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CLIMATE SCENARIOS 2011-2040 DISTRICTS HARIPUR, SWABI, ATTOCK AND CHAKWAL PAKISTAN

CLIMATE CHANGE CENTRE
THE UNIVERSITY OF AGRICULTURE
PESHAWAR - PAKISTAN

Conducted for:
Up-scaling WUMP+3R
Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED)
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This report has been thoroughly discussed in stakeholders' workshop on 23rd June 2014 in Islamabad and various consequences of changes in temperature and rainfall were interpreted to draw recommendations for the project (chapter 5).

LIST OF ACRONYMS

BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters
CCC	Climate Change Centre
CDPC	Climate Data Processing Centre
CMIP	Coupled Model Intercomparison Project
DFID	Department For International Development
IC	Intercooperation
PMD	Pakistan Meteorological Department
RCP	Representative Concentration Pathways
UAP	The University of Agriculture Peshawar

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Rainfall and temperature scenarios of four rainfed districts of Pakistan were studied using the newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5) and appropriate statistical downscaling. Based on CMIP5 using the RCP2.6 scenarios, the projections for the two main variables, surface temperature and precipitation have been developed using only one ensemble mean of CMIP5 models. This report provides multi-model temperature and precipitation projections for Pakistan for the period 2011-2040 using the baseline data of 1981-2010.

In short, following temperature and rainfall variations have been projected till 2040:

Table 1: Summarised Rainfall and Temperature trends during 2011-2040

	Rainfall Scenario 2011-2040 (Average mm from base period 1981-2010)					Temperature Scenario 2011-2040 (Average °C from base period 1981-2010)								
Districts	Annual rainfall	Winter	Spring	Summer	Fall	Annual temp	Winter		Spring		Summer		Fall	
							Max	Min	Max	Min	Max	Min	Max	Min
Haripur	↷	↘	↗	↘	↘	↗	↗	↗	↗	↘	↗	→	↗	↗
Swabi	↷	↘	↗	→	↘	↗	↗	↘	↗	↘	↗	↗	↗	↗
Attock	↷	↘	↗	↗	↘	↗	↗	↘	↗	↘	↗	↗	↗	↗
Chakwal	↗	↘	↗	↗	↘	↗	↗	↘	↗	↘	↗	↗	↗	↗
Legend	↷ Initially increasing, then decreasing ↷ Initially increasing, then steady					↗ Trend towards increasing rain / temperature ↘ Tends towards decreasing rain / temperature								

In Haripur district, the annual rainfall may continue to increase during next two decades with a rate of 4% per decade from the base line. Then it may decrease during 2031-2040 with a rate of 2%. As a whole, except for spring, rains are decreasing in all the seasons. In summer the decrease is not consistent. It is initially on the increasing side and then decreases in the last decade of the study period. The annual average temperature is increasing gradually. The annual average temperature of base line period is 21.32 °C, which is likely to reach 22.77 °C up to 2040. The average temperature of winter is increasing, indicating winters are getting warmer. The average temperature of spring is decreasing, indicating spring is getting colder. The average temperatures of summer & falls are increasing, indicating that summers and falls are getting hotter. Winter days and nights are getting warmer.

Spring days are getting warmer and nights are getting cooler. Summer and fall days are getting hotter and no change observed in night temperatures of summers. Fall nights are becoming warmer.

These temperature trends, when seen together with the rainfall trends, suggests that Haripur will face dryer situation with time, with an exception of spring, in which temperatures are slightly cooler (interpreted as extended winter) with more rains.

Decrease in winter rainfall and increase in temperature will impact growth and productivity of winter crops due to water stress. Increase in temperature will adversely affect the grain formation stage of wheat.

In Swabi, the Annual rainfall may continue to increase during next two decades with a rate of 5% per decade from the base line. Then it may be stable during 2031-2040 with a rate of 2%. The winter rainfall is continuously decreasing – with a rate of 7.6% per decade. The spring rainfall is continuously increasing with a rate of 7% per decade. The summer (monsoon) rainfall indicates an increasing trend during next two decades - with a rate of 12% per decade. Then it may be stable during third decade (2031-2040). The fall season is indicating a continuous decreasing trend during next three decades. As a whole, rainfall in fall and winter is on decreasing side, whereas spring and summer rains are increasing. Annual average temperature is increasing gradually from base 20.91°C to 22.81°C up to 2040. The average temperature of winter is increasing slightly. The average spring temperature is increasing. The average temperatures of summer and falls are increasing, indicating summers and falls are getting even hotter. All day and night temperatures are increasing except winter and spring nights are becoming cooler.

This trend, together with reduced rain in winter and fall indicates certain worries for winter crops. There is a fear of drought during this period. Summer is to be studied more carefully since increase in rain is insignificant but temperature increase may cause more evapo-transpiration.

Due to decrease in winter rains and subsequent increase in spring rains, the productivity of wheat crop will be affected. There will be a negative impact on production and quality of vegetables and fruits. Summer crops will benefit from increased rain in spring and summer.

In case of Attock, annual rainfall may continue to increase during next two decades with a rate of 5% per decade from the base line. Then it may be stable during third decade (2031-2040). The winter rainfall is continuously decreasing with a rate of 7% per decade. The spring rainfall is endlessly increasing with a rate of 7% per decade. The summer (monsoon) rainfall indicates an increasing trend during next two decades - with a rate of 11% per decade. Then it becomes steady during third decade (2031-2040). The fall season is indicating a continuous decreasing trend during next three decades. As a whole, fall and winter rains are reducing and spring and

summer rains are increasing. Annual average temperature is increasing gradually from 21.79 °C to 23.49°C up to 2040. The average temperature of winter is increasing slightly, indicating winters are getting warmer. The average temperature of spring is increasing, indicating spring is getting warmer. The average temperatures of summer and falls are also increasing, indicating summers and falls are getting hotter. All day and night temperatures are increasing except winter and spring where nights are becoming cooler.

In case of spring, day and night difference is increasing which may be worth looking into by crop scientists. While fall and spring day temperatures are increasing, rainfalls are reducing which may have consequences in the form of drought.

Increasing early summer temperature will cause reduction of grain, size and weight. Decreases of about 7% per decade winter rainfall will negatively impact crops especially wheat and animal production. Increased rain in spring/ early summer is beneficial for groundnut growth and productivity. Insect pest occurrence may possibly increase in groundnut due to increased water and humidity as a result of increased rain and rising temperature. Increased rain in late winter and early summer may result in improved pastures and better fodder for livestock. However, increased temperature and humidity may result in disease spread in animals.

In case of Chakwal, the annual rainfall may continue to increase with a rate of 8.5% per decade from the base line during next two decades, and with a rate of 3.6% during third decade (2031-2040). The winter rainfall is indicating decreasing trends in next three decades with a rate of 6%, 5% and 12% respectively. The spring rainfall is endlessly increasing with a rate of nearly 11.5% per decade. The summer (monsoon) rainfall indicates increasing trends - with a high rate of 12% per decade during next two decades, and with a rate of 5% during third decade (2031-2040). The fall season is indicating a continuous decreasing trend during next three decades. As a whole, fall and winter rains are reducing and spring and summer rains are increasing. The annual average temperature is increasing gradually from 22.16°C to 23.56°C up to 2040. The average temperature of winter is decreasing, indicating winters are likely to become colder. The average temperature of spring is increasing, indicating spring is getting warmer. The average temperatures of summer and falls are also increasing. Winter and spring days are getting warmer and nights are getting cooler. Summer and fall days and nights are getting hotter.

Fall and winter rains are decreasing. With days becoming warmer the consequence may be drought.

Increase in annual rainfall will result in soil erosion in already fragile landscape of Chakwal. Integrated watershed management is suggested including construction of runoff harvesting structures, water storage structures and in-situ rainwater harvesting. Decrease in early winter rainfall will result in crop failure. More rainfall in spring will increase survival percentage of forest and fruit tree species. Increasing monsoon rainfall trends may result in pounding of crops especially groundnut.

2. STUDY AREAS

Four districts of Pakistan, mostly relying on rainfed agriculture system have been considered in this study. Climate change is already affecting agriculture, water sectors and the livelihoods of northern parts of Pakistan where these four districts are located.

According to Köppen Climate Classification[1], the climate of this region is humid subtropical climate with hot summers and cold winters. The map of four study areas (districts) considered in this report is highlighted in Figure 1.

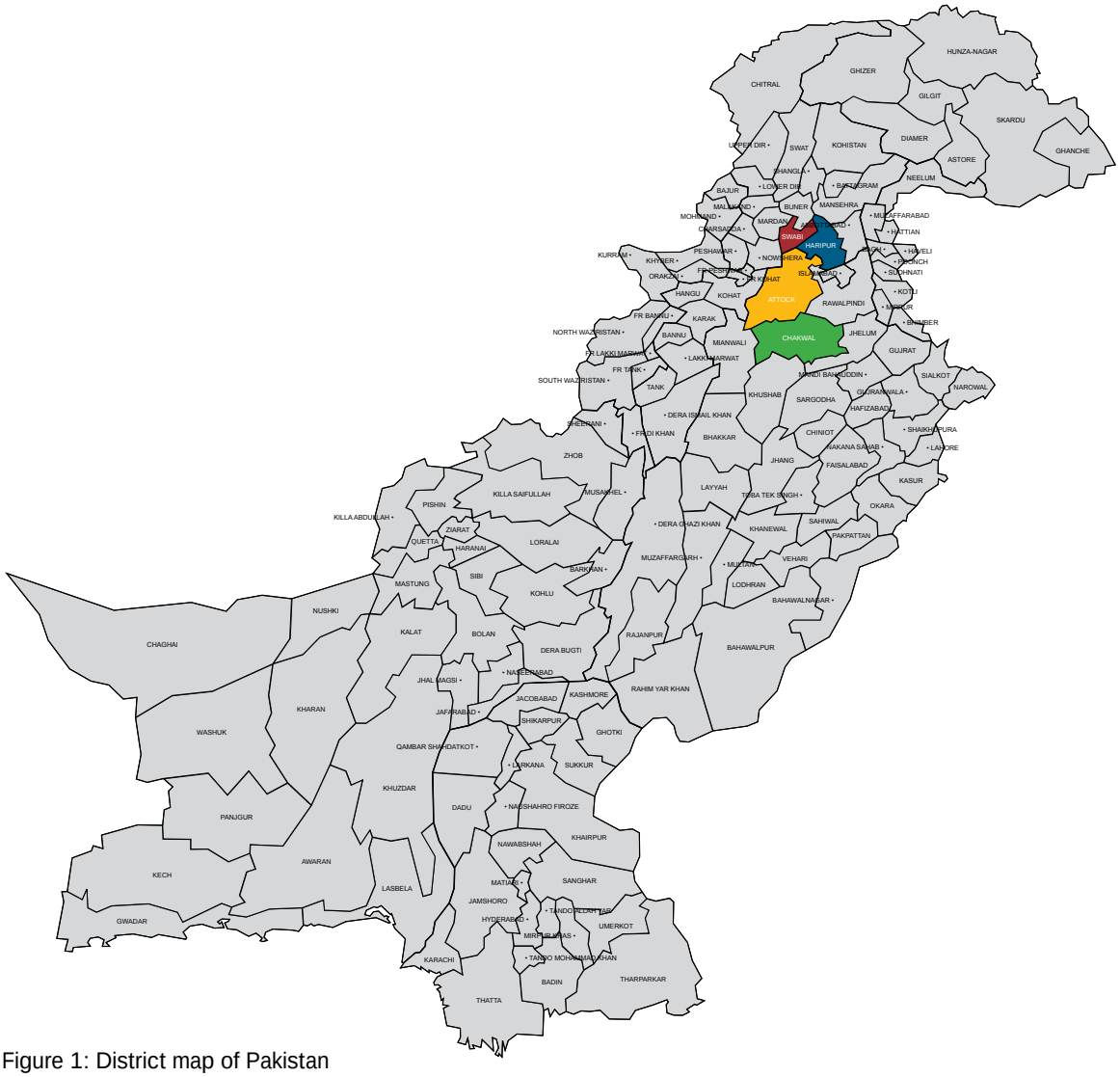


Figure 1: District map of Pakistan

[1]The Köppen climate classification is one of the most widely used climate classification systems. It was first published by Russian German climatologist Wladimir Köppen in 1884, with several later modifications by Köppen himself, notably in 1918 and 1936. Later, German climatologist Rudolf Geiger collaborated with Köppen on changes to the classification system, which is thus sometimes referred to as the Köppen–Geiger climate classification system. The system is based on the concept that native vegetation is the best expression of climate. Thus, climate zone boundaries have been selected with vegetation distribution in mind. It combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation. http://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification June 2014.

3. METHODOLOGY AND DATA INTERPRETATION

Climate projections for four districts of Pakistan are made using the newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5) and appropriate statistical downscaling. The CMIP5 ensemble mean climate is closer to observed climate and therefore current work is based on CMIP5 model output. In CMIP5, four RCP scenarios: RCP2.6, RCP4.5, RCP6.0 and RCP8.5 which represent pathways of radioactive forcing, have been used. For computation of rainfall and temperature scenarios of four districts (Haripur, Swabi, Attock and Chakwal) for the next three decades, RCP2.6 pathway has been used. Under RCP2.6 scenario greenhouse gas emissions and emissions of air pollutants are reduced substantially over time by 2100.

CMIP5 models are generally of higher resolution and are available at common spatial scale of 0.5 × 0.5 deg resolution. The CMIP5 model data is freely available for research purpose to scientific community. The CMIP5 model data is available for different forcing factors. Only CO2 emission data based on RCP2.6 has been used in the present work to develop the climate scenarios. For this study, only two variables, rainfall and temperatures were required. The required data were extracted from climate explorer (http://climexp.knmi.nl) and was simulated on decadal basis. The results were bias corrected with climate of the region. Statistical downscaling was used to run the precipitation and temperature scenarios for the study areas. Finally, the projected decadal scenarios have been compared with the base line period and with the previous decade to understand the rate of change of climate variables. The decadal CMIP5 scenario runs for four study areas have been shown separately in tabular and graphical form in the next section. The observational rainfall and temperature data of 1981-2010 have been used as a base line collected from Climate Data Processing Centre (CDPC) of Pakistan Meteorological Department (PMD).

In the present study, based on CMIP5 using the RCP2.6 scenarios, the projections for the two main variables, surface temperature and precipitation, for four districts of Pakistan have been developed using only one ensemble mean of CMIP5 models. This report provides multi-model temperature and precipitation projections for Pakistan for the period 2011-2040 using the base line data of 1981-2010.

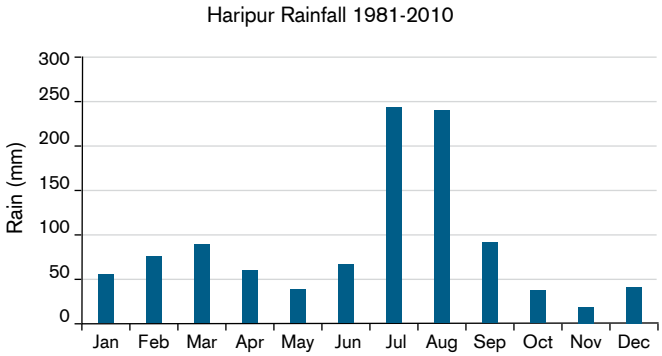
The temperature and precipitation projections for four districts were presented to the participants of stakeholders' workshops held in Islamabad on 23rd June 2014 to discuss possible implications of the projections for farming systems in the districts. The participants were divided into four groups and each group discussed projections and implications for one district. Each projection was thoroughly discussed and various consequences of changes in temperature and rainfall were interpreted for agriculture and water sectors to draw recommendations for the project (chapter 5). The participants included experts from The University of Agriculture Peshawar, Intercooperation Pakistan, Lead Pakistan, Soil and Water Conservation Institute Punjab, Farm Services Centre Khyber Pakhtunkhwa (KP), On-farm Soil and Water Conservation Department KP and district based NGOs.

4. RESULTS

4.1 HARIPUR

Haripur lies in KP province and its geographical coordinates are 33° 59' 50" North, 72° 56' 1" East. It is located in a hilly and plain area at an altitude of 520 m along Karakoram Highway. Climate of Haripur is characterized by relatively high temperatures and evenly distributed precipitation throughout the year, which is Humid Subtropical Climate according to the Köppen Climate Classification. Monsoon is the major rainy season of Haripur district with July and August as peak rainy months. According to the climate of 1981-2010 (base line period), the annual rainfall of Haripur District is 1065.8mm with a major contribution of 643.8mm of monsoon season. Haripur district is one of the wettest districts of Pakistan where rainfall is almost equally distributed throughout the year. Monthly average rainfall of base line period (1981-2010) is displayed in Figure 2.

Fig 2: Haripur - Monthly average rainfall of base line period (1981-2010)



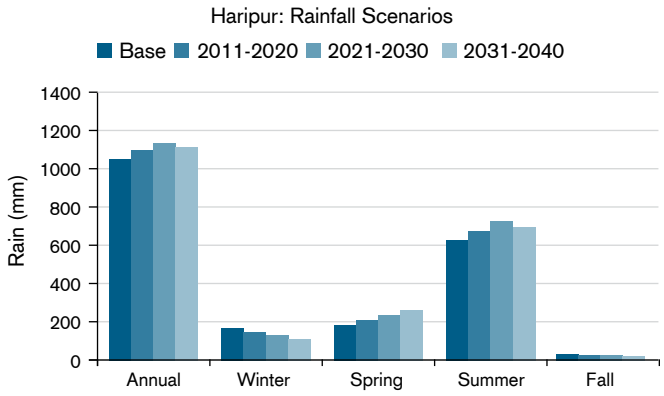
4.1.1 Seasonal rainfall scenarios

The computed rainfall scenarios using the base line data of 1981-2010, for each season with departures from base line period and the preceding decades are shown in Table 2. The projected scenarios for each season are also displayed in Figure 3 for visual examination.

Table 2: Haripur: Seasonal rainfall scenarios (projections & departures for three decades)

Haripur Rainfall (mm)	Base 1981-2010	Projection 2011-2020	% change from Base	Projection 2021-2030	% change from Base	% change from 2011-2020	Projection 2031-2040	% change from Base	% change from 2021-2030
Annual	1065.8	1111.9	4.3	1155.2	8.4	3.9	1133.0	6.3	-1.9
Winter	179.3	160.4	-10.6	142.1	-20.7	-11.4	121.9	-32.0	-14.2
Spring	192.6	219.9	14.2	244.6	27.0	11.2	272.1	41.3	11.2
Summer	643.8	690.8	7.3	733.0	13.8	6.1	709.8	10.2	-3.2
Fall	48.3	40.8	-15.5	35.5	-26.4	-13.0	29.2	-39.5	-17.7

Fig 3: Haripur: Seasonal rainfall projections for three decades



Highlights for rainfall

The computed rainfall scenarios for Haripur District reveal;

- Annual rainfall may continue to increase during next two decades with a rate of 4% per decade from the base line. Then it may decrease during 2031-2040 with a rate of 2%.
- The winter rainfall is continuously decreasing – with a rate of -11.5% per decade.
- The spring rainfall is continuously increasing with a rate of 12% per decade.
- The summer (monsoon) rainfall indicates an increasing trend during next two decades - with a rate of 6.5% per decade. Then it may decrease during third decade (2031-2040) with a rate of -3%.
- The fall season is also indicating a continuous decreasing trend during next three decades.

As a whole, except for spring, rains are decreasing in all the seasons. In summer the decrease is not consistent. It is initially on the increasing side and then decreases in the last decade of the study period.

4.1.2 Temperature Scenarios

The mean monthly maximum and minimum temperatures, according to the base line data (1981-2010) are displayed in the Figure 4. The annual average temperature of Haripur District is 22.1°C.

Figure 4: Mean maximum and minimum temperatures (1981-2010)

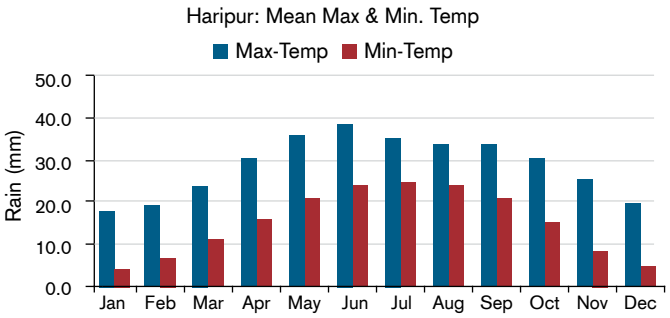


Table 3: Haripur: Annual and seasonal temperature scenarios (projections and departures) for three decades									
Haripur Temp °C Scenarios	Base (1981-2010)	Projected 2011-2020	% Change From Base	Projected 2021-2030	% Change From Base	% change from 2011- 2020	Projected 2031-2040	% Change From Base	% change from 2021-2030
Annual									
Average	21.32	21.62	1.41	22.12	3.75	2.31	22.77	6.80	2.94
Minimum	14.25	14.00	-1.76	13.85	-2.81	-1.07	13.60	-4.56	-1.81
Maximum	28.39	28.59	0.70	28.89	1.76	1.05	29.34	3.35	1.56
Winter									
Average	12.28	12.58	2.44	13.08	6.51	3.97	13.73	11.81	4.97
Minimum	5.18	5.28	1.93	5.48	5.80	3.79	5.68	9.66	3.65
Maximum	19.38	19.88	2.58	20.53	5.93	3.27	21.28	9.80	3.65
Spring									
Average	23.28	23.08	-0.84	22.70	-2.48	-1.65	22.60	-2.91	-0.44
Minimum	16.22	16.00	-1.38	15.50	-4.46	-3.13	15.00	-7.54	-3.23
Maximum	30.00	30.60	2.00	31.30	4.33	2.29	32.10	7.00	2.56
Summer									
Average	29.62	29.92	1.01	30.42	2.70	1.67	31.07	4.90	2.14
Minimum	24.00	24.10	0.42	24.20	0.83	0.41	24.25	1.04	0.21
Maximum	35.50	36.00	1.41	36.80	3.66	2.22	37.70	6.20	2.45
Fall									
Average	20.11	20.41	1.49	20.91	3.98	2.45	21.56	7.21	3.11
Minimum	11.87	12.17	2.53	12.67	6.74	4.11	13.32	12.21	5.13
Maximum	28.34	28.64	1.06	29.14	2.82	1.75	29.79	5.12	2.23

Figure 5: Temperature anomalies for next three decades using base line period (1981-2010)

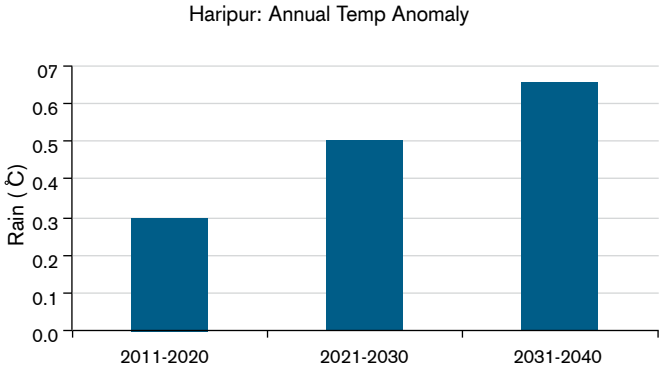


Figure 6: Annual and seasonal mean temperature projections for next three decades

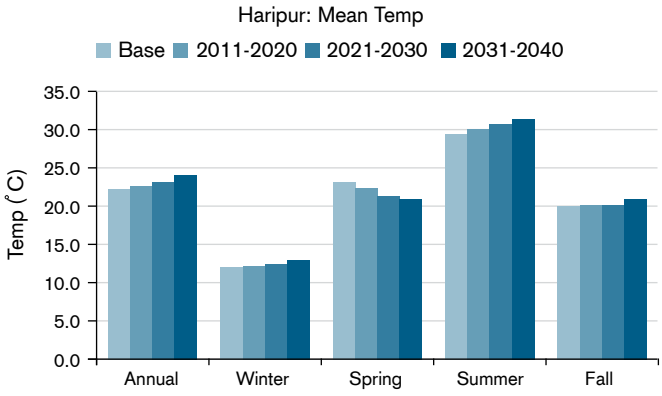


Figure 7: Annual and seasonal mean maximum temperature projections for next three decades

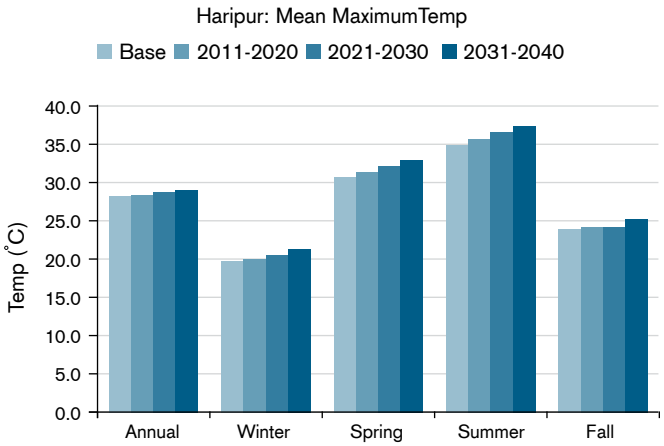
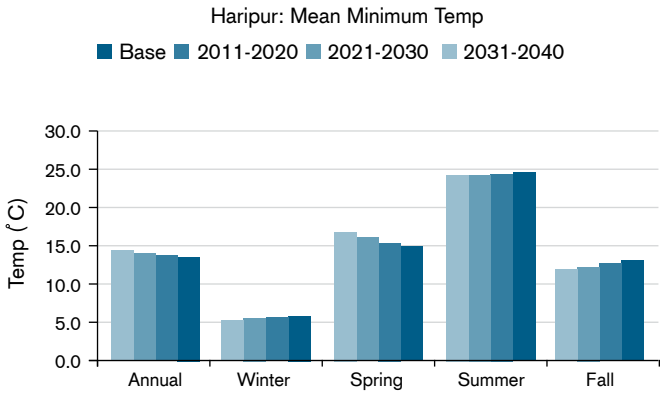


Figure 8: Annual and seasonal mean minimum temperature projections for next three decades



Highlights for temperature

The projected average annual and average seasonal temperatures of Haripur district for next three decades (Figure 6) indicate;

- Annual average temperature is increasing gradually. The annual average temperature of base line period is 21.32 °C, which is likely to reach 22.77°C up to year 2040.
- The average temperature of winter is increasing, indicating winters are getting warmer.
- The average temperature of spring is decreasing, indicating spring is getting colder.
- The average temperatures of summer & falls are also increasing, indicating that summers and falls are getting hotter.

The projected annual and seasonal mean maximum temperatures of Haripur district for next three decades (Figure 7) indicate;

- Winter and spring days are getting warmer.
- Summer and fall days are getting hotter.

The projected annual and seasonal mean minimum temperatures of Haripur district for next three decades (Figure 8) indicate;

- Winter nights are becoming warmer.
- Spring nights are getting cooler.
- No change observed in summer night temperatures.
- Fall nights are becoming warmer.

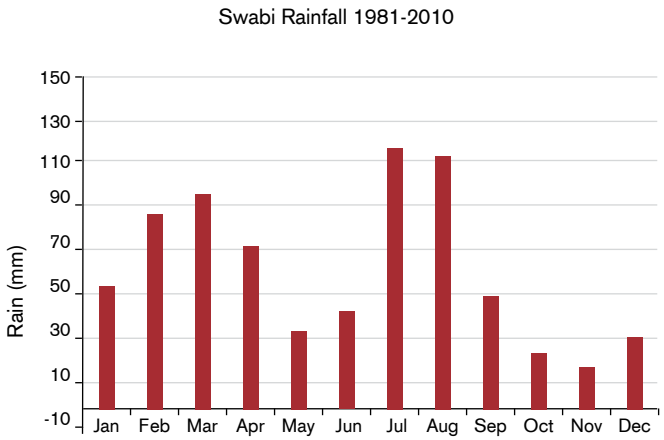
These temperature trends, when seen together with the rainfall trends, suggest that Haripur will face dryer situations with time, with an exception of spring, where temperatures are slightly cooler (interpreted as extended winter) with more rains.

4.2 SWABI

4.2.1 Seasonal Rainfall Scenarios

Swabi District in the Khyber Pakhtunkhwa province, located at 34°7'0N 72°28'0E between the Indus and Kabul Rivers. Tobacco is a cash crop of the irrigated Swabi belt, along with vegetables, wheat, sugar cane and maize. Its climate is well suited for citrus fruits in particular, but many other fruits like watermelon, peaches and apricots are also grown there. The monthly average rainfall of base line period (1981-2010) is displayed in Figure 9.

Figure 9: Monthly average rainfall of base line period (1981-2010)

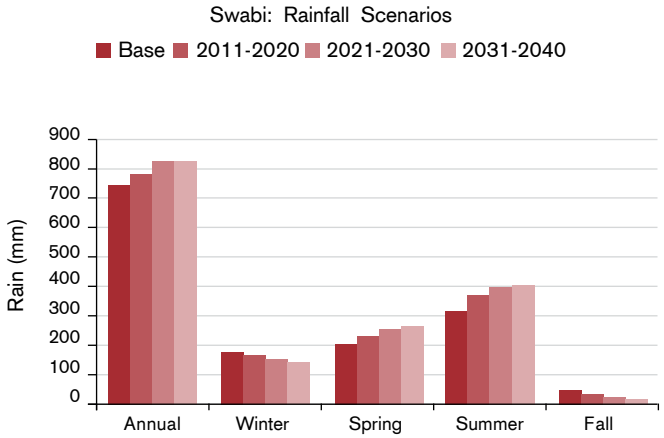


The computed rainfall scenarios using the base line data of 1981-2010, for each season with departures from base line period and the preceding decades are shown in Table 4. The projected scenarios for each season are also displayed in Figure 10 for visual examination.

Table 4: Swabi: Seasonal rainfall scenarios (projections & departures for three decades)

Swabi Rainfall (mm)	Base 1981-2010	Projection 2011-2020	% change from Base	Projection 2021-2030	% change from Base	% change from 2011-2020	Projection 2031-2040	% change from Base	% change from 2021-2030
Annual	744.0	784.7	5.5	820.7	10.3	4.6	820.2	10.2	-0.1
Winter	177.3	164.9	-7.0	151.7	-14.4	-8.0	140.1	-21.0	-7.7
Spring	203.8	220.1	8.0	235.5	15.6	7.0	249.5	22.4	5.9
Summer	319.9	362.5	13.3	401.3	25.4	10.7	400.7	25.2	-0.1
Fall	43.0	37.3	-13.2	32.2	-25.0	-13.7	30.8	-28.3	-4.3

Figure 10: Swabi: Seasonal rainfall projections for three decades



Highlights for rainfall

The computed rainfall scenarios for Swabi District reveal that:

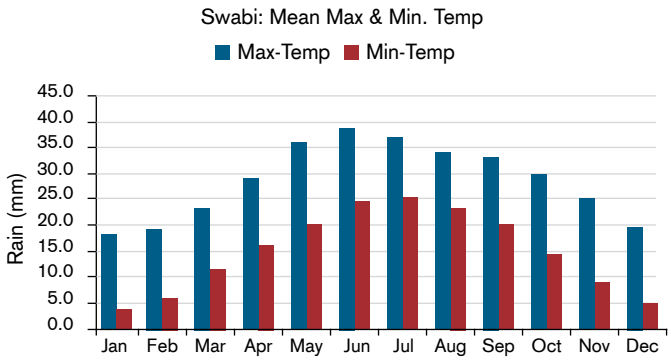
- Annual rainfall may continue to increase during next two decades with a rate of 5% per decade from the base line. Then it may be stable during 2031-2040 with a rate of 2%.
- The winter rainfall is continuously decreasing – with a rate of -7.6% per decade. This is a significant decrease.
- The spring rainfall is continuously increasing with a rate of 7% per decade, a significant increase.
- The summer (monsoon) rainfall indicates an increasing trend during next two decades - with a rate of 12% per decade. Then it may be stable during third decade (2031-2040).
- The fall season is indicating a continuous decreasing trend during next three decades.

As a whole, rainfall in winter and fall is on a decreasing trend, whereas spring and summer rains are increasing.

4.2.2 Temperature Scenarios

The mean monthly maximum and minimum temperatures, according to the base line data (1981-2010) are displayed in the Figure 11. The annual average temperature of Swabi District is 28.6°C.

Figure 11: Swabi - Mean maximum and minimum temperatures (1981-2010)



Annual and seasonal temperature scenarios (projections & departures) for next three decades are shown in Table 5.
Decadal temperature increase (anomalies of base line period) in next three decades is shown in Figure 12.
Annual and seasonal mean temperature projections for next three decades with base line data are displayed in Figure 13.
Annual and seasonal mean maximum temperature projections for next three decades are displayed in Figure 14.
Annual and seasonal mean minimum temperature projections for next three decades are displayed in Figure 15.

Table 5: Swabi: Annual and seasonal temperature scenarios (projections & departures) for three decades									
Swabi Temp (°C) Scenarios	Base (1981-2010)	Projected 2011-2020	% Change From Base	Projected 2021-2030	% Change From Base	% change from 2011-2020	Projected 2031-2040	% Change From Base	% change from 2021-2030
Annual									
Average	20.91	21.36	2.15	22.01	5.26	3.04	22.81	9.09	3.63
Minimum	13.92	14.47	3.95	15.32	10.05	5.87	16.32	17.24	6.53
Maximum	27.89	28.24	1.25	28.69	2.87	1.59	29.29	5.02	2.09
Winter									
Average	11.76	11.90	1.17	12.00	2.02	0.84	12.20	3.72	1.67
Minimum	4.93	4.63	-6.09	4.18	-15.23	-9.73	3.58	-27.41	-14.37
Maximum	18.60	19.35	4.03	20.24	8.82	4.60	21.44	15.27	5.93
Spring									
Average	22.53	22.98	2.00	23.63	4.88	2.83	24.43	8.43	3.39
Minimum	15.60	15.40	-1.31	15.20	-2.59	-1.30	15.00	-3.87	-1.32
Maximum	29.46	30.21	2.55	31.26	6.11	3.48	32.51	10.35	4.00
Summer									
Average	29.67	30.12	1.52	30.77	3.71	2.16	31.57	6.40	2.60
Minimum	23.53	23.78	1.06	24.23	2.98	1.89	24.83	5.53	2.48
Maximum	35.81	36.46	1.82	37.31	4.19	2.33	38.31	6.98	2.68
Fall									
Average	19.68	20.13	2.29	20.78	5.59	3.23	21.58	9.66	3.85
Minimum	11.64	12.09	3.87	12.74	9.45	5.38	13.54	16.32	6.28
Maximum	27.71	28.16	1.62	28.81	3.97	2.31	29.61	6.86	2.78

Figure 12: Temperature anomalies for next three decades using base line period (1981-2010)

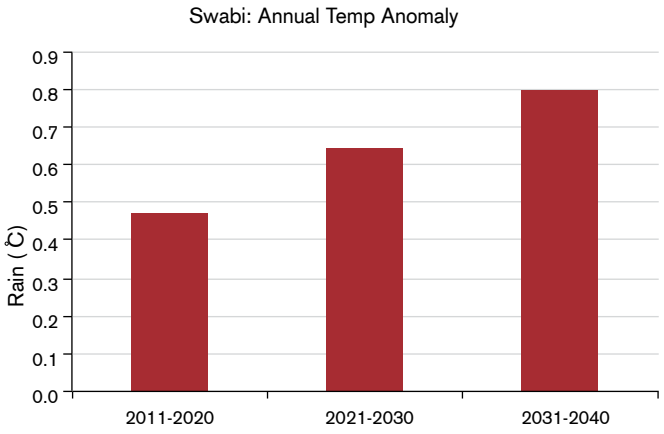


Figure 13: Annual and seasonal mean temperature projections for next three decades

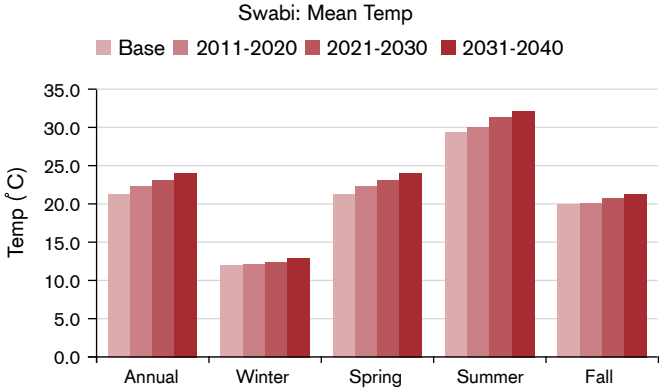


Figure 14: Annual and seasonal mean maximum temperature projections for next three decades

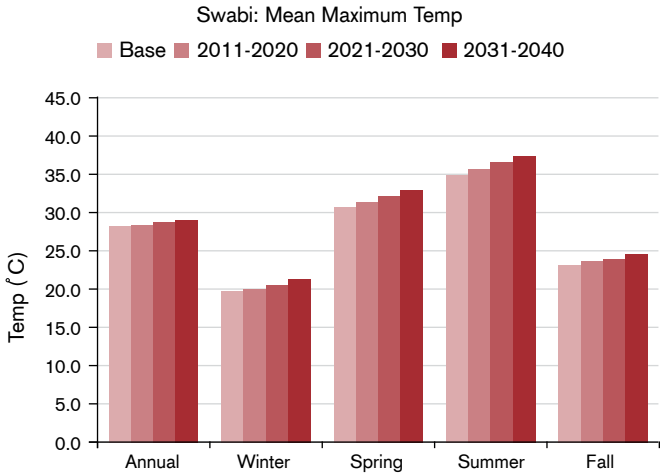
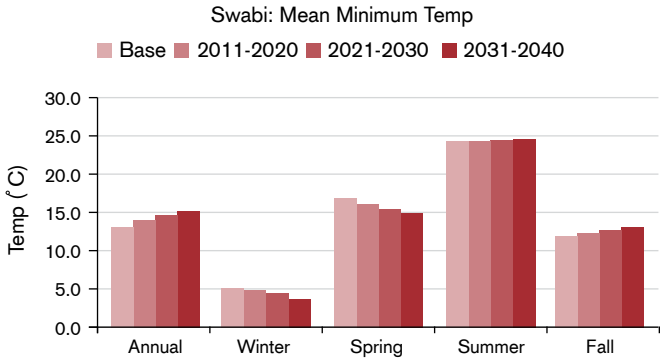


Figure 15: Annual and seasonal mean minimum temperature projections for next three decades



Highlights for temperature

The projected average annual and average seasonal temperatures of Swabi district for next three decades (Figure 13) indicate:

- Annual average temperature is increasing gradually. The annual average temperature of baseline period is 20.91 °C, which is likely to reach 22.81°C up to year 2040.
- The average temperature of winter is increasing slightly, indicating winters are getting a little warmer.
- The average temperature of spring is increasing, indicating spring is getting warmer.
- The average temperatures of summer & falls are also increasing, indicating summers and falls are getting even hotter.

The projected annual and seasonal mean maximum temperatures of Swabi district for next three decades (Figure 14) indicate:

- Winter and spring days are getting warmer.
- Summer and fall days are getting hotter.

The projected annual and seasonal mean minimum temperatures of Swabi district for next three decades (Figure 15) indicate:

- Winter and spring nights are becoming cooler. This indicates high temperature difference between day and night.
- Summer and fall nights are becoming warmer, which is consistent with increase in mean maximum temperature.

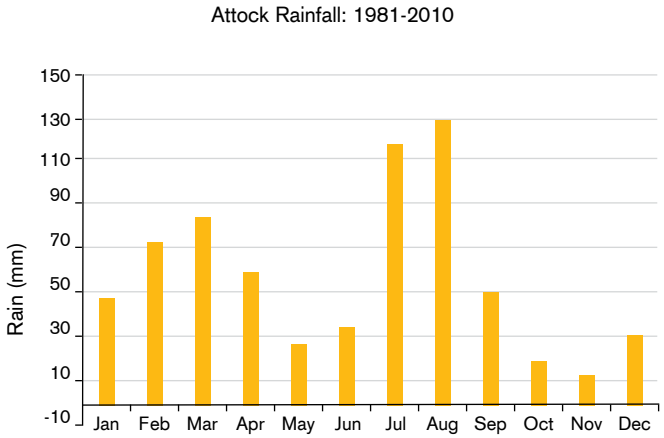
This trend, together with reduced rain in fall and winter indicates certain worries for winter crops. There is a fear of drought during this period. Summer is to be studied more carefully since increase in rain is insignificant but temperature increase may cause more evapo-transpiration.

4.3 ATTOCK

4.3.1 Rainfall Scenarios

Attock District is located in the northern border of the Punjab province; on the bank of the Indus. Attock District has a climate of hot summers and cold winters. The northern part of the district is more humid and is more moderate in climate relative to the southern part of the district due to the higher altitude. Geographically, the district is mainly hills, plateaus and dissected plains. The Indus River flows on the northern and western borders of the district. The monthly average rainfall of baseline period (1981-2010) is displayed in Figure 16.

Figure 16: Monthly average rainfall of base line period (1981-2010)

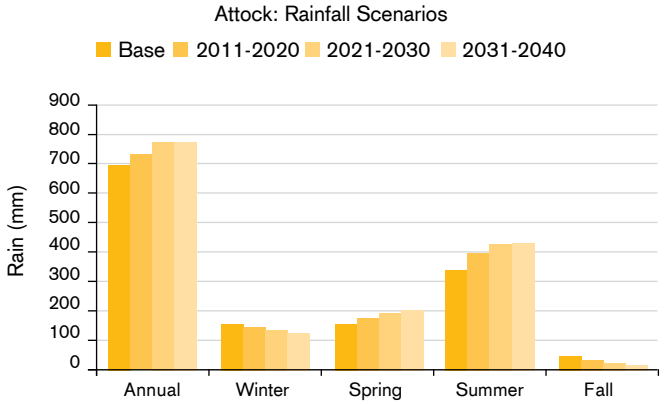


The computed rainfall scenarios using the base line data of 1981-2010, for each season with departures from base line period and the preceding decades are shown in Table 6. The projected scenarios for each season are also displayed in Figure 17 for visual examination.

Table 6: Attock: Seasonal rainfall scenarios (projections & departures for three decades)

Attock Rainfall (mm)	Base 1981-2010	Projection 2011-2020	% change from Base	Projection 2021-2030	% change from Base	% change from 2011-2020	Projection 2031-2040	% change from Base	% change from 2021-2030
Annual	691.6	726.4	5.0	762.9	10.3	5.0	763.1	10.3	0.0
Winter	148.5	136.6	-8.0	124.3	-16.3	-9.0	111.9	-24.7	-10.0
Spring	168.2	180.0	7.0	192.6	14.5	7.0	204.7	21.7	6.3
Summer	341.0	383.7	12.5	420.9	23.4	9.7	428.4	25.6	1.8
Fall	33.4	26.7	-20.2	22.3	-33.3	-16.5	18.2	-45.6	-18.4

Fig 17: Attock: Seasonal rainfall projections for three decades



Highlights for rainfall

The computed rainfall scenarios for Attock District reveal:

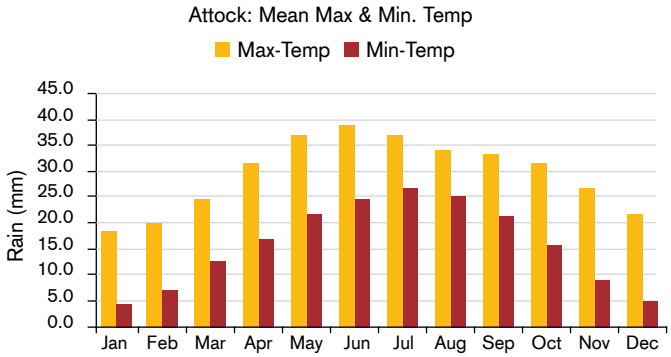
- Annual rainfall may continue to increase during next two decades with a rate of 5% per decade from the base line. Then it may be stable during the third decade (2031-2040).
- The winter rainfall is continuously decreasing with a rate of -7% per decade. This is a relatively high change.
- The spring rainfall is endlessly increasing with a rate of 7% per decade, a significant increase.
- The summer (monsoon) rainfall indicates an increasing trend during next two decades - with a rate of 11% per decade which is relatively high. Then it becomes steady during third decade (2031-2040).
- The fall season is indicating a continuous decreasing trend during the next three decades.

As a whole, fall and winter rains are reducing and spring and summer rains are increasing.

4.3.2 Temperature Scenarios

The mean monthly maximum and minimum temperatures, according to the base line data (1981-2010) are displayed in the Figure 18 below. The annual average temperature of Attock District is 29.4°C.

Figure 18: Attock - Mean maximum and minimum temperatures (1981-2010)



Annual and seasonal temperature scenarios (projections & departures) for next three decades are shown in Table 7. Decadal temperature increase (anomalies of baseline period) in the next three decades is shown in Figure 19. Annual and seasonal mean temperature projections for next three decades with base line data are displayed in Figure 20. Annual and seasonal mean maximum temperature projections for next three decades are displayed in Figure 21. Annual and seasonal mean minimum temperature projections for next three decades are displayed in Figure 22.

Table 7: Attock: Annual and seasonal temperature scenarios (projections & departures) for three decades									
Attock Temp (°C) Scenarios	Base (1981-2010)	Projected 2011-2020	% Change From Base	Projected 2021-2030	% Change From Base	% change from 2011- 2020	Projected 2031-2040	% Change From Base	% change from 2021-2030
Annual									
Average	21.79	22.14	1.61	22.74	4.36	2.71	23.49	7.80	3.30
Minimum	14.79	15.24	3.04	15.94	7.77	4.59	16.89	14.20	5.96
Maximum	28.79	29.04	0.87	29.54	2.61	1.72	30.09	4.52	1.86
Winter									
Average	12.64	12.80	1.28	13.20	4.44	3.12	13.50	6.82	2.27
Minimum	5.54	5.20	-6.11	4.90	-11.53	-5.77	4.50	-18.75	-8.16
Maximum	19.74	20.29	2.79	21.29	7.85	4.93	22.54	14.19	5.87
Spring									
Average	23.67	24.02	1.48	24.62	4.01	2.50	25.37	7.18	3.05
Minimum	16.70	16.50	-1.21	16.30	-2.41	-1.21	16.00	-4.20	-1.84
Maximum	30.64	31.24	1.96	32.14	4.90	2.88	33.34	8.81	3.73
Summer									
Average	30.30	30.65	1.16	31.25	3.14	1.96	32.00	5.61	2.40
Minimum	24.41	24.56	0.61	24.96	2.25	1.63	25.40	4.06	1.77
Maximum	36.18	36.73	1.52	37.53	3.73	2.18	38.03	5.11	1.33
Fall									
Average	20.56	20.91	1.70	21.51	4.62	2.87	22.26	8.27	3.49
Minimum	12.52	12.87	2.80	13.47	7.59	4.66	14.22	13.58	5.57
Maximum	28.59	28.94	1.22	29.54	3.32	2.07	30.29	5.95	2.54

Fig 19: Temperature anomalies for next three decades using base line period (1981-2010)

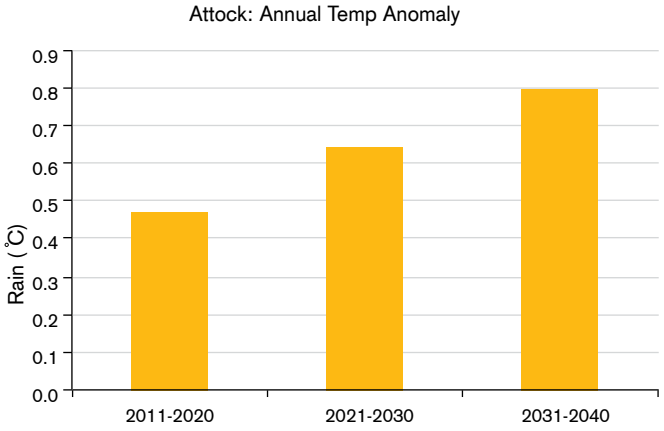


Fig 20: Annual and seasonal mean temperature projections for next three decades

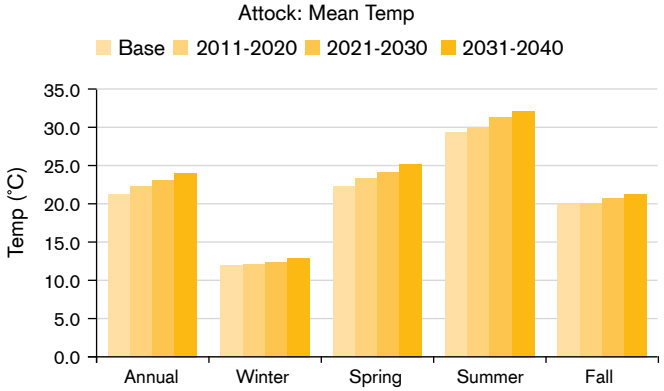


Fig 21: Annual and seasonal mean maximum temperature projections for next three decades

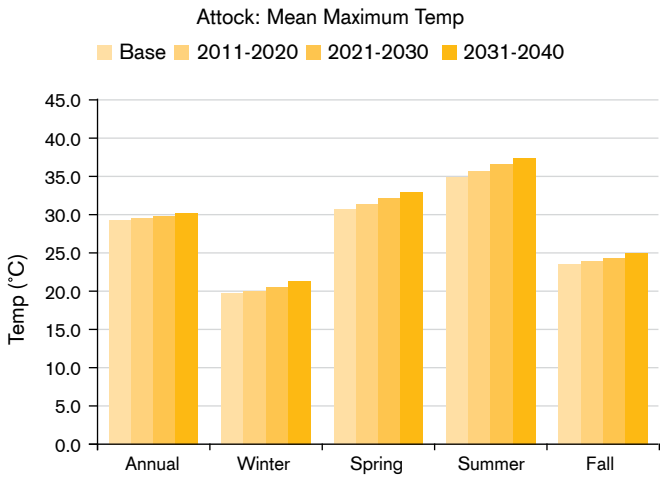
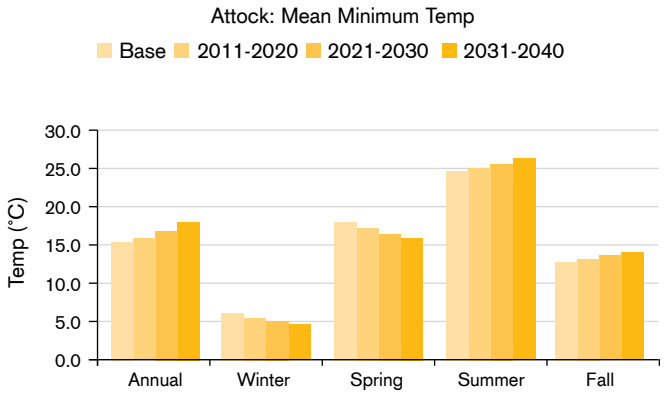


Fig 22: Annual and seasonal mean minimum temperature projections for next three decades



Highlights for temperature

The projected average annual and average seasonal temperatures of Attock district for next three decades (Figure 20) indicate:

- Annual average temperature is increasing gradually. The annual average temperature of base line period is 21.79 °C, which is likely to reach 23.49°C up to year 2040.
- The average temperature of winter is increasing slightly, indicating winters are getting warm.
- The average temperature of spring is increasing, indicating spring is getting warmer.
- The average temperatures of summer & falls are also increasing, indicating summers & falls are getting hotter.

The projected annual and seasonal mean maximum temperatures of Attock district for next three decades (Figure 21) indicate;

- Winter days are getting warmer.
- Spring days are likely to become warmer.
- Summer and fall days are getting hotter.

The projected annual and seasonal mean minimum temperatures of Attock district for next three decades (Figure 22) indicate;

- Winter and spring nights are becoming cooler.
- Summer and fall nights are becoming warm.

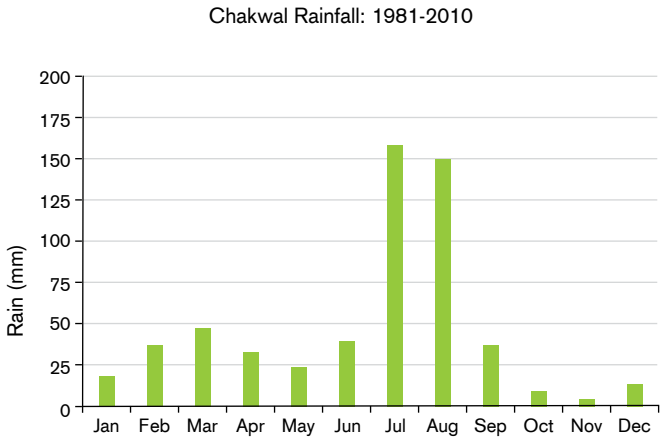
In case of spring, day and night difference is increasing which may be worth looking into by crop scientists. While fall and spring day temperatures are increasing, rainfalls are reducing which may have consequences in the form of drought.

4.4 CHAKWAL

4.4.1 Rainfall Scenarios

Chakwal is located in the Dhanni region of the Potohar in northern Punjab, which is a semi-arid area with a shortage of irrigation systems and water sources for agriculture. Over 70% of the population engages in agriculture, mostly subsistence agriculture dependent on rainfall. Monthly average rainfall of base line period (1981-2010) is displayed in Figure 23.

Figure 23: Monthly average rainfall of base line period (1981-2010)

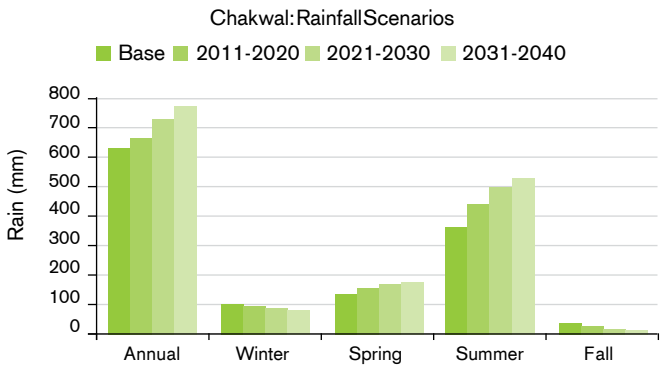


The computed rainfall scenarios using the base line data of 1981-2010, for each season with departures from base line period and the preceding decades are shown in Table 8. The projected scenarios for each season are also displayed in Figure 24 for visual examination.

Table 8: Chakwal: Seasonal rainfall scenarios (projections & departures for three decades)

Chakwal Rainfall (mm)	Base 1981-2010	Projection 2011-2020	% change from Base	Projection 2021-2030	% change from Base	% change from 2011-2020	Projection 2031-2040	% change from Base	% change from 2021-2030
Annual	624.0	673.7	8.0	734.2	17.7	9.0	760.4	21.9	3.6
Winter	90.1	84.7	-6.0	80.5	-10.7	-5.0	70.8	-21.4	-12.0
Spring	120.3	135.1	12.3	149.6	24.4	10.7	163.3	35.8	9.2
Summer	391.3	437.1	11.7	490.4	25.3	12.2	515.1	31.6	5.0
Fall	21.8	17.3	-20.5	13.6	-37.5	-21.4	11.2	-48.6	-17.6

Figure 24: Annual and seasonal rainfall projections for three decades



Highlights for rainfall

The computed rainfall scenarios for Chakwal District reveal;

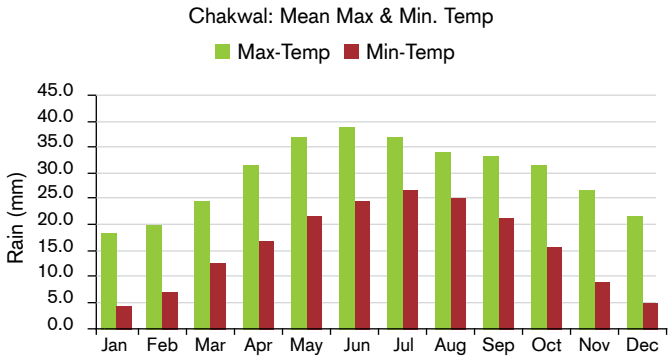
- Annual rainfall may continue to increase with a rate of 8.5% per decade from the base line during next two decades, and with a rate of 3.6% during the third decade (2031-2040).
- The winter rainfall is indicating decreasing trends in next three decades with a rate of -6%, -5% and -12% respectively.
- The spring rainfall is endlessly increasing with a rate of nearly 11.5% per decade.
- The summer (monsoon) rainfall indicates increasing trends - with a high rate of 12% per decade during next two decades, and with a rate of 5% during third decade (2031-2040).
- The fall season is indicating a continuous decreasing trend during next three decades.

As a whole, fall and winter rains are reducing and spring and summer rains are increasing.

4.4.2 Temperature Scenarios

The mean monthly maximum and minimum temperatures, according to the base line data (1981-2010) are displayed in the Figure 25 below. The annual average temperature of Chakwal District is 29.6°C.

Figure 25: Mean maximum and minimum temperatures (1981-2010)



Annual and seasonal temperature scenarios (projections & departures) for next three decades are shown in Table 9.
Decadal temperature increase (anomalies of base line period) in next three decades is shown in Figure 26.
Annual and seasonal mean temperature projections for next three decades with base line data are displayed in Figure 27.
Annual and seasonal mean maximum temperature projections for next three decades are displayed in Figure 28.
Annual and seasonal mean minimum temperature projections for next three decades are displayed in Figure 29.

Figure 26: Temperature anomalies for next three decades using base line period (1981-2010)

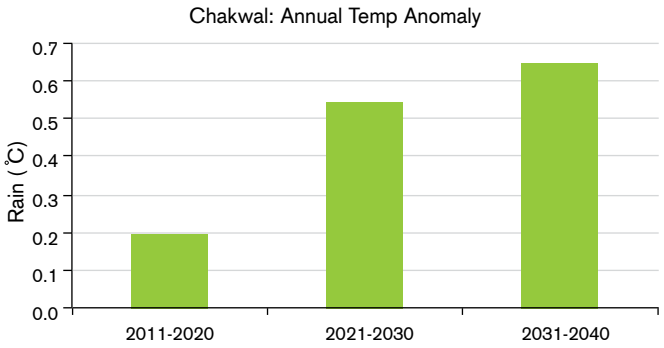


Figure 27: Annual and seasonal mean temperature projections for next three decades

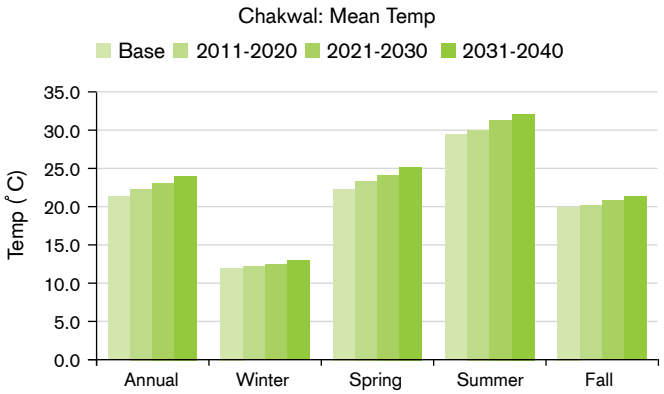


Figure 28: Annual and seasonal mean maximum temperature projections for next three decades

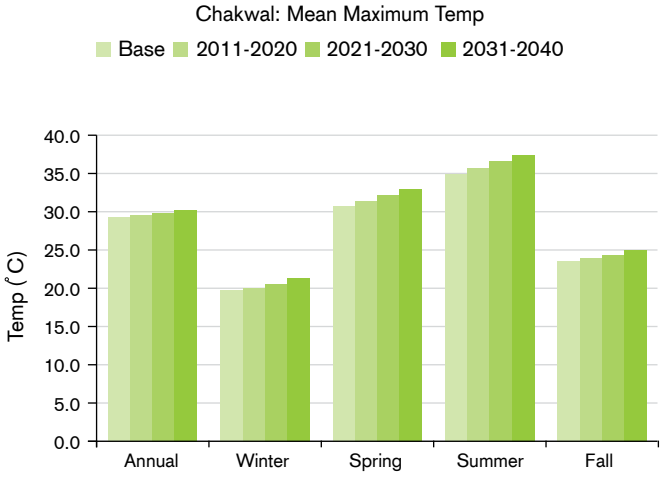
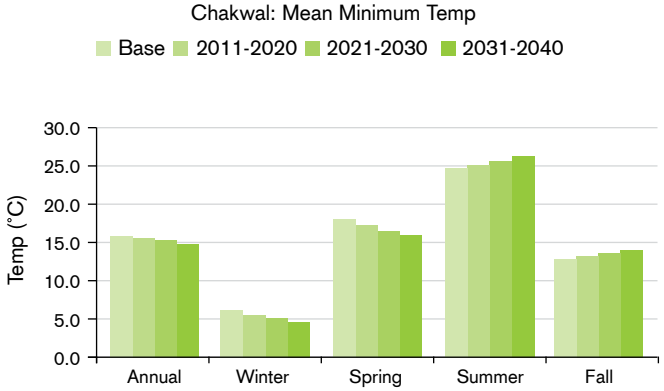


Figure 29: Annual and seasonal mean minimum temperature projections for next three decades



Highlights of temperature change

The projected average annual and average seasonal temperatures of Chakwal district for next three decades (Figure 27) indicate;

- Annual average temperature is increasing gradually. The annual average temperature of base line period is 22.16 °C, which is likely to reach 23.56°C up to year 2040.
- The average temperature of winter is decreasing, indicating winters are likely to become colder.
- The average temperature of spring is increasing, indicating spring is getting warmer.
- The average temperatures of summer & falls are also increasing, indicating summers and falls are getting hotter.

The projected annual and seasonal mean maximum temperatures of Chakwal district for next three decades (Figure 28) indicate:

- Winter days are getting warmer.
- Spring days are likely to become warmer.
- Summer and fall days are getting hotter.

The projected annual and seasonal mean minimum temperatures of Chakwal district for next three decades (Figure 29) indicate;

- Winter days are warmer and nights are becoming colder.
- Spring days are warmer and nights are getting colder.
- Summer and fall days and nights are becoming warmer.

Fall and winter rains are decreasing. With days becoming warmer, the consequence may be drought.

5. IMPLICATIONS OF CLIMATE SCENARIOS TO WATER RESOURCES AND FARMING SYSTEMS

5.1 Implications for Haripur

Haripur will face dryer situation with time, with an exception of spring, when temperatures are slightly cooler (interpreted as extended winter) with more rains. Decrease in winter rainfall and increase in temperature will impact growth and productivity of winter crops due to water stress. Increase in temperature will adversely affect the grain formation stage of wheat. The following is suggested:

- Introduction of short duration varieties
- Introduction of drought resistant varieties
- Rain water harvesting for supplement irrigation
- Use of high efficiency irrigation systems for conserving water

Increase in spring and summer rainfall as well as temperature will have the following implications for the farming systems:

- In the steep topographic areas, likelihood and severity of flash floods will increase
- Wheat harvesting will get delayed due to increase in spring rainfall and cooler temperature
- Productivity of a number of vegetables including pea, onion, garlic and tomato will decrease
- Adverse effect on flowering of fruit trees resulting in decreased quality and quantity of production

The following measures are suggested to avoid losses and to improve farm production:

- Construction of small/mini dams/storage tanks to harvest rain water for irrigation, drinking and recharge
- Introduction of drought resistant crop varieties
- Promotion of tunnel farming for vegetables
- Effective coordination between various stakeholders especially research organizations government line departments and farming communities for research and action on adaptation to climate change.

5.2 Implications for Swabi

Increasing temperatures and reduced rain in winter and fall indicates certain worries for winter crops. There is a fear of drought during this period. Summer is to be studied more carefully since increase in rain is insignificant but temperature increase may cause more evapo-transpiration. Due to decrease in winter rainfall and subsequent increase in summer rainfall, the productivity of wheat crop will be affected. There will be a negative impact on production and quality of vegetables and fruits.

Due to increased rainfall in spring and summer, the production of tobacco will increase and quality will improve. The prevailing weather conditions will also be beneficial for cultivation and production of maize. The changed weather conditions will also be beneficial for production from rangelands and pastures due to more rainfall in late winter and early summer.

In general, the changed weather conditions are not suited to the current farming system. Crop yields are especially expected to decrease. Therefore the entire cropping system needs to be studied for adjustment according to the

changed temperature and rainfall conditions. The following measures are suggested to avoid major losses:

- Development of suitable production technology for the crops/fruits to be affected by the changed climatic conditions
- Development of early maturing crop varieties
- Development and application of efficient irrigation systems, rain water harvesting and water conservation.

5.3 Implications for Attock

In case of spring, day and night difference is increasing which may be worth looking into by crop scientists. While fall and spring day temperatures are increasing, rainfalls are reducing which may have consequences in the form of drought. Increasing early summer temperature will cause reduction of grain numbers, size and weight. Decreases of about 7% per decade winter rainfall will negatively impact crops especially wheat and animal production. Therefore introduction of drought resistant varieties and conservation and rain water harvesting for irrigation, is crucial for sustainable farming. Availability of less moisture for winter crops necessitates revalidation of input application.

Increased rain in spring/early summer is beneficial for groundnut growth and productivity, therefore, high yielding variety and nutrient management should be further studies. However, at the time of maturity, re-growth/re-sprouting is expected due to lack of dormancy as a result of increased temperature. This is due to the trend showing an increase in both mean minimum and mean maximum temperature for summer.

Insect pest occurrence may possibly increase in groundnut due to increased water and humidity as a result of increased rain and rising temperatures. Therefore plant protection management needs adjustments and improvements.

Increased rain in late winter and early summer may result in improved pastures and better fodder for livestock. However, increased temperature and humidity may result in disease spread in animals. Therefore, animal health management needs adjustments and improvements.

To benefit from increased rain in the spring and summer, improved and increased rain water harvesting techniques are suggested to address water shortages and to improve ground water resources through water recharge.

5.4 Implications for Chakwal

Fall and winter rains are decreasing. With days becoming warmer, the consequence may be drought. Increase in annual rainfall will result in soil erosion in an already fragile landscape of Chakwal. Integrated watershed management is suggested including construction of runoff harvesting structures, water storage structures and in-situ rainwater harvesting.

Decrease in early winter rainfall will result in crop failure. Cultivation of drought resistant wheat varieties with adjustment or standardization of production practices is suggested to avoid crop losses.

More rainfall in spring will increase survival percentage of forest and fruit tree species. A focus on planting in spring is suggested instead of planting in fall. With increasing summer temperature fire hazards in forests may increase which needs due attention to minimize fire risks.

Increasing monsoon rainfall trends may result in pounding of crops especially groundnut. Improved planting methods including ridge/bed sowing, contour sowing and planting is recommended to avoid losses.

The changing temperature, annual and seasonal rainfall necessitates awareness raising and training of resource poor farming communities, professionals and community based services' providers.