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Multi-model Ensemble Climate Change Projection for Kunduz River Basin, Afghanistan under Representative Concentration Pathways

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Abstract: In this study, the most important aim is to project the future temperature and precipitation of Kunduz River Basin in north-eastern part of Afghanistan. A Multi-GCMs ensemble approach climate modeling was applied for best representation of future projection. The SimCLIM climate model was applied for detailed projection. The future projection done under RCP4.5 and RCP8.5 scenarios in three periods 2030s (2021-2040), 2060s (2051-2070) and 2090s (2081-2100) with respect to baseline 1980-2010. The comprehensive ensembles GCMs outputs illustrated the future temperature increasing and precipitation showed downward trend. However, the future temperature indicated slightly rise at winter season and lower warming at spring season. Annual Tmax warming under RCP4.5 and RCP8.5 projected 1.65°C and 4.10°C by 2090 respectively. However, annual Tmin increase under both RCP4.5 and RCP8.5 rates 1.50°C and 3.71°C respectively by end of century from the baseline. On the other hand, the annual future precipitation pictured decreasing. However, the seasonal variation of precipitation illustrated significant decrease in summer, under RCP8.5 pathway the decline of precipitation represented 10.68 percent in 2090s. In contrary, future precipitation in winter showed increasing, under high radiative pathway RCP8.5 increase of precipitation projected 3.72 percent in 2090s from the baseline. Therefore, a precaution measures must be undertaken due to possible negative risks in any sectorial planning and development options.

Key words: climate change, GCMs, RCP, temperature, precipitation, Kunduz River Basin

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) AR5 concluded; the averaged combined land and ocean air temperature of the globe, represent warming of 0.85°C, over period 1880-2012 [1]. The main cause of this change is human activities which is resulted significant changes in the composition of atmospheric gases especially intensive emission of CO^2 to the atmosphere. Other factors such as natural variability of climate system and external radiative forcing must be considered as natural process which causes of global warming [2]. The global warming results from the imbalance between the heat received and reradiated heat by the Earth's surface. The GHGs may trap the reradiated heat and leading the greenhouse effect which is caused of earth surface warming [3]. Therefore, the most significant circumstances of this change may put impacts on water cycle and subsequent changes in water resources quantity [4, 5].

Afghanistan is dominated by mountains with fragile ecosystem. The climate of country is varying from arid to semi-arid, with warm summer and cold winter. The precipitation occurs between November and April with peaks in February and March. The winter precipitation accumulates as snow form as well as make permanent snow cover at the high altitude of Hindukush region. During the spring and summer season these snows are

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thawing, all streams are feeding from this snow melting. However, the mountain plays the role storage in winter and release it in spring and summer. The rises of temperature will lead earlier spring and more rapid snow melts. Hence, the early, rapid snow melt and intensive rainfall leads severe flash flooding in the spring and summer months which is make the basin vulnerable due to changing climate.

The Kunduz River Basin located in northern eastern part of Afghanistan is highly vulnerable to flooding and droughts; the recent evidence at the heavy rainfall of 24-25 April 2014 caused flash flooding in the basin, in this risky disaster 10 people killed, more than thousands of people affected. Later, in June another heavy rainfall caused flash flood in Baghlan province, killed 81 people, 35 people injured, nearly 400 houses, irrigation infrastructure damaged [6]. In contrast, low precipitation making water resources scarcer. lead droughts than directly effect on natural resources and agriculture products which is nearly 80 percent of population of country rely on it [7]. In 2001 about 5 million people mainly northern provinces such as Takhar, Bghlan, Balkh, Jowzjan, and Badghis faced severe drought. The report confirm that main cause of drought was low precipitation in the northern region of Afghanistan [8].

The basin covers four provinces such as Bamyan, Baghland, Takhar and Kunduz which is hosts around three million inhabitants [9]. The people are highly dependent to natural resources, agriculture production, main income of people is coming from agriculture products. Therefore, both agriculture and irrigation water demand are vulnerable to climate change. The most important aims of this study were; to analyse the future climate situation of the Kunduz River Basin under the new CMIP5 RCPs scenarios, to translate the Global Circulation Model outputs into the river basin level. To project the future changes of maximum, minimum temperature and precipitation of Kunduz River Basin under two selected representative concentration pathways such RCP4.5 and RCP8.5 scenarios. The study outcomes could be used in agricultural development planning, water resources management and environmental change. Considering for better adaptation measures due to possible impacts of climate change over the Kunduz River Basin.

2. Material and Methods

2.1 Study Area

The Kunduz River Basin located in the north-eastern part of Afghanistan. The total area of river basin is about 35000skm. The basin located between 66.70-70.30E longitude and 34.80-37.20N latitude. The basin is one of major watershed tributary of Amu Darya River Basin. Amu Darya is the longest international share river in Central Asia. From its headwaters at an altitude of 4,900 meter above the sea level on the Wakhan mountain's glacier in Afghanistan, it travels 2,540 km, of which 1,250 km are within the land of Afghanistan or along its border with the Tajikistan. However, after passing the frontier from Khamaab area of Afghanistan, it flows to the Central Asian countries such as Uzbekistan and Turkmenistan and drain into Aral Sea. Of course, it is the main source of irrigation and drinking water supply of riparian countries [10,11].

Digital elevation model (DEM) map represent the elevation of study area was downloaded from USGS public geoportal database with 90-meter resolution [12]. The DEM map of the study area clipped by

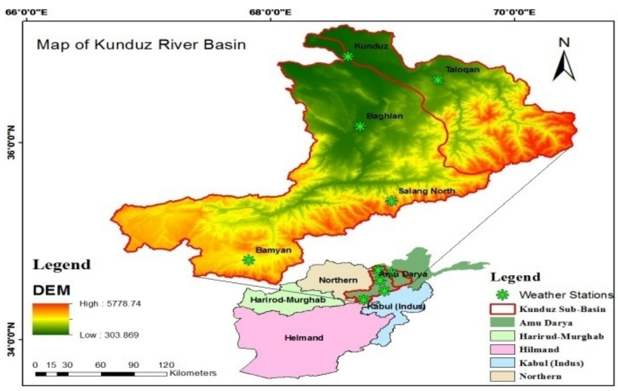

Fig. 1 location map of the study area.

ArcGIS 10.1 Clipping tool. DEM shows range of elevation between 5778.7 to 307.6 above the mean sea level.

Meanwhile, Kunduz rivers is sourcing from the high-altitude part of HinduKush and Baba mountains in the central part of Afghanistan. The river is running as usable water resources for household, agriculture use and environmental flow in basin. Kunduz river itself has two major tributaries such as Taloqan and upper Kunduz (Bamyan river) rivers which is originating from Hindu-Kush and Baba mountains respectively. The Bamyan river which is upper Kunduz river originate from Baba and Hindukush mountains with tributaries such as Bamyan and Kohmard rivers which joins at the Doab Bamyan and then flowing through Baghlan province. At the Dushi area of Baghlan province another stream tributary by the name of Shirin Tagab river joins to the river. After passing the center of Baghlan province the river flows to the lower part of Baghlan and entering to Kunduz province. Finally, two rivers such as upper Kunduz and Taloqan rivers joining in downstream and establishing the Kunduz River Basin. after passing downstream part of Kunduz province the river drains to Amu Darya River Basin.

2.2 Data Collection

The monthly observed data of temperature and precipitation of 5 weather stations was collected from Afghanistan Meteorological Authority (AMA) Table 1. The collected observed data set available from 1961-1978 and 2003-2014 time periods [13].

The collected observed climate data had long gaps in term of records. However, for solving the gaps problem

Table 1 The observed data set used in this study.

station	Lat (D)	Long (D)	Alt (M)	past period	new record	total record period
Bamyan	34.81	67.82	2550	-	2003-2014	11
Baghlan	36.17	68.73	550	1961-1972	-	11
SalangN	33.41	68.99	3365	1961-1977	-	16
Taloqan	33.64	69.37	804	1968-1978	2004-2014	20
Kunduz	37.01	69.1	460	-	2005-2014	10

of observed, the supplementary climate data is used. The supplementary data for filing the gaps were downloaded from Climate Research Unit (CRU) of the University of East Anglia. The unit constructed high spatial resolution at the 0.5°×0.5° grids degree for the globe at period of Jan. 1901-Dec. 2012 without the future scenarios [14, 15]. 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 location observed of stations. Lastly, the maximum, minimum temperature and precipitation were used for filling the gaps of recorded data set.

Furthermore, the future projection climate data of CMIP5 of 10 ensemble GCMs outputs was used [16], Table 2. Based on it is ability and validity to simulate the future climate variables [17]. Moreover, the RCP4.5 and RCP8.5 paths used which is represent the stabilizing 4.5w/m^2 and rising of radiative forcing of8.5w/m^2 paths respectively by end of this century [18, 19].

Table 2 Global and GCMs data set used in the study.

Global supplementary dataset				
Name	Resolution		Research Institute	source link
	Lat (D)	Long (D)		
CRU	0.5	0.5	University of East Anglia	http://www.cgiar-csi.org/data

GCMs dataset						
Name	Grid Resolution		source		RCP pathways	
	Lat (D)	Long (D)	Country	Developer/ Research Institute	4.5	8.5
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	2.0	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	√	√

2.3 Current Climate of the Basin

The climate of the basin characterizing by influence of the mountains, temperature dominated by elevation, the stations located at higher altitudes represent colder than the lower elevation of the basin. The monthly analysis of temperature depicted July warmest (31.14 C) month and January is coldest (-6.49) month. The Fig. 2 represents clear that maximum and minimum temperature shows high variability during the day time.

In addition, distribution of monthly precipitation at the Kunduz River Basin demonstrate more rainfall in spring with maximum value in March (90.4mm per month and lowest rainfall in August 1.61mm per month) Fig. 2. In winter, the precipitation occurs in form snowfall and accumulates in top mountains, getting melt in spring and summer for running the life of peoples for drinking and irrigation purposes.

2.4 SimCLIM Model

The SmiCLIM model was applied for future climate projection. Whatever the climatic data can be divided into two periods as baseline and future climate change periods. While, future scenario separated or combined with baseline. during constructing of future scenario, SimCLIM model follows IPCC, AR5 Report [16, 20 21].

Where the site scenarios generation follows this formula:

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

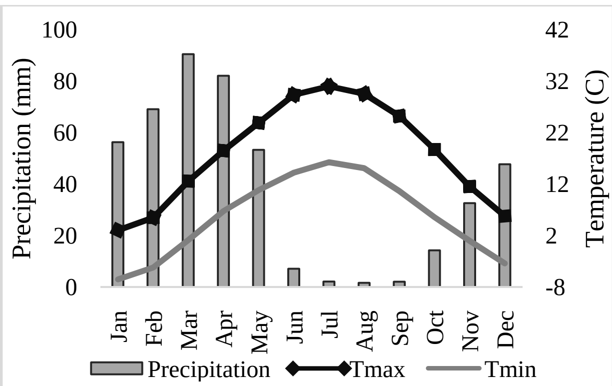

Fig. 2 Monthly average, temperature and precipitation.

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

3. Results and Discussion

3.1 Analysis of Temperature

Firstly, the SimCLIM model applied to understand the Tmax variation over Kunduz River Basin. The multi-model ensemble of CMIP5 data set was used, the station based climate modelling results summarized in Table 3. The finding exhibited high increase of Tmaxin the weather stations which located in upper catchment. For example, Tmax increase at the North Salang ranges from 0.90°C, 1.44°C and 1.69°C under the stabilized radiative forcing pathway RCP4.5 during 2030s,2060s and 2090s period respectively. In the meantime, under the RCP8.5 scenariosTmax rise projected 1.04°C, 2.48°C and 4.20°C for early, mid and late period respectively from the observed baseline. On the other hand, Kunduz station showed lower rise of Tmax rather than other stations entire the basin. For instance, the rate of rise under RCP4.5 projected 0.85°C, 1.36°C and 1.60°C in all three periods, meanwhile, under RCP8.5 projected rise be 0.98°C, 2.34°C and 3.97°C in period of 2030s, 2060s and

Table 3 Future projected increase of Tmax under selected RCPs.

Stations	Baseline	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Bamyan	16.00	16.89	17.43	17.68	17.03	18.46	20.17
Baghlan	22.80	23.66	24.18	24.43	23.80	25.18	26.84
SalangN	4.09	4.98	5.52	5.78	5.12	6.56	8.29
Tolaqan	21.72	22.59	23.12	23.37	22.73	24.13	25.82
Kunduz	24.98	25.82	26.34	26.58	25.96	27.32	28.95

Table 4 Future projected increase of Tmin under selected RCPs.

Stations	Baseline	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Bamyan	0.91	1.73	2.23	2.46	1.86	3.18	4.75
Baghlan	8.15	8.92	9.39	9.61	9.05	10.29	11.78
SalangN	-4.01	-3.20	-2.71	-2.48	-3.07	-1.77	-0.20
Tolaqan	10.17	10.96	11.44	11.67	11.09	12.35	13.87
Kunduz	12.95	13.71	14.18	14.39	13.83	15.06	16.53

2090s respectively, which is represent the lowest warming at all pathways among the stations of the Kunduz River Basin.

Secondly, at the station level the minimum temperature (Tmin) simulated by multi-model ensemble outputs for entire study area as summarized in table.4.out of five weather stations Bamyan represent high increasing value for all three periods of this century. For example, under the RCP8.5 the simulated increase is 0.95°C, 2.27°C and 3.84°C by 2030s, 2060s and 2090s respectively. In contrary, Kunduz station represents lowest value of warming at all trajectories entire the Basin. For instance, under the RCP8.5 increase range 0.88°C, 2.11°C and 3.58°C by 2030s, 2060s and 2090s respectively. Indeed, the likely future increase of Tmin at the site level from ensemble outputs, the Bamyan shows peak value at the selected scenarios as well as time periods and followed by Salang, Taloqan, Baghlan and Kunduz stations respectively. From site data analysis under the selected pathways the high elevation regions is indicated peak warming in both maximum and minimum temperatures parameters.

The monthly variation of two climate parameters Tmax and Tminanalyzed under the selected RCPs at all three study periods. while the comparison of the ensemble GMCs results and baseline pictured significant changes, details in Tables 5-6. The monthly Tmax variation of multi-model ensemble outputs demonstrated February getting peak rising value rather than other months. For example, Tmax simulated 7.29°C and 9.95°C under the RCP4.5 and RCP8.5 scenarios respectively by end of century from the baseline 5.50°C. In the meantime, the month June expected to experience moderate warming in all three periods. In contrary, the lower change of Tmax likely be in November, under the both RCP4.5 and RCP8.5 predicted 13.02°C and 15.16°C by 2090s with comparison to baseline 11.57°C. On the other hand, monthly variation of Tmin shows highest increase in February where it means that the winter season be likely warmer than other seasons for current century. For example, under RCPs 4.5 and 8.5 the future Tmin likely be -2.37°C and 0.31°C respectively by 2090s with comparison to baseline Tmin -4.19°C. Moreover, the moderate increase of Tmin simulated in the month of June too. In contrast, the lowest increase of Tmin projected in the November. For instance, the late century projection of Tmin under RCPs 4.5 and 8.5 projected 2.72°C and 3.93°C respectively with comparison to observed baseline 0.99°C (Table 6).

In addition, multi-model of scenarios comparisons of both Tmax and Tmin indicated the big warming in December, January and February with peak rise in the February, the rise of the Both Tmax and Tmin exceed 4.44°C and 4.50°C respectively under RCP8.5 by end

Table 5 Monthly projection of Tmax under RCP scenarios.

Mon	Baseline (C)	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jan	3.08	3.96	4.49	4.75	4.10	5.52	7.21
Feb	5.50	6.45	7.03	7.29	6.60	8.12	9.95
Mar	12.59	13.49	14.03	14.29	13.63	15.07	16.80
Apr	18.54	19.38	19.89	20.13	19.51	20.86	22.48
May	23.95	24.76	25.25	25.49	24.89	26.20	27.76
Jun	29.37	30.25	30.79	31.04	30.39	31.82	33.53
Jul	31.01	31.89	32.42	32.67	32.03	33.43	35.12
Aug	29.58	30.48	31.03	31.29	30.63	32.08	33.82
Sep	25.24	26.13	26.67	26.92	26.27	27.69	29.40
Oct	18.74	19.63	20.17	20.43	19.78	21.20	22.92
Nov	11.57	12.34	12.80	13.02	12.46	13.69	15.16
Dec	5.82	6.72	7.26	7.51	6.86	8.29	10.01

Table 6 Monthly projection of Tmin under RCP scenario.

Mon	Baseline (C)	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jan	-6.49	-5.56	-5.00	-4.74	-5.42	-3.93	-2.14
Feb	-4.19	-3.23	-2.65	-2.37	-3.08	-1.54	0.31
Mar	1.17	1.93	2.39	2.61	2.05	3.27	4.74
Apr	6.78	7.44	7.84	8.02	7.54	8.60	9.87
May	10.86	11.54	11.95	12.14	11.65	12.73	14.02
Jun	14.24	15.01	15.48	15.70	15.14	16.38	17.88
Jul	16.26	17.05	17.52	17.75	17.17	18.44	19.96
Aug	15.09	15.96	16.49	16.73	16.10	17.49	19.16
Sep	10.66	11.50	12.02	12.26	11.64	13.00	14.64
Oct	5.61	6.34	6.79	7.00	6.46	7.64	9.04
Nov	0.99	1.62	2.00	2.17	1.72	2.72	3.93
Dec	-3.38	-2.50	-1.96	-1.70	-2.35	-0.93	0.78

the century. However, the simulated results clarify the lower warming in autumns months.

In this study, to investigate the seasonal variation of the Tmax and Tmin the months divided four proper seasons. Indeed, climate of Afghanistan divided into these four seasons; Spring (March, April, May), summer (June, July, August), Fall (September, October, November) and Winter (December, February, March). The future projection of seasonal Tmax under the selected pathways represent higher increase in winter which is the cold time in Kunduz River Basin. For example, under RCP4.5 the future simulated change ranges 0.91°C, 1.45°C and 1.71°C in early, mid and late period respectively. Meantime, in worst-case RCP8.5 path the peak warming simulated 1.05°C, 2.51°C and 4.25°C by 2030s, 2060s and 2090s respectively with respect to baseline period. On the other hand, lowest warming projected in the Fall season which is range 0.85°C, 1.36°C and 1.60°C under RCP4.5 at early, mid and late projection time scale. Similarly, under RCP8.5 future peak value of Tmax range 0.98°C, 2.34°C and 3.98°C by 2030s, 2060s and 2090s respectively from the baseline. In addition, the winter represent peck warming and followed by summer, fall and spring season respectively Figs. 3-4.

From the seasonal analysis of Tmin by using ensemble approach under the selected RCPs the winter stands in peak increase of Tmin entire the seasons in all three study periods. In context of stabilized radiative forcing trajectory RCP4.5 projected rise is 0.92°C, 1.48°C and 1.75°C in early, mid and late century respectively. Meanwhile, under the RCP8.5 peak rise simulated 1.07°C, 2.56°C and 4.34°C by 2030s, 2060s and 2090s respectively relative to baseline. On the other hand, the spring clarify the lowest seasonal warming in the projected time periods. For instance, under RCP4.5 future simulated increase ranges between 0.70°C, 1.12°C and 1.32°C by early, mid and late periods respectively, meanwhile, based on RCP8.5 rise of Tmin simulated 0.81°C,1.93°C and 3.27°C by 2030s, 2060s and 2090s respectively from the baseline Fig. 4.

Furthermore, the seasonal calculation of Tmax and Tmin illustrated the peak warming in winter time and followed by summer, fall and with lowest warming in spring months. The consequences of increase of Tmin in winter and summer will put pressure on snow cover storages of high Hindukush and Baba mountains, the upper catchment plays role of water storage of the Basin.

The Fig. 5 shows the mean annual increase in Tmax from baseline, the narrow rising of Tmax under RCP4.5 projected to be 18.79°C, 19.32°C and 19.57°C by early, mid and late future period respectively. The gradually rise of Annual Tmax simulated under RCP8.5 and likely be 18.93°C, 20.33°C and 22.01°C in period of 2030s, 2060s and 2090s respectively with comparison to baseline 17.92°C. However, the annual Tmax increase within the study period shown in Fig. 3. Under the selected RCP 4.5 scenario, rate of increase

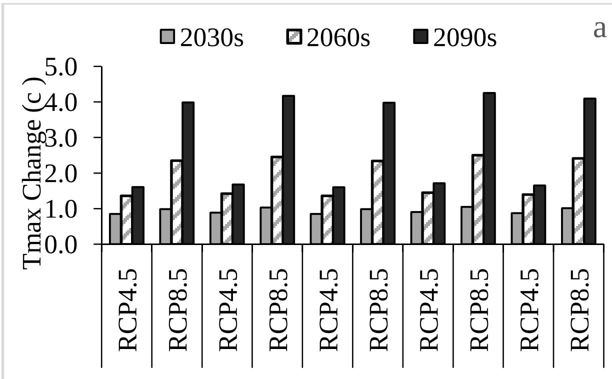

Fig. 3 Seasonal projected increase Tmax of the Basin.

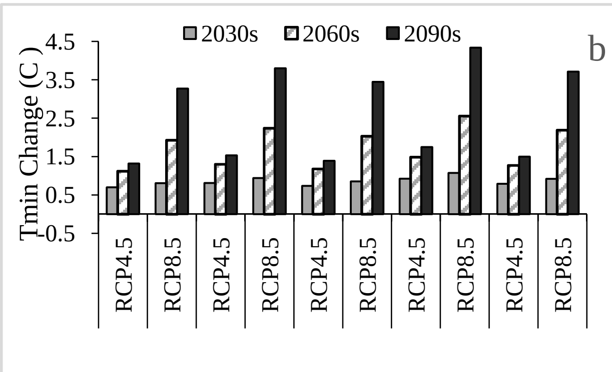

Fig. 4 Seasonal projected increase Tmin of the Basin.

projected 0.87°C, 1.40°C and 1.65°C by 2030s, 2060s and 2090s respectively. At the same time, under RCP 8.5 peak rise of annual Tmax simulated 1.01°C, 2.41°C and 4.10°C, from the baseline.

As shown in Fig. 6 the future trend of annual Tmin simulated steady change under RCP 4.5 and gradually increase under RCP8.5. So, under RCP 4.5 path Tmin trend simulated to be 6.42°C, 6.90°C and 7.13°C by early, mid and late period respectively. Meanwhile, under RCP8.5 scenario the annual Tmin projected to be 6.55°C, 7.82°C and 9.35°C in 2030s, 2060s and 2090s respectively with respect to baseline 5.63°C. However, the annual rise of Tmin represented in Fig.4. As seen under the RCP 4.5 scenario future increase is predicted 0.79°C, 1.27°C and 1.50°C by early, mid and late of this century respectively. In the meantime, under the RCP 8.5 path annual Tmin rise likely simulated 0.92°C, 2.19°C and 3.71°C, relative to baseline period.

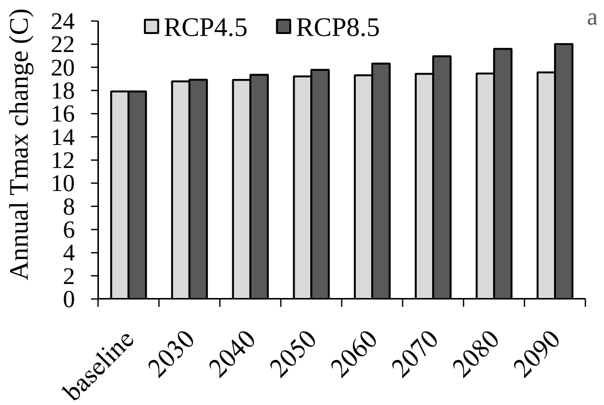

Fig. 5 Projected trend of annual Tmax over basin.

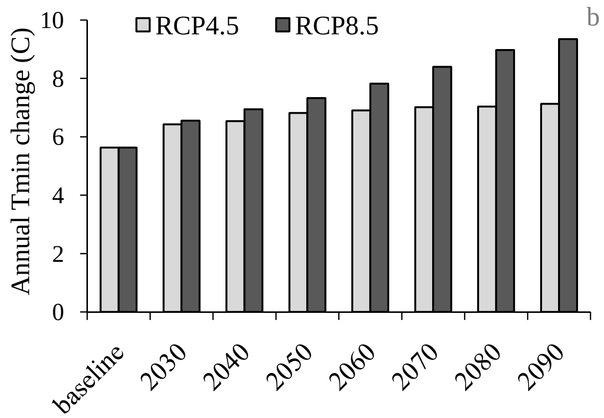

Fig. 6 Projected trend of annual Tmin over basin.

Finally, the ensemble multi-GCMs pathways illustrated peak rise of both Tmax and Tmin in the winter, the second largest rise of both climate parameters obtained in summer and lowest warming trend represented in fall season. The winter temperature increase is big threaten to the snow covers at high altitude of Hindukush and Baba mountain. The effect of winter warming may be pose in forms; precipitation patterns may change from snow to rainfall. Furthermore, if river basin receives less snow and rainfall which subsequently the volume of snow cover and river streams flow gets shrinking. In contrast, summer season temperature projected rise too. Summer hot days may melt the current snow covers or disappear it. In addition, the irrigation water demand will be increased due to increase temperature. Any change at the situation of snow cover will make disrupted on the ecosystem and natural resources services as well as river flow regime of the Kunduz River Basin.

3.2 Analysis of Precipitation

The site data analysis of future precipitation done by SimCLIM model. The site scenario generation of precipitation display decreasing in upper catchment stations, the Bamyan and Salang North stations reveal significant decreasing of precipitation. Simply, looking to results of Bamyan station, under RCP4.5 projected percentage of declining range (-1.24%, -2.00% and -2.34%) for (2030s, 2060s and 2090s) respectively. Under RCP8.5 scenario the decreasing values projected (-1.44%, -3.44% and -5.84%) for (2030s, 2060s and 2090s) respectively from the baseline. Moreover, the Northern Salang station illustrated the negative change too, for instance, under RCP8.5 rate of downtrend simulated -0.73%, -1.74% and -2.96% for 2030s, 2060s and 2090s respectively. In contrast, the Kunduz stations located at northern part of basin demonstrated positive trend of precipitation. For example, under RCP4.5 pathway the percentage of increase projected 1.39% by 2090s. Moreover, under

RCP8.5 path the percentage of precipitation predicted to rise 0.86%, 2.04% and 3.46% by 2030s, 2060s and 2090s period respectively from the baseline Table 7.

The monthly variation of precipitation under both RCP 4.5 and 8.5 based on multi-model ensemble outputs summarized in Table 8. The results depicted highest increase of 73.42 mm under RCP8.5 by end of century with referring to baseline precipitation 69.09 mm, while this time is winter season in the basin. However, whole basin receiving more precipitation during the winter in form of snowfall while this snow accumulates as snow cover at the top mountains at upper catchment of basin and subsequently getting melt in the spring and summer season and feeding of rivers during spring and summer seasons. In contrast, the future precipitation pictured decline in May to 49.74 mm and 44.38 mm under the both RCPs 4.5 and P8.5 respectively by the end of this century with respect to recorded baseline 53.35 mm.

Table 7 Annual changes of precipitation (%).

Station	Baseline (mm)	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Bamyan	220	-1.24	-2.00	-2.34	-1.44	-3.43	-5.84
Baghlan	296	-0.14	-0.22	-0.26	-0.17	-0.38	-0.65
SalangN	1010	-0.63	-1.01	-1.19	-0.73	-1.74	-2.96
Tolaqan	446	0.11	0.19	0.22	0.13	0.33	0.55
Kunduz	322	0.74	1.19	1.39	0.86	2.04	3.46

Table 8 Monthly precipitation change (mm) under RCP 4.5 and 8.5.

Mon	Baseline (mm)	RCP4.5			RCP8.5		
		2030s	2060s	2090s	2030s	2060s	2090s
Jan	56.33	56.08	55.94	55.87	56.05	55.66	55.19
Feb	69.09	70.01	70.57	70.84	70.16	71.64	73.42
Mar	90.48	90.55	90.59	90.61	90.56	90.66	90.79
Apr	82.07	81.98	81.92	81.90	81.96	81.82	81.64
May	53.35	51.44	50.28	49.74	51.13	48.06	44.38
Jun	7.16	6.88	6.71	6.63	6.84	6.39	5.86
Jul	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Aug	1.68	1.70	1.72	1.72	1.71	1.75	1.79
Sep	2.12	2.15	2.16	2.17	2.15	2.20	2.25
Oct	14.29	13.91	13.68	13.57	13.85	13.24	12.51
Nov	32.61	32.45	32.36	32.32	32.43	32.18	31.88
Dec	47.71	48.41	48.83	49.03	48.52	49.64	50.98

The seasonal change of precipitation illustrated in the Fig. 7. The total picture of future precipitation clarifies both decrease and increase at the seasonal level. The summer shows significant downward trend. For example, the percentage dropped values of precipitation at summer under the selected RCP4.5 pathway forecasted -2.30, -3.66 and -4.33 percent in early, mid and late century respectively. In like manner, under RCP8.5 path slightly decline of precipitation projected -2.64, -6.32 and -10.68 percent in 2030s, 2060s and 2090s period respectively with respect to baseline. In contrast, the winter projected to receive more precipitation than current baseline. For example, under RCP4.5 the upward simulated 0.80, 1.28 and 1.53 percentage in early, mid and late study period respectively. In like manner, under high radiative forcing pathway RCP8.5 increase of precipitation predicted 1.0, 2.20 and 3.80 percent in 2030s, 2060s and 2090s period respectively with comparison baseline. However, the most significant downward of precipitation illustrated in summer followed by fall and spring. Therefore, seasonal decline of precipitation in spring and summer will lead reduction water demand for irrigation purposes.

The annual precipitation demonstrated slightly decline under both scenarios. Under RCP4.5 annual precipitation projected 457.77 mm, 456.97 mm and 456.60 mm by early, mid and late period of this century respectively. Meanwhile, under worst case scenario RCP8.5 the dramatically downward projected 457.56 mm, 455.45 mm and 452.89 mm from the observed baseline 459.10 mm. Fig. 8 demonstrates, the annual precipitation projected represent decline by current century, the maximum dropdown of precipitation projected -1.53 mm, -3.66 mm and -6.21 mm under the RCP8.5 scenario by 2030s, 2060s and 2090s respectively regarding the baseline Figs. 7-8.

Despite increase in winter, the geographical pattern of future precipitation represents decline in upper catchment. Any decreasing at amount of precipitating in this area will results decreasing of river flow. The

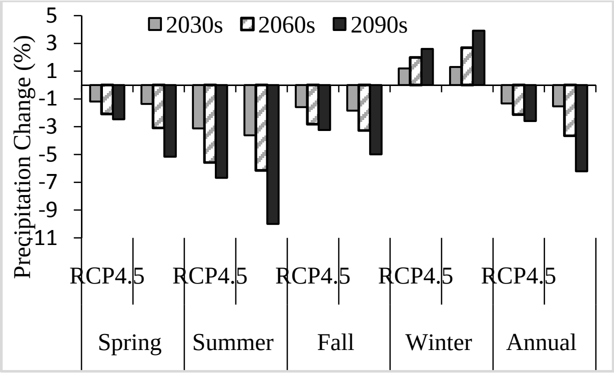

Fig. 7 Seasonal change preciptiation of Basin.

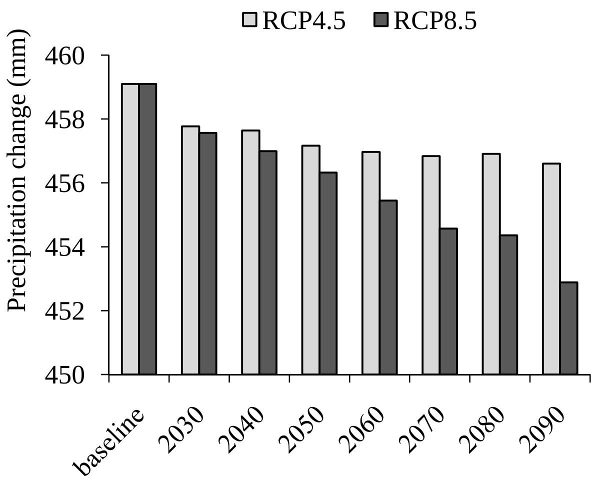

Fig. 8 Annual trend of preciptiation projection of Basin.

river water decrease directly impacts on local people's incomes, where the local and rural communities are highly dependent to agriculture and farm related products.

4. Conclusions

In conclusion, climate change may have considerable impacts on water resources as well as natural resources services of the Kunduz River Basin. Therefore, in this study we analysed Multi-GCMs ensemble outputs under two selected Representative Concentration Pathways (RCPs) 4.5 and 8.5 with three future periods such as early period 2021-2040 (2030s), mid-century from 2051-2070 (2060s) and late century from 2081-2100 (2090s) relative to observed baseline 1980-2010.In this study, the GCMs selected based on the ability of them to represent the current and future condition of climate variables of the Kunduz River Basin of Afghanistan. The multi-GCMs ensemble of 10 Global Circulation Models and the SmiCLIM model was used for site specific climate change modelling at station level. The projection done for two climate variables such as temperature and precipitation.

Firstly, the projection of Tmax indicated increase values. For example, under RCP4.5 scenario the projected change is 0.87°C, 1.40°Cand 1.65°C by 2030s, 2060s and 2090s respectively. Meanwhile, under the RCP8.5 scenario the rate of warming projected 1.01°C, 2.41°C. In addition, Tmin projected to increase within the study period. The rate of increase based on RCP4.5 ranges 0.79°C, 1.27°C and 1.50°C in 2030 s, 2060 s and 2090 s respectively. At the same time, under RCP8.5 pathway the rising trend of Tmin are 0.92°C, 2.19°C and 3.71°C.

Secondly, the results of annual precipitation values demonstrated decreasing trend. However, seasonal precipitation variation illustrated significant decrease in summer. For example, under high radiative forcing scenario RCP8.5 decline of precipitation represented 2.64%, 3.62% and 11.68% at the period of 2030s, 2060s and 2090s respectively. In contrary, winter precipitation showed increasing values. For instance, the under RCP8.5 pathway increase of precipitation projected 0.93%, 2.19% and 3.72% at time span of 2030s, 2060s and 2090s respectively with respect to base line.

Precipitation is a major source of freshwater at basin. Precipitation events occur in two types of snow and rainfall in annual basis. The precipitation falls in form snow at the high altitudes areas of basin which is local temperature declining in autumn and winter. Because of low or even below zero Celsius degree of temperature the snow accumulates and forming snow cover in the upper parts of Kunduz River Basin. During the spring and summer local temperature are rising the accumulates snow getting melt and make renew freshwater at the basin which is widely used in irrigation purpose. Due to lack of storage infrastructures inside of the basin, the mountain plays role of water storage too. The rise of temperature associated with global warming will have considerable impacts on snow patterns. Late autumn and early spring make shorter the cold period which is snow precipitation accumulates as snow or the precipitation patterns shifts from snow to rain due to early spring time. On the other hand, the future projection of precipitation at the Kunduz River Basin demonstrated decrease in annual basis. Seasonality of precipitation illustrated significant decline in summer and increase at winter.

This is anticipated temperature value increased, precipitation patterns showed downward trend, the implication of this change will impact on different sectors such as freshwater, natural ecosystem services and livelihoods of inhabitants of the river basin. While increasing of temperature and decrease of precipitation may increase the irrigation water demand and may put effects on crop yields too. The policy makers, farmers and rural community must formulate and design proper policies for adapting to negative implication climate change on water resources, agriculture related planning and management.

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