount of precipitation itself. In this study, we are focusing on the future condition precipitation as important climatic parameter which is the main sources of renewable water resources of the Kabul River Basin only precipitation. However, any change at the volume of precipitation will directly effects on water regime. At the basin level, there is no strong option for water resources management. The snow fall occurs in the winter season and accumulate as snow cover at the top of the mountains. The snow cover melting at the spring and summer seasons, the rivers are feeding directly from the melting of it. The decrease of precipitation directly impacts renewable river flow.

Table.4. illustrates the annual simulated and observed precipitation, as seen the future precipitation represent significant decline in the northern part of the basin. For example, the south Salang weather station exemplify a considerable dropdown of annual precipitation 18.39mm under RCP8.5 by end the century. However, the eastern part of basin represents increasing in the precipitation, for instance, in Jalalabad station the rate of increase obtained 3mm by end of century.

Table 4: Annual Changes of Precipitation (%)

Stations	*Baseline*	*RCP4.5*			*RCP8.5*		
		2030s	*2060s*	*2090s*	*2030s*	*2060s*	*2090s*
Jabulsaraj	*441.72*	*440.37*	*439.52*	*439.16*	*440.14*	*437.92*	*435.25*
Kabul	*295.96*	*294.57*	*293.71*	*293.33*	*294.34*	*292.10*	*289.42*
Karizmir	*368.95*	*366.52*	*365.05*	*364.36*	*366.13*	*362.20*	*357.53*
Paghman	*440.76*	*437.95*	*436.23*	*435.43*	*437.50*	*432.96*	*427.48*
Salang South	*1028.07*	*1024.16*	*1021.79*	*1020.67*	*1023.52*	*1017.22*	*1009.68*
Jalalabad	*144.19*	*144.85*	*145.25*	*145.43*	*144.97*	*146.01*	*147.3*

The detail of future monthly precipitation summarized in the table.5, the calculated outputs of monthly precipitation projection results revealed fluctuation with significant increase and decrease at the study period. The monthly comparison of precipitation performs February and May with possible increase and decrease respectively. For example, under RCP4.5 the precipitation projected to be 463.94 mm, 466.14mm and 467.20 mm by early, mid and late century period respectively. Meanwhile, under RCP 8.5 precipitation arise simulated 464.52mm, 470.39mm and 477.42mm by 2030s, 2060s and 2090s respectively with comparison to baseline recorded precipitation 460.29mm. In contrast, the significant decline of precipitation predicted in the month of May. For instance, under RCP4.5 downfall of precipitation forecasted 187.34 mm, 183.43 and 181.59mm by the early, mid and late time the current century. Meanwhile, under RCP8.5 the downtrend of precipitation expected to be 186.31mm, 175.93mm and 163.48 mm by 2030s, 2060s and 2090s respectively with comparison of observed baseline of this month 193.80mm.

Table 5: Monthly Precipitation Change (mm) under RCP 4.5 and 8.5

Months	*baseline*	*RCP4.5*			*RCP8.5*		
		2030s	*2060s*	*2090s*	*2030s*	*2060s*	*2090s*
Jan	*323.77*	*322.22*	*321.26*	*320.85*	*321.96*	*319.47*	*316.47*
Feb	*460.29*	*463.94*	*466.14*	*467.20*	*464.52*	*470.39*	*477.42*
Mar	*549.97*	*549.28*	*548.86*	*548.67*	*549.17*	*548.06*	*546.72*
Apr	*532.60*	*527.33*	*524.13*	*522.60*	*526.47*	*517.98*	*507.79*
May	*193.80*	*187.34*	*183.43*	*181.59*	*186.31*	*175.93*	*163.48*
Jun	*24.38*	*23.53*	*23.00*	*22.76*	*23.39*	*22.00*	*20.35*
Jul	*19.73*	*19.82*	*19.89*	*19.91*	*19.84*	*19.99*	*20.19*
Aug	*16.16*	*16.44*	*16.59*	*16.68*	*16.48*	*16.91*	*17.42*
Sep	*22.39*	*22.82*	*23.07*	*23.19*	*22.87*	*23.54*	*24.34*
Oct	*50.78*	*49.57*	*48.83*	*48.49*	*49.38*	*47.40*	*45.06*
Nov	*141.80*	*140.30*	*139.40*	*138.98*	*140.08*	*137.67*	*134.77*
Dec	*239.79*	*240.98*	*241.70*	*242.03*	*241.16*	*243.06*	*245.35*

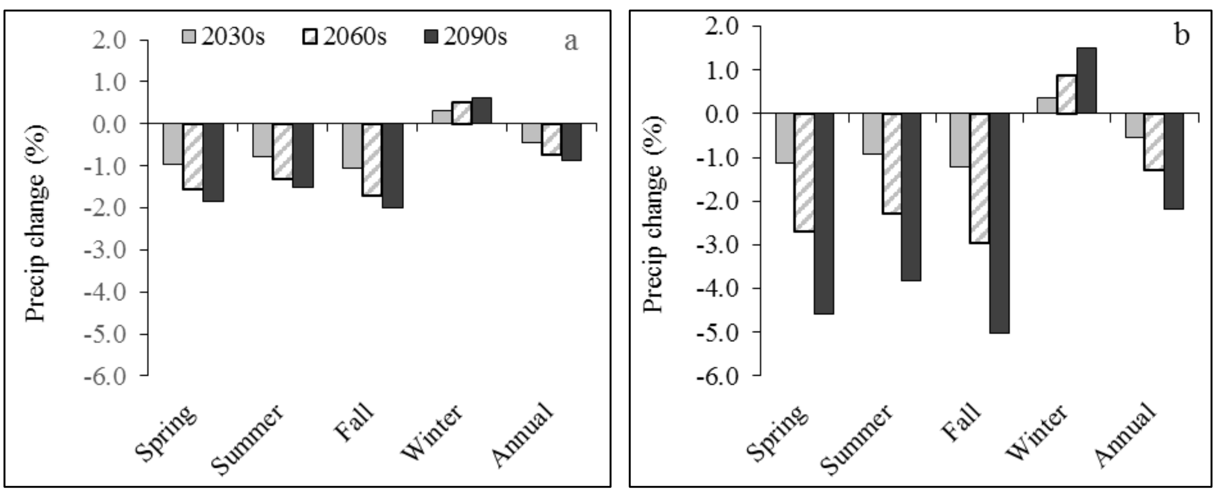

Fig. 5a, b: seasonal Change Preciptiation under the RCPs(4.5 and 8.5) over the Basin

In general, fig.5 illustrated the detail the seasonal precipitation for future study period, the seasonal precipitation demonstrated both downward and upward values. The greater decrease in found in fall season and small increase obtained in winter months. For example, under RCP4.5 pathway values precipitation decline -1.06, -1.71 and -2.00 percent over period of 2030s, 2060s and 2090s respectively, in the meantime, under RCP8.5 percentage of downward trend simulated -1.23, -2.96 and -5.02 percent. In contrast, increse of precipitation obtained in winter season, based on the long-term climatological manual book records, precipitation frequency is more in the winter rather than other seasons, under RCP8.5 the percentage of increase projected 1.50 percent by the end of the century. In addition, the spring precipitation variability is big concern, because these months are time for maximum rainfall entire the year, any decrease in volume of spring rainfall will directly put impacts on water resources of river basin. This change may make shorter the months of water year at the hydrologic regime of the basin.

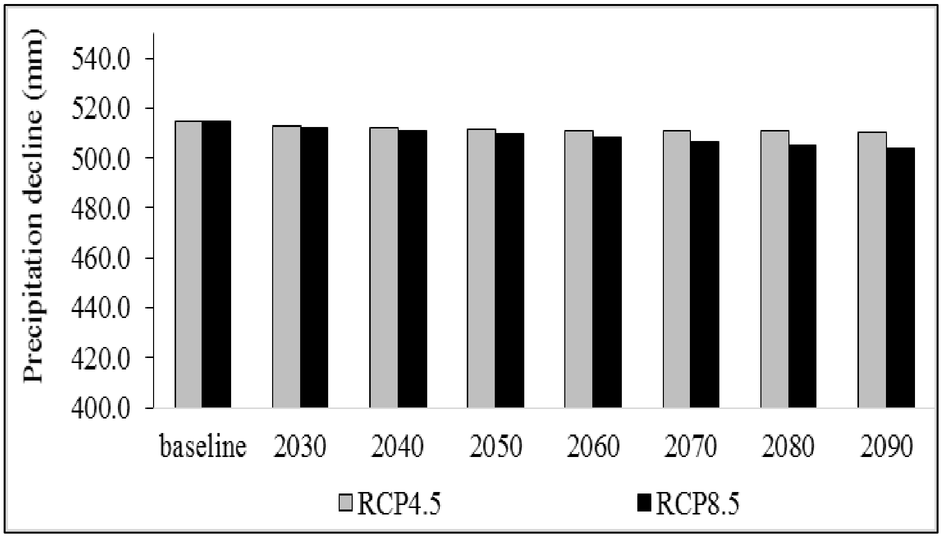

Fig. 6: Annual Trend of Precipitation Projection of Basin

The Fig.6 shows the annual precipitation time series. As can be seen, average annual future precipitation display steady decrease under the both selected pathways, under RCP4.5 the annual precipitation expected decline at level of 512.71 mm, 511.26 mm and510.59mm by early, mid and late periods respectively from the base line. In a like manner, based on RCP8.5 scenario the annual average of precipitation simulated to downward to 512.33 mm, 508.48mm and 503.87 mm in period of 2030s, 2060s and 2090s respectively with comparison of the baseline precipitation records 515.09mm.

IV. CONCLUSION

In conclusion, the main aim of this paper was to project total image of future climate of the Kabul River Basin and quantify the potential change of Tmax, Tmin and precipitation of the basin. Both climate parameters analyzed under RCP4.5 and 8.5 by using of the latest data set of IPCC fifth assessment report AR5. In this study, the SimCLIM model was used for climate modeling. A multi-GCMs ensemble applied for best representation of future climate and plausible future change at the station point of river basin. And the study carried out for three time periods of 2021-2014 (2030s), 2051-2017 (2060s) and 2081-2100 (2090s) with respect to baseline period of 1961-2010.

The future temperature of the Kabul river basin represented rise over future period. Under the selected scenarios, projected Tmax showed increase in all seasons. But the most significant rise projected at winter and low increase simulated summer. However, the future annual Tmax demonstrated positive change under the two selected scenarios, under the RCP4.5 the future increase projected 0.87˚C,1.40˚C, 1.65˚C by early, mid and late period respectively, moreover, under 8.5 path the annual increase of Tmax simulated 1.01˚C, 2.41˚C, 4.10˚C in periods of 2030s, 2060s and 2090s respectively relative to baseline. Furthermore, in case of future Tmin, the peak rise projected for winter season and steep lower increase are projected in spring months. The annual Tmin performance of change under the two selected pathways. For instance, under RCP4.5 pathway annual increase of Tmin projected 0.82˚C,1.32˚C, 1.55˚C by the early, mid and late study periods meanwhile under RCP8.5 pathway annual rise of Tmin predicted 0.95˚C, 2.27˚C, 3.85˚C by 2030s, 2060s and 2090s respectively from the baseline period.

The annual precipitation of the basin demonstrated decline and fluctuation in seasonal perspective. Hence, under RCP8.5 path the annual decrease is quite significant over the study period. However, both downward and upward trend of precipitation obtained from seasonal point of view. The precipitation pattern illustrated significant decrease in fall and followed by spring months. In general, in fall season there no too much frequencies of rainfall or precipitation observed. However, the significant decline of precipitation in spring season is big threaten for water resource as well as agriculture water demand for irrigation purpose. As discussed under RCP8.5 the percentage of rainfall decrease in spring season obtained -1.13, -2.70 and -4.57 percent over period of 2030s, 2060s and 2090s respectively with respect to baseline period of study.

In addition, the future spring precipitation variability is big concern, because these months are time for maximum rainfall entire the year in the basin, any decrease in volume of spring rainfall will directly put impacts on water resources of river basin. However, normal water regime of the basin likely increasing from April with maximum flow in June and lowest flow in the winter time, along the river streams there is not big dam or reservoir to control big seasonality distribution of water to meet the increasing irrigation demand in spring or summer time and, any abruption may make alter monthly flow at the hydrologic regime of the basin as well as country. It must be undertaken new development policies for seasonal distribution of water in the basin via construction of multipurpose dam and reservoir to reduce uncertainty of water shortage for use sectors inside of the basin.

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