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Impact of climate uncertainties on agriculture in Fergana Valley of Uzbekistan

[1]Sardorbek Musayev, [2]Jonathan Mellor, [3]Ilhomjon Musaev, [4]Mashkhurakhon Nuretdinova
[1]PhD Candidate, [2]Assistant Professor, [3]Associate Professor, [4]PhD researcher
[1, 2]Department of Civil and Environmental Engineeing, University of Connecticut, USA
[3]Department of Geodesy and Geoinformatics, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Uzbekistan
[4]State Scientific-Design Institute "Uzdavyerloyiha", Uzbekistan
Email – [1]sardorbek.musayev@uconn.edu, [2]jonathan.mellor@uconn.edu, [3]ilkhommus@mail.ru, [4]sardorm@mail.ru

Abstract: *Future climate will probably have an impact crop production and food security in developing countries. Though irrigation infrastructure is improved, the weather still plays and important role in agricultural productivity. Global Climate Models envision increase in temperature and precipitation in the coming century. This paper studies whether precipitation contributes to irrigation of cotton and winter wheat crops in the future climate scenarios. Paper focuses Fergana Valley of Uzbekistan as case study. The main assumption that may affect the effectiveness of this study is that this analysis assumes to one site in Fergana Valley and only assumes cotton and winter wheat. Any further research on this topic should include more sites in different climate zones and more crop patterns. Further research in this area should aim to extend these findings to other areas of the Central Asia regions. Although climate change may not have a large impact on rainfall patterns in Fergana, Uzbekistan over the next century, other developing countries may face large changes in rainfall patterns and thus return different results on effectiveness of rainfall contribution irrigation. Additionally, further research could determine the threshold precipitation amounts that make it effective, ineffective, or unnecessary in areas of varying rainfall.*

Key words: *precipitation, temperature, climate change, irrigation.*

1. INTRODUCTION:

As warming occurs, the hydrological cycle is predicted to intensify. However, an elevated rate of evaporation and precipitation is not expected to continue the same distribution patterns as historical rain has, causing climates and weather patterns to change significantly around the world. Central Asia has a unique climate condition with arid, semiarid and even continental humid climate that involve the region into an interesting research in the study of hydrometeorology. Synthetic future climate data produced using a stochastic weather generator allowed for the analysis of future rainfall in Fergana Valley of Uzbekistan. The data is analysed if precipitation contributes to irrigation of cotton and winter wheat production to meet future food security in the region.

2. LITERATURE REVIEW:

Future climate change will likely to affect crop production and probably increase the risk of food insecurity in developing countries (Cline, 2008, Musayev et.al, 2018). Even though irrigation system is upgraded, the weather still plays a key factor in agricultural productivity (Wegerich et.al, 2012). In many developing countries rainfed crops are near their maximum temperature tolerance, so any small climate change will significantly fall agricultural productivity up to 30% over the 21st century (IPCC 3rd Assessment Report, 2000). Hence, in due course, the climate change could affect agricultural productivity in terms of quantity and quality of crops. In some cases, that even minor drought might have big impacts on food security that could trigger a massive famine in developing countries.

Lobell et al. (2008a) assessed how climate change might affect 12 food-insecure regions in 2030. The purpose of their analysis was to assess where adaptation measures to climate change should be prioritized. They found that without sufficient adaptation measures, South Asia and South Africa would likely suffer negative impacts on several crops which are important to large food insecure human populations. Based on IPCC (2007) projections in Central and South Asia, yields might decrease by up to 30% by middle 21st century. Taken together, the risk of hunger was projected to remain very high in several developing countries.

Cline (2008) looked at how climate change might affect agricultural productivity in the 2080s. He concluded that global agricultural productivity could be negatively affected by climate change, with the worst effects in developing countries. Climate change will be the main concern in water and agriculture sector in the next century.

Topography of Central Asia is landlocked and a home for multiple type of climates. Mountains act as a barrier for moisture carrying winds lacking maritime air masses from the Indian Ocean. Hence, it is semi-arid or arid towards humid continental. Large seasonal and daily fluctuations in temperature are characteristic. The summer is dry, cloudless, and very hot. In July, the warmest month, the average monthly temperature is 25-31 C. The dry, cold Siberian air mass has free access from the north where there are no mountains. The average January air temperature varies from -8 to -12 C in the northwest, -6 to -8 C in the mountains, and 0 to 2 C in the south. (Anon., 1993).

Snow and glacial melt are important hydrologic processes in Central Asia. Glaciers of Tien Shan and adjacent mountains ranges are considered the water towers whose rivers feed the region. More than one-sixth of the world's population lives in glacier-or snowmelt-fed river basins (Stern, 2007). IPCC Assessment Report states that climate change poses serious threats to Central Asia's environment, agriculture and socio-economic systems, particularly because of the arid nature of the region.

3. METHODS:

This study used LARS-WG to generated 100 years (1907 - 2007) of synthetic daily rainfall data based upon two sets of historic temperature (Tmin and Tmax) and rainfall data from the NOAA Climate Data Online information system for Fergana Station in Uzbekistan which sits at an elevation of 420 meters and receives a total of 190 mm of rain annually.

LARS-WG is a stochastic weather generator, which uses historic weather station data to produce synthetic daily weather for both baseline and future climates (Semenov & Stratonovich, 2010). The future weather data is produced using 15 global climate model simulations, three emissions scenarios, and three time periods. The emissions scenarios include the A2, A1B, and B1 and the time periods are 2011-2030, 2045-2065, and 2080-2099. The A2 scenario is the worst case, highest emission scenario while the B1 scenario has a decrease in current greenhouse gas emissions. The A1B scenario is between these two, with emissions continuing similarly to current levels, but steadily increasing into the future (Aizen, 2013). The simulated daily rainfall was then used to model irrigation scheduling using Cropwat 8.0 to study the contribution of effective rainfall to total irrigation requirements in the region (FAO, 2006). Cotton and winter wheat are selected to study crops respectively (Bozorov et.al, 2018) (Fig.1). Next, the data was taken from each iteration of the program and saved in a Microsoft Excel Workbook (Microsoft Corporation - Redmond, WA) where all further statistical analysis was performed.

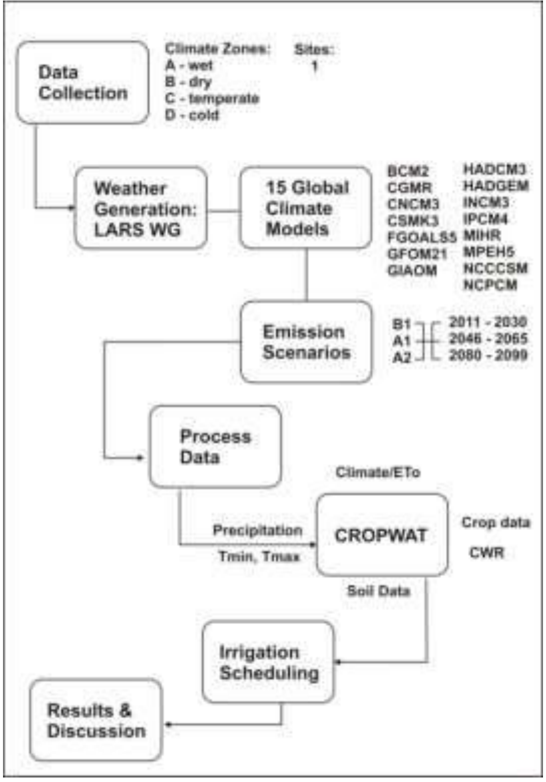

Fig. 1. Framework of the study

Data Acquisition

Data for Fergana climate station, Lat 40.35, Lon 71.75, obtained from NOAA for 100 years, 1907 – 2007, (Fig.2.). CROPWAT calculates crop ET by Penman-Monteith method. CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO, which calculates crop water requirements and irrigation requirements based on soil, climate and crop data.

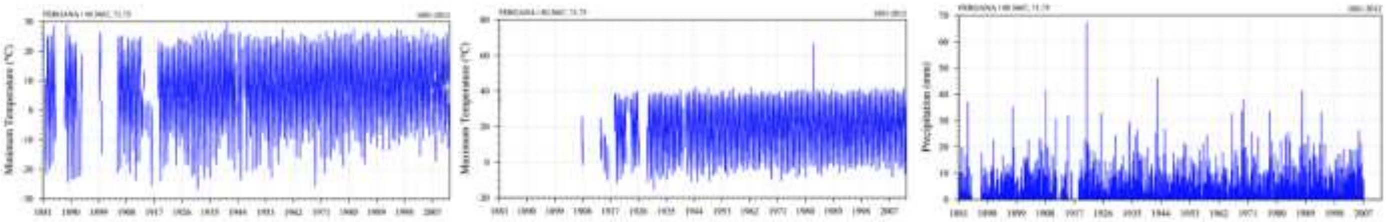

Fig. 2. Tmin, Tmax and Precipitation data for 1881 – 2012

In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. It can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions (Doorenbos, 1979). Climate data such as mean relative humidity in %, mean wind speed in km/day, mean sunshine hours per day, mean solar radiation in MJ/m2/day were obtained by ClimWat 2.0 program developed by FAO for Fergana climate station. Winter wheat is produced in 210 days, planting date 15 October and harvesting date 12 May till June. Cotton is planted on 21 April and harvested on 27 September, 160 days.

4. RESULTS AND DISCUSSION:

Mean values were analysed to see if there is a significant difference among the three scenarios. The use of different combinations of emission and periods demonstrate trend of increase in Tmin and Tmax. Tmin increases by 1.39 ºC, 2.76 ºC and 4.19 ºC during 20 years period 2011-2030, 2046-2065 and 2080-2099 respectively with up to 53% increase by 2100 comparing to baseline scenario (Table 1).

Table 1. Combining of all scenarios, Tmin

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	TOT
Baseline	-4.72	-2.03	4.04	9.72	13.89	17.21	19.21	17.42	12.69	7.01	1.75	-2.09	7.84
2011-2030	-3.28	-0.54	5.32	11.04	15.21	18.58	20.65	18.88	14.14	8.35	3.18	-0.75	9.23
2046-2065	-1.82	0.89	6.70	12.39	16.53	19.96	22.15	20.32	15.40	9.57	4.49	0.64	10.60
2080-2099	-0.38	2.30	8.01	13.73	17.90	21.36	23.57	21.80	16.85	11.00	6.02	2.17	12.03

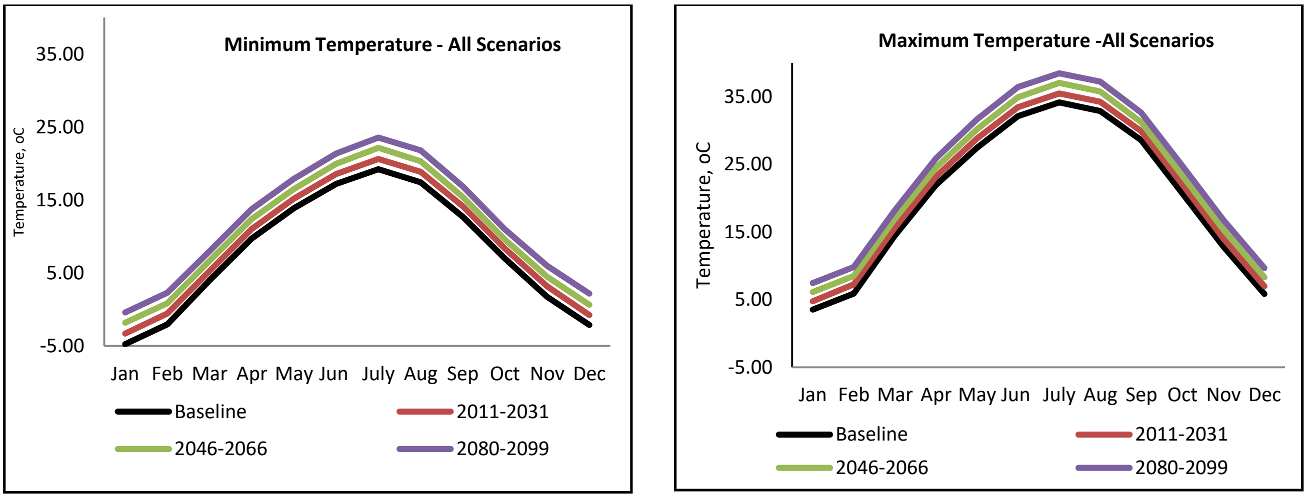

Fig.3. Temperature trend, Tmin and Tmax

Similarly, Tmax also increases by 4.06 ºC by 2100 with 20.3 % increase comparing to baseline temperature (Table 2). Between the three time periods, there were significant differences between group means by one –way ANOVA (F(3,33) = 2.89, $p < 0.001$) for both Tmin and Tmax (Fig.3 and Fig.4).

Table 2. Combining of all Scenarios, Tmax

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	TOT
Baseline	3.53	5.88	14.42	21.94	27.45	32.11	34.14	32.87	28.58	20.70	12.82	5.83	20.02
2011-2030	4.77	7.24	15.61	23.17	28.81	33.47	35.46	34.26	29.88	21.99	14.02	6.96	21.30
2046-2065	6.12	8.51	16.90	24.51	30.17	34.92	37.03	35.76	31.25	23.30	15.35	8.30	22.68
2080-2099	7.43	9.79	18.18	25.87	31.65	36.42	38.48	37.23	32.66	24.76	16.78	9.69	24.08

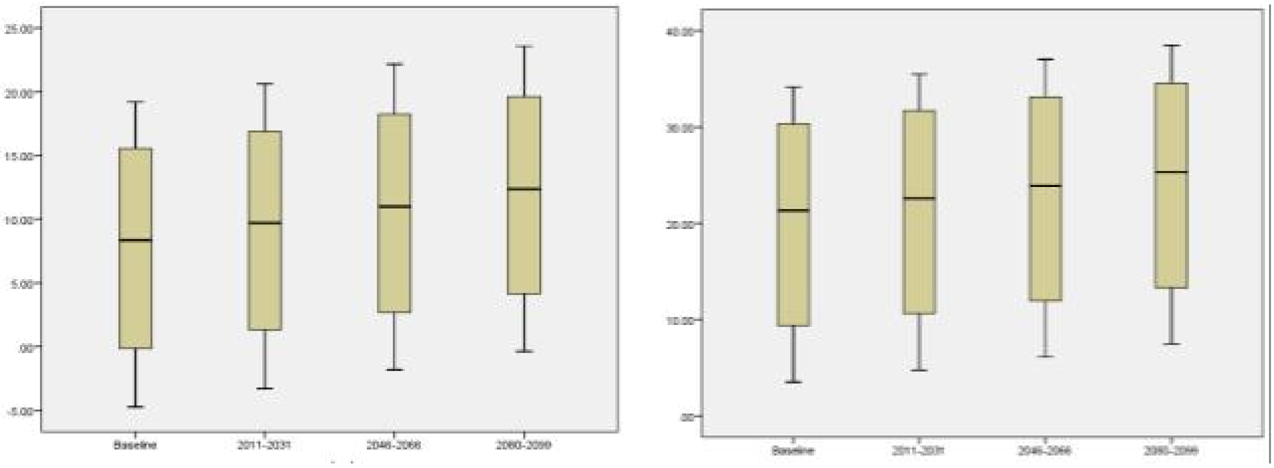

Fig.4. Tmin and Tmax mean values

Precipitation

Climate change impact to rainfall in the region is not significant. Annual precipitation decreases to 2% in first 20 years but it increases to 1% in middle 20 years and decreases to 2 % the last 20 years' period of the century.

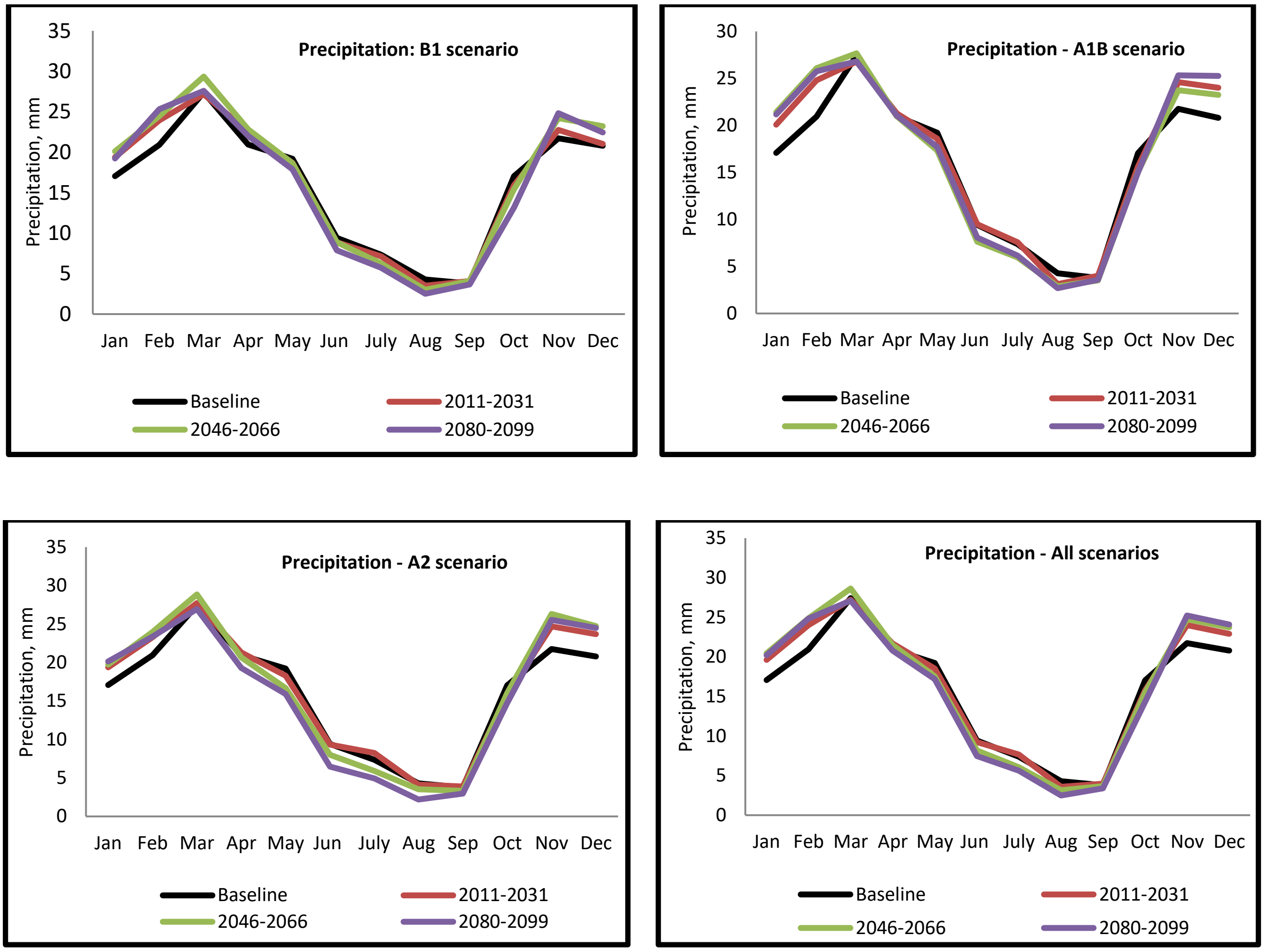

Fig.5. Precipitation scenarios

A1B scenario (p=0.41), A2 scenario (p=0.14) and B1 scenario (p=0.23) with overall scenarios (p=0.37) demonstrate difference only in the range of 1.4 % to 4.3% comparing to baseline benchmark. Total precipitation will increase from 189.94 mm to 197.87 mm by 2065 and decreases to 192.54 mm by 2100. Future changes in annual precipitation are far more pronounced during the winter (DJF) than during summer (JJA) months (Fig.5).

Table 3. Precipitation all scenarios

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	TOT
Baseline	17.06	20.93	27.42	20.95	19.21	9.42	7.36	4.26	3.77	17.03	21.74	20.79	189.94
2011-2030	19.61	24.00	27.22	21.69	18.52	9.22	7.64	3.59	3.98	15.78	24.02	22.90	198.17
2046-2065	20.42	24.85	28.62	21.48	17.54	8.16	6.04	3.14	3.63	15.50	24.75	23.74	197.87
2080-2099	20.18	24.80	27.11	20.77	17.16	7.46	5.60	2.47	3.39	14.30	25.23	24.06	192.54

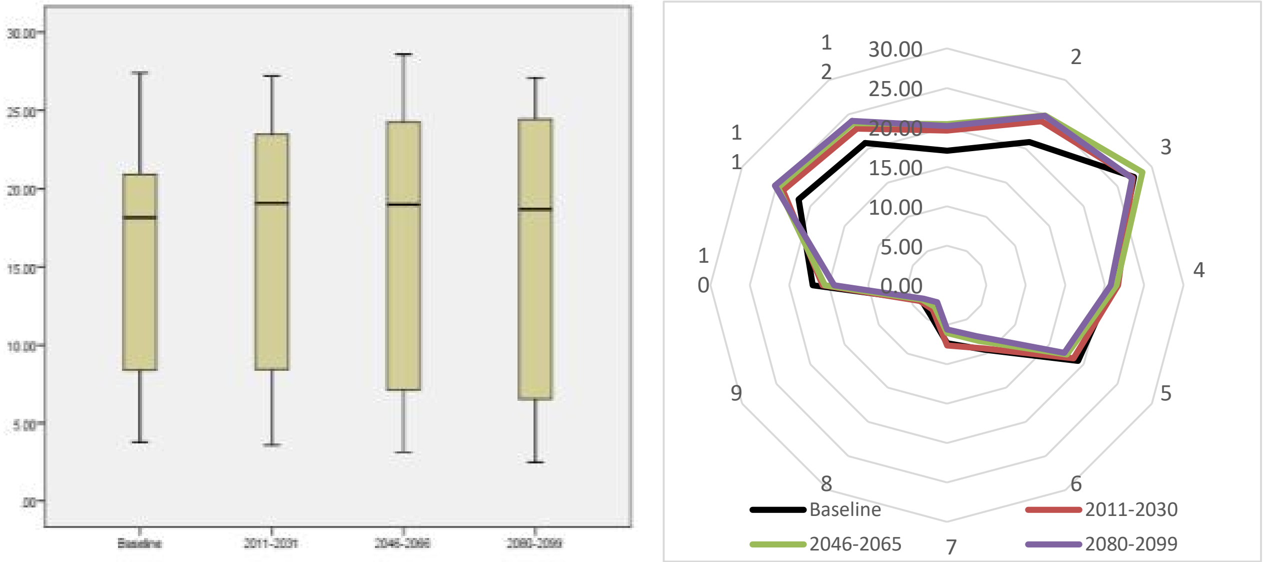

Fig. 6. Future precipitation prediction

Assumption to more precipitation in winter and less precipitation in summer could be explained as warmer temperature in winter means to melt more of glaciers of mountain ranges in Central Asia. Glaciers are considered the water bank of the region to supply two main rivers. This complicates the hydrology of the region to experience more stress in vegetation period. Atmospheric circulation is dominated by Siberian High, anticyclone comes from Northern Hemisphere designates the local climate. Tmin increase in winter could weaken the Siberian High strong wind power to facilitate to rapid melting of glaciers which adds more winter precipitation, whereas in the summer Intertropical convergence zone migrates north to reduce air pressure and decreases wind movement to avoid cloud formation and rainfall.

Table 4. Winter wheat and cotton scenarios results

Winter wheat	Total P, mm	P eff,mm	P lost	P effc	Act Irr Req	Cr Act Wuse	Total Gr Irr	N Irr
Baseline	145.3	145.3	0.0	1.0	177.5	322.8	119.6	1.0
2011-2030	155.1	153.8	1.3	1.0	182.8	336.6	118.2	1.0
2046-2066	159.1	157.7	1.4	1.0	193.7	351.4	118.6	1.0
2080-2099	156.6	151.3	5.3	1.0	215.8	367.1	204.4	2.3

Cotton	Total P, mm	P eff,mm	P lost	P effc	Act Irr Req	Cr Act Wuse	Total Gr Irr	N Irr
Baseline	50.7	49.6	1.1	1.0	768.3	817.9	1082.1	9.0
2011-2030	49.9	46.9	3.0	0.9	788.7	835.6	1031.7	9.0
2046-2066	45.3	44.3	1.0	1.0	828.4	872.7	1127.1	9.7
2080-2099	42.7	41.8	0.9	1.0	859.4	901.2	1145.0	10.0

Temperature rising increase crop water requirement in vegetation period. Most crops especially cash crops grow in vegetation period. Hence, water management stakeholders should think about other alternative irrigation system (Kazbekov et.al, 2015). Number of Irrigation times also increases for both crops (Table 4).

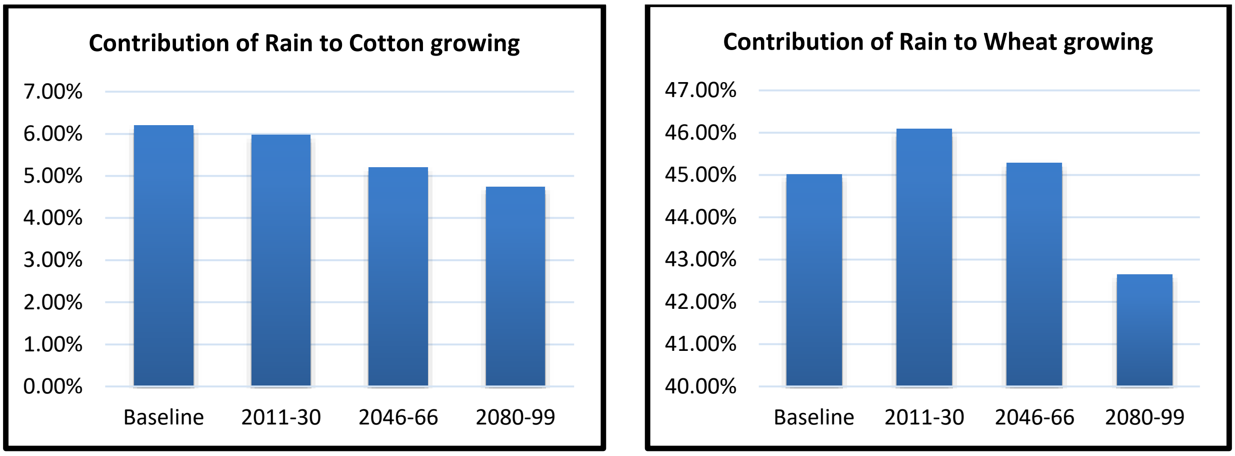

Fig.7. Contribution of precipitation on crop irrigation

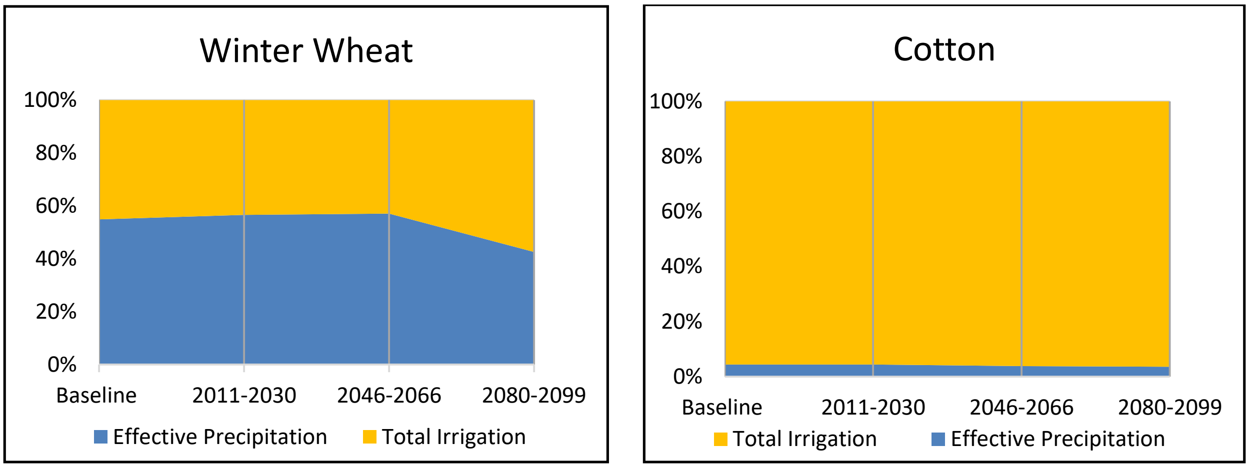

Fig.8. Ratio of effective precipitation to total irrigation

Irrigation water requirement for cotton in vegetation period also increases due to temperature increase in summer causes to 768mm to 859 mm as well as from 177 mm to 215 mm for winter wheat. This puts more stress to take water from surface water sources such as rivers, small tributaries and canals. Being dependent on upstream riparian states, Uzbekistan has to think to transfer irrigation methods from flood irrigation to other water conserving methods such as sprinkle or drip irrigation (Musayev, 2010). Rainfed irrigation will not contribute much to relieve this stress in coming 100 years in Fergana Valley of Uzbekistan.

5. CONCLUSION:

The most important conclusion of this research is that climate change appears to have little effect on precipitation. Hence, this might not hold promising contribution to irrigation in the form of rainfed irrigation in regions arid areas. The data from the different climate scenarios, time periods indicated that precipitation change cannot add more water to farmland regardless of greenhouse gas emission scenarios for the next century. This is important for the planning of irrigation systems into the future and not to seek major water scarcity solutions from precipitation in the coming century. The dry season in vegetation period in late spring and summer indicates water is scarce and in need. However, slight increase in precipitation in DJF helps minimize the need for winter wheat.

These conclusions are made with certain assumptions and limitations. The main assumption that may affect the effectiveness of this study is that this analysis assumes to one site in Fergana Valley and only assumes cotton and winter wheat. Any further research on this topic should include more sites in different climate zones and more crop patterns. Further research in this area should aim to extend these findings to other areas of the Central Asia regions. Although climate change may not have a large impact on rainfall patterns in Fergana, Uzbekistan over the next century, other developing countries may face large changes in rainfall patterns and thus return different results on effectiveness of rainfall contribution irrigation. Additionally, further research could determine the threshold precipitation amounts that make it effective, ineffective, or unnecessary in areas of varying rainfall. Additionally, the box and whisker plots that reflect the solid increase in Tmin, Tmaxand decrease of precipitation in summer at this site indicates higher crop water demand. Farmer who crops cotton will have less rainfall to winter wheat farmer. Fair allocation of excess winter water to cotton growers could motivate the studies of groundwater banking into regional aquifers to make use of it during summer time.

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