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# POTHOHAR WATER RESOURCES AND CLIMATE CHANGE IMPACT

**Dr. Saleem Sarwar**

# POTHOHAR WATER RESOURCES AND CLIMATE CHANGE IMPACT

By

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## 1. Abstract

The Pothohar region is situated in northern part of Punjab province. Total area is 23438 $km^2$, administratively divided into four districts. Total runoff from Pothohar area is estimated as 3.19 BCM. Optimum utilization of every drop of available water is becoming increasingly important with the ever-increasing population to meet their food needs. Efficient use of land and water is the key to the economic crop production. In the Pothohar Region where good agricultural land is not a limiting factor and where rain water is wasted by flowing over steep slopes, rather causing soil erosion and damaging the water ways and dams.

Climate change may pose various threats to agriculture in the Pothohar region. Based on the Intergovernmental Panel on Climate Change (IPCC) / Global Circulation Model (GCM outputs and historical observation from the Pothohar area, quantitative climate projections and their associated uncertainty for the key climate variables that affect the Pothohar region were generated. From such quantitative and other relevant information, it is then possible to identify adaptation options that could enhance the sustainability (e.g. lifetime) of the agriculture to climate change impact by "climate proofing" Climate scenario analysis has revealed that, by 2050 and towards the end of this century, climate change may have small impact on the total rainfall amount. In contrast, climate change will manifest largely as changes in the frequency and consequences of extreme rainfall, hence has significant impact on floods.

The rainwater harvesting possibilities and other management options are also discussed in the paper.

## 2. Introduction

Pakistan is a highly diverse country not only in terms of its geographical and climatic features but also in terms of the development of various regions and the socio-economic conditions of people inhabiting those regions. Due to these variations, the impact of climate change is not likely to be uniform across regions within Pakistan (Malik et al. 2012). Agriculture is the mainstay of Pakistan and the country has one of the highest ratios of irrigated croplands in the South Asian region with four-fifths of its total crop land being currently irrigated (MHHDC, 2005). According to International Food Policy Research Institute (IFPRI), climate change will have a major impact on three of the world's main staple food: rice, wheat and maize from 2010 to 2050. IFPRI further predicts that global warming will decrease agricultural production by 16 percent by the

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year 2020 with developing countries suffering much more than the developed ones. Due to low technological and scientific base of agriculture in Pakistan, there is low capacity to adapt to changes related to climate change. Second, Pakistan does not have adequate monitoring systems that predict the occurrence of extreme weather events in a timely manner. The recent flooding in Pakistan - resulting in an inundation of more than a quarter of the total land area in Pakistan and affecting close to a twenty million people - is the most recent as well as the most shocking manifestation of the lack of emergency preparedness (Nelson et al. 2010).

## 3. Materials and Methods

### 3.1 Pakistan and climate change

Pakistan is highly vulnerable to climate change due to its geographic location, high dependence on agriculture and water resources, low adaptive capacity of its people, and weak system of emergency preparedness (Malik et al. 2012). The country can be classified into nine Agro Ecological Zones based upon an Asian Development Bank study on agricultural growth and rural poverty in Pakistan (ADB, 2005). In the present study Pothohar region that falls in zone 5 (rainfed irrigation) was selected. The areas include in zone 5 are Attock, Rawalpindi, Jhelum and Chakwal (Figure 1-1).

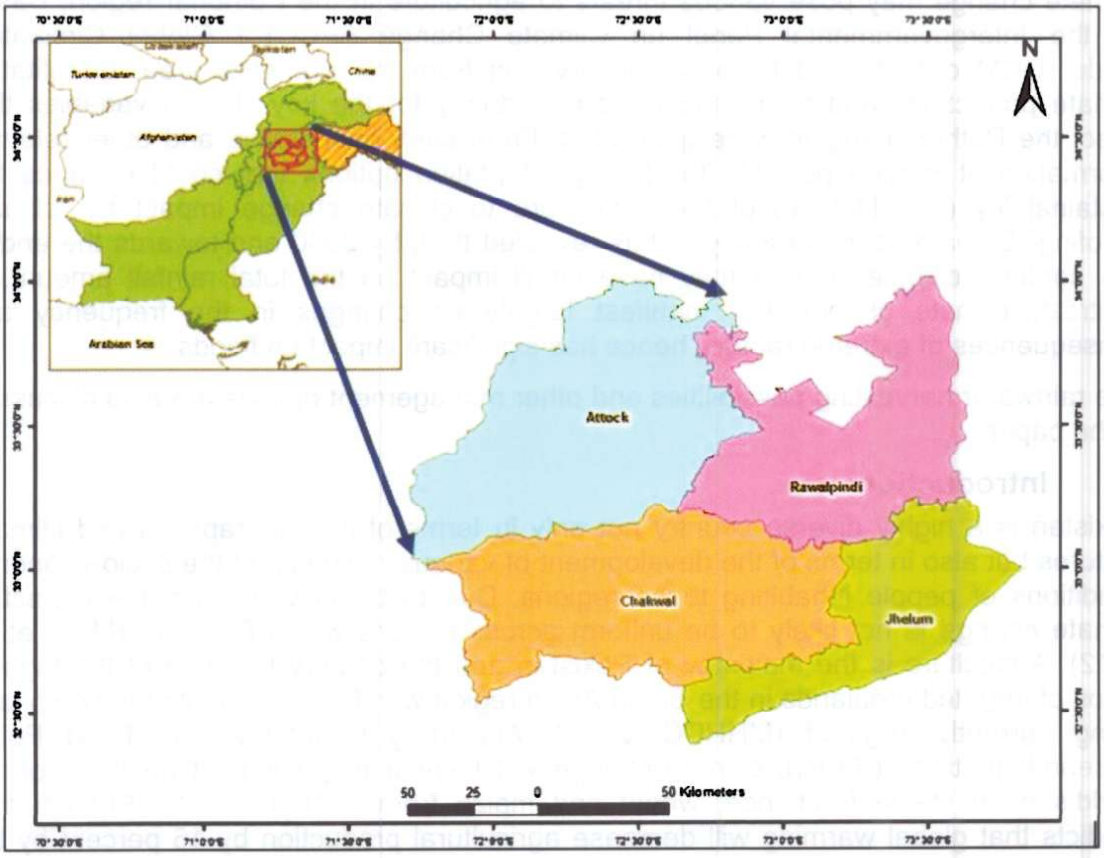



***Figure 1-1:*** Location Map of the Project Area

Malik et al., (2012) has developed the Vulnerability Index (VI), based upon three sub-indices namely: Exposure; Sensitivity; and Adaptive Capacity for the Agro Ecological Zones of Pakistan. The results of VI (Vulnerability Index) for the selected zone are presented in Table 1-1.

**Table 1-1:** Climate change vulnerability index for different agro-climatic zones

| Agro-climatic zones | Exposure (E) | Sensitivity (S) | Lack of Adaptive Capacity | Climate change vulnerability index | Rank |
|---|---|---|---|---|---|
| Other Balochistan | 0.60 | 0.58 | 0.92 | 0.70 | 1 |
| Low-Intensity Punjab | 0.54 | 0.54 | 0.79 | 0.62 | 2 |
| Cotton/Wheat Sindh | 0.53 | 0.63 | 0.66 | 0.61 | 3 |
| Other KPK | 0.39 | 0.37 | 0.75 | 0.50 | 4 |
| **Cotton/Wheat Punjab** | **0.31** | **0.47** | **0.53** | **0.44** | **5** |
| Cotton/Wheat Punjab | 0.47 | 0.45 | 0.36 | 0.43 | 6 |
| Rice/Other Sindh | 0.37 | 0.40 | 0.45 | 0.41 | 7 |
| Rice/Other Sindh | 0.54 | 0.29 | 0.18 | 0.34 | 8 |
| Mixed Punjab | 0.39 | 0.28 | 0.22 | 0.30 | 9 |

***Source:*** Malik et al. (2012)

The VI (Vulnerability Index) suggests that the selected study area is ranked 2nd among the agro-ecological zones of Pakistan. The most critical parameter in case of this zone is the lack of adaptive capacity which sets the basis of the selection of this study area for detailed analysis. This study investigates the evidence and future predictions of climate change and in Pothohar.

## 3.2 Study area

Pothohar region is situated in northern part of Punjab province. The river Indus flows in western side of the plateau whereas river Jhelum flows in the eastern side. The area being hilly in nature includes the great Salt Mine Range. Its altitude of this highland varies from 300 to 600 m, the topography of the area does not allow any canal system to be constructed for utilizing the river flows.

The climate of the area is sub-tropical continental. The normal annual rainfall in Pothohar region varies from 400 mm to 1200 mm. The months of significant rainfall are July, August and September in a year. About 55 % of the rainfall occurs in these months. This region falls in sub-tropical zone. There is an appreciable variation in the summer

and winter temperatures. January is the coldest month, while June is the hottest month. The absolute mean monthly temperature in the valley ranges from 1° C in January to 46°C in June. Based on variation of climatic factors i.e. temperature, precipitation, humidity and evaporation, the following five climatic seasons can be recognized:

Pre-monsoon season (May – June)

Monsoon season (July – September)

Post monsoon season (October – November)

Winter season (December – February)

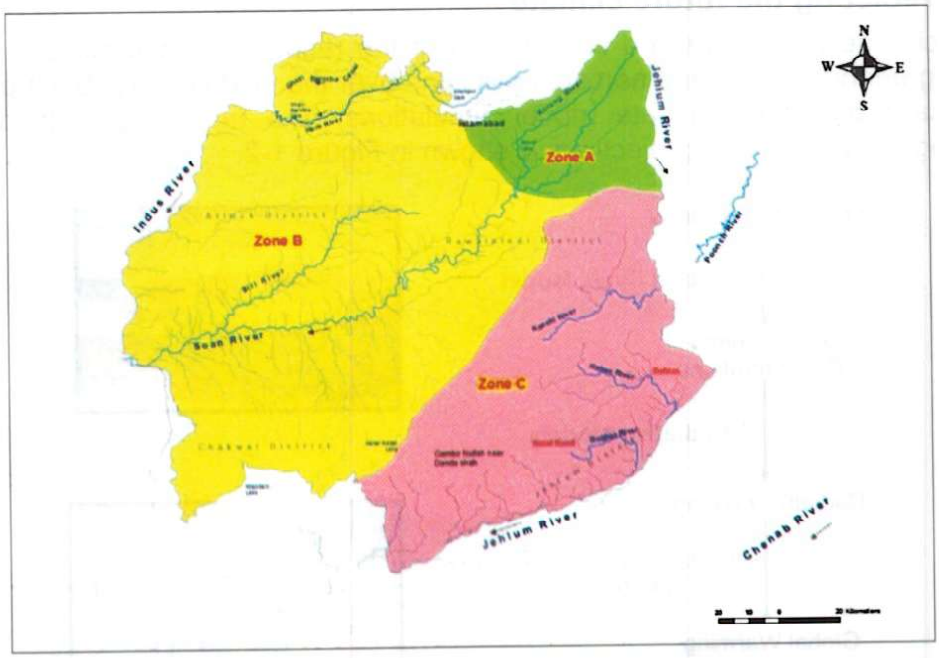
Spring season (March – April)

Five major rivers i.e., Haro, Soan, Kanshi, Kahan and Bunha flows in the area. Former two are tributaries of the river Indus and remaining three are tributaries of the river Jhelum. Soan river, a tributary of the Indus, flows in the central part of the Pothohar plateau and it forms major basins of the area with many tributaries. The Sil river is one of the tributaries of the Soan river and flows in the northern subbasin (land with similar geological and climatic conditions). The Haro basin forms the north-western part of the area. The Kanshi, Kahan and Bunha rivers flow eastward to the river Jhelum.

The major part of the Terrecial plains is Rabi season (winter) crop growing area, since rainfall in the project area is very eratic and most of it comes down in moonsoon season (July to September). The slope of the area ranges from 0 to 42% but is between 0 to 9 % for most of the areas. The elevation of the basin ranges from 200 meters to 2200 meters. The northeastern area in the basin having the steep slope and maximum elevation while southwestern area of the basin having very mild slope and elevation varying from 200 to 300 meters from mean sea level. The major type of the soil in the area is loamy soil (Calcareous Loamy Soils, Calcareous Silty Soils - Gullied Land and Calcareous Loamy and Clayey Soils) having 32% of the total area. Rainfed agricultural land is the major land cover in the Pothohar region. The irrigated land is mostly found on flat plains and gentle slopes, forming terraces and comprising post flooding or irrigated croplands, rainfed crop land and mosaic crop land. In total, the irrigated agricultural areas cover an area of approximately 55% of the total basin. Maize and wheat are the main crops grown in the area. Fruits, including fig, citrus and guava, grapes are grown locally under irrigation. Vegetables are also grown locally, and kitchen gardens are gaining popularity in the area.

Rainfall is the only source creating runoff in the Valley. Several major streams/nullahs bring flows towards the low-lying areas. There is a limited information on gauging stations at any of the streams/nullahs in the project area. For the estimation of water availability, Pothohar Rgion is divided into three zones, A, B and C and annual water availability is estimated using empirical approach[1]. The zones of the region and annual water availability is shown in below Figure and Table.

[1] Design Manual Volume 1 Hydrology and Hydraulics for small dams projects




| Zone | Average Rainfall (mm) | Area (Km2) | Runoff (BCM) | Runoff (MAF) |
|---|---|---|---|---|
| A | 1481 | 2317 | 1.03 | **0.8** |
| B | 773 | 13927 | 1.74 | **1.4** |
| C | 546 | 7194 | 0.42 | **0.3** |
| **Total** | **933** | **23438** | **3.19** | **2.5** |

As Pothohar Region is mainly represented by Sandstone lithological beds, although limestone beds can be found on eastern side, except for some flow, no perennial surface flow in the valley. Therefore, only source of recharge to groundwater is rainfall that falls in and all along up to the zero periphery of the valley. Since, Sandstone is found in most of the valley and slope of the area is steep, the rainwater has very little chance to soak and build-up the groundwater reservoir.

The water balance of the Pothohar Region under average rainfall year depicts that there is about 1.120 meter decline in the groundwater due to excessive pumpage and abstraction in the region.

| Average | Inflow MCM) | | Outflow Surface Water (MCM) | | | | | Inflow | Estimated | Change in |
|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall | Estimated | Total | Estimated | | Surface | Recharge | Total | - Outflow | ground | Ground |
| (mm) | Vol. of | Inflow | Runoff | $R_{ET}$ | Water | to ground | Outflow | | water | Water |
| | Rain water | | of Dams | | use | Water | | | use | Storage |
| | | | | | | | | | (MCM) | (MCM) |
| 2799.40 | 65612.34 | 65612.34 | 3182.38 | 55868.72 | 0.00 | 6561.23 | 65612.34 | 0.00 | 7873.48 | -1312.25 |
| Note: RET = Evapotrans piration Component w.r.t Rainfall | | | Average decline in Water Table per year (m) = | | | | | | | 1.120 |

### 3.3 Predicting the future climate

Climate change projections are an estimate of the response of the climate system to possible greenhouse gas and aerosol emissions over the next century. Such projections are typically based on climate model simulations. The modelling methodology for generating climate change projections is shown in Figure 1-2.

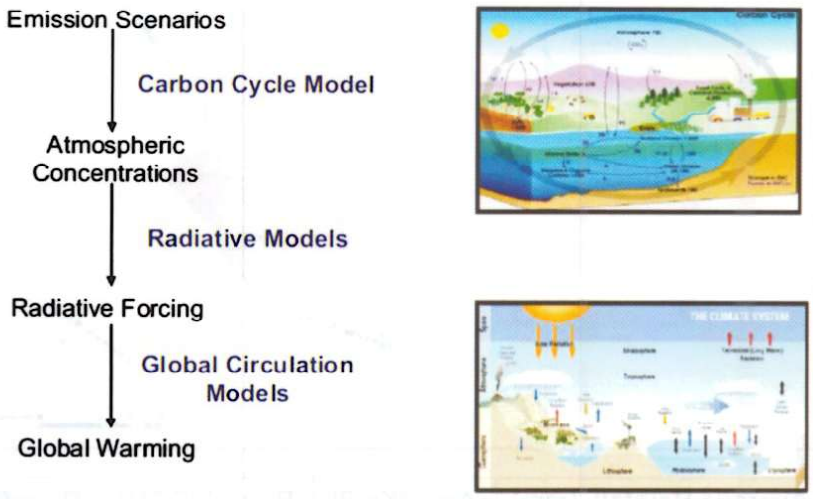



***Figure1-2:*** The modelling methodology for generating climate change projections (Source: Climate Change Catchments and Coasts, University of the Sunshine Coast)

To estimate future climate change, IPCC developed a series of greenhouse emission scenarios-Special Report Emission Scenarios (SRES) scenarios represented different assumptions on pollution, land use change and other driving forces of climate change. This scenario list was refined to six families for application in risk assessments with the descriptors A1FI, A1B, A1T, A2, B1 and B2.

In 2005, the process moved away from SRES with the development of Representative Concentration Pathways (RCPs) introduced at an IPCC Expert Meeting on Emissions Scenarios, followed by IPCC workshops (2005, 2007). For the first time the RCPs include scenarios that explore approaches to climate change mitigation in addition to traditional 'no climate policy' scenarios. Each RCP represents a different emission pathway: RCP8.5 leads to a greater than 1370 PPM (parts per million) $CO_2$ equivalent by 2100 with a continued rise post-2100.

- RCP8.5 Peaks by 2100 at 1370 PPM $CO_2$ equivalent to 2100 without overshoot;
- RCP6.0 stabilizes by 2100 at 850 PPM $CO_2$ equivalent to 2100 without overshoot;
- RCP4.5 stabilizes by 2100, but at 650 PPM $CO_2$ equivalent without overshoot;
- RCP2.6 peaks at 490 PPM $CO_2$ equivalent before 2100 and then declines.

## 3.4 Projected climate variability for the study area

Following projections for the climate change have been carried out SimCLIM (Simclim, 2013) that uses pattern downscaling methodology, where outputs are generated by adjusting local climate variables.

### 3.4.1 Temperature

Based on analysis of observational data, the IPCC (IPCC 2007) has identified that there is evidence of increasing temperatures across the globe. The analysis of data for area also shows increasing trend to support this IPCC statement as, in general terms, the local data indicates that annual mean temperatures have been increasing across the Pakistan.

The IPCC (2007) has also indicated that temperatures will continue to shift in concert with increasing atmospheric concentrations of greenhouse gas emissions. Fewer cold days and more hot days are expected, with associated shifts in annual and seasonal means and extremes.

Higher annual mean temperature are associated within the project area. Figure 1-3 shows the mean annual temperature within the project area for the current climate (1960-1995) along with mean annual temperatures for the project area for the 2025 and 2050 timeframes using ensemble of 40 General Circulation Models (GCM) for RCP 6.0. The percentage change in temperature for the project site is illustrated in the Figure 1-4.

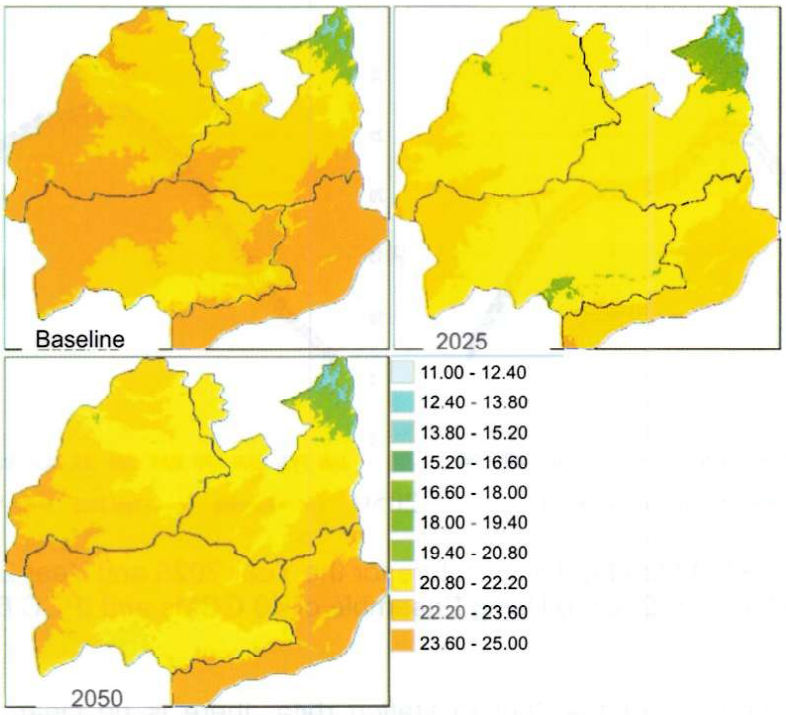



***Figure 1-3:*** Distribution of Annual Mean Temperatures for the Project Area (Baseline), Year 2025 and Year 2050 (Source: WMO included in the SimCLIM Model)

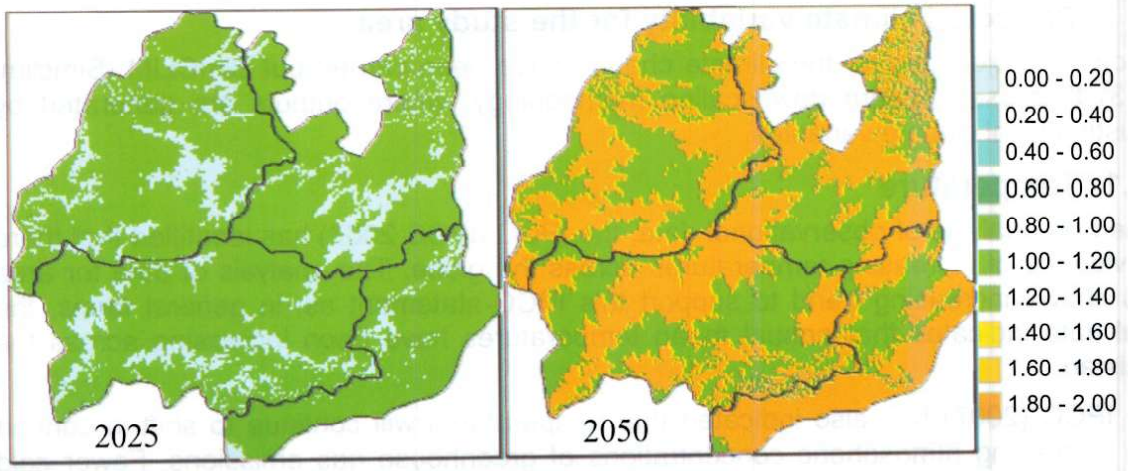



**Figure 1-4:** Projected Mean Annual Temperature Change for the Project Site Using Ensemble of 40 GCMs and IPCC 6.0 RCP

The results indicate that there is an increase of 0.84°C in the year 2025 and 1.50°C for the maximum and minimum mean annual temperature in the year 2050 from the baseline period (1980-2013) for Jhelum as shown in the Figure 1-5.

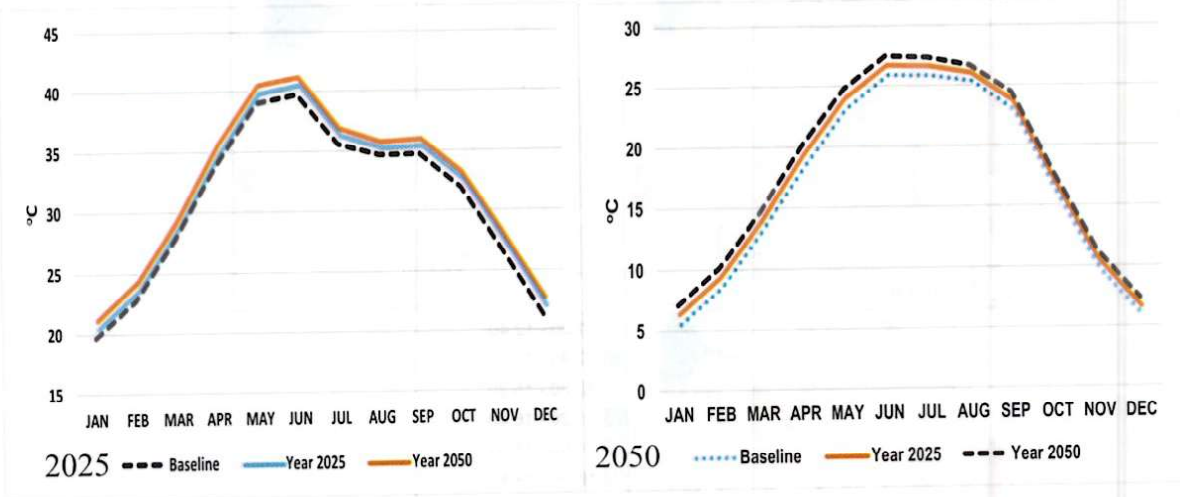



***Figure 1-5:*** Projected Monthly Temperature for the Year 2025 and Year 2050 for the Project Site (Jhelum Station) Using Ensemble of 40 GCMs and IPCC 6.0 RCP

## 4. Rainfall

Based upon the analysis of the Jhelum station data, there is no clear trend for the decrease or increase in the rainfall pattern. There is about 11% increase in annual rainfall in the decade (1990-2000) from the previous decade (1980-1990) while decrease (10%) in the annual rainfall was recorded in the next decade (2001-2010).

Rainfall is projected to increase in the future for the project area. However, there is considerable variability between the projected range of rainfall changes for different GCMs. The results indicated that there is about 4% increase in annual rainfall for the year 2025 and 6.5% for the year 2050 using ensemble of 40 GCMs under IPCC emission scenario of RCP 6.0 as shown in Figure 1-6.

Figure 1-7 shows the annual spatial variability of rainfall for the baseline and future periods and Figure 5-6 shows the percentage change in annual rainfall in the region for the year 2025 and year 2050.

The mean monthly analysis was also carried out for the Jhelum station to determine the spatial variability of rainfall. The results show that maximum increase in the rainfall is likely to occur in the monsoon season (July to September) while there is decrease in the rainfall in the months from December to April as shown in Figure 1-8.

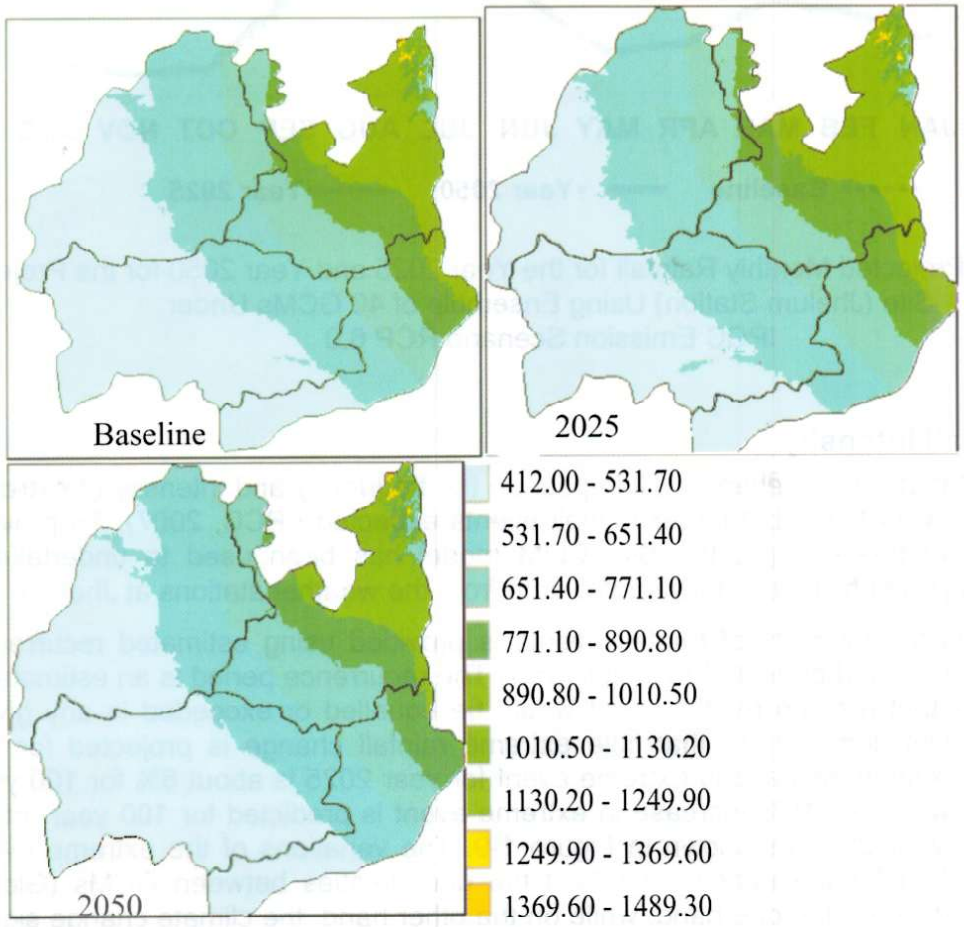



***Figure 1-6:*** Projected Annual Rainfall (mm) for the Baseline Period, Year 2025 and Year 2050 for the Region Using Ensemble of 40 GCMs under IPCC Emission Scenario RCP 6.0

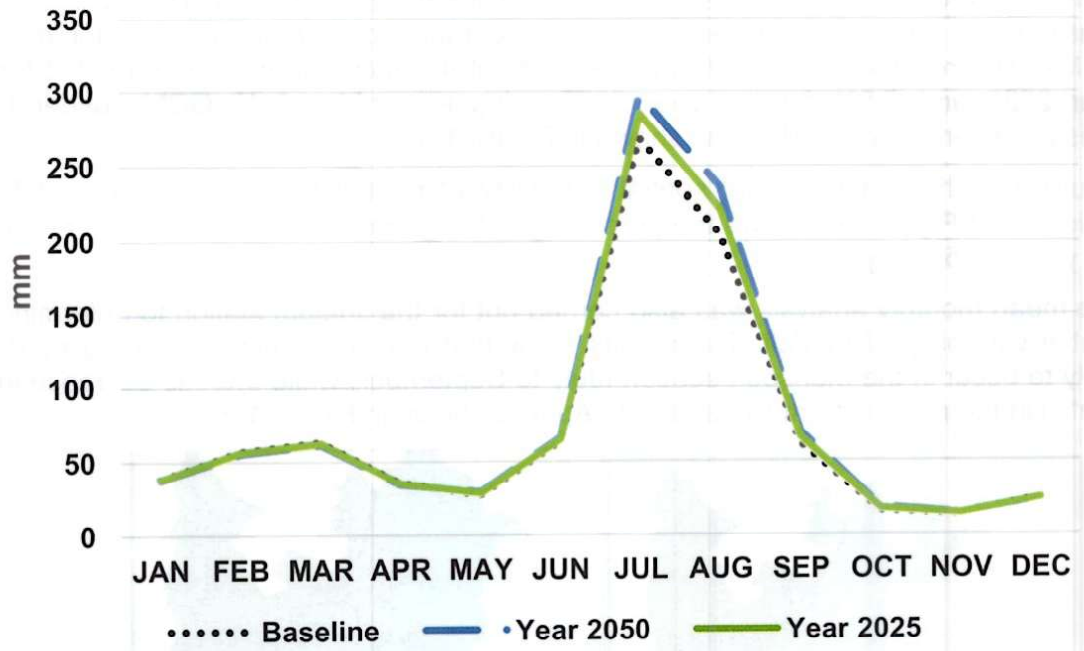



***Figure 1-8:*** Projected Monthly Rainfall for the Year 2025 and Year 2050 for the Project Site (Jhelum Station) Using Ensemble of 40 GCMs Under IPCC Emission Scenario RCP 6.0

### 4.1.1 Rainfall Intensity

It is projected that climate change will impact on the frequency and intensity of extreme rainfall events, with fewer but larger rainfall events expected (IPCC, 2007). To provide an indication of this change, the Sim CLIM model has been used to undertake a statistical analysis of historical daily rainfall data from the weather stations at Jhelum.

The change in the intensity of rainfall events is provided using estimated recurrence periods for historic and projected rainfall events. The recurrence period is an estimate of the probability that a given rainfall event would be equalled or exceeded in any given year. The results demonstrate that little extreme rainfall change is projected for the future. The maximum increase in extreme event for year 2025 is about 6% for 100 year return period, whereas, 10% increase in extreme event is predicted for 100 year return period for the year 2050 as shown in Figure 1-9. The variations of the extreme event change projection for the near term reflect the uncertainties between GCMs (Global Circulation Models) on the one hand, while on the other hand, the climate change signal may be still too weak to be identified in the near term and the analyzed result may be influenced by the natural climate variability included in the GCM simulated data.

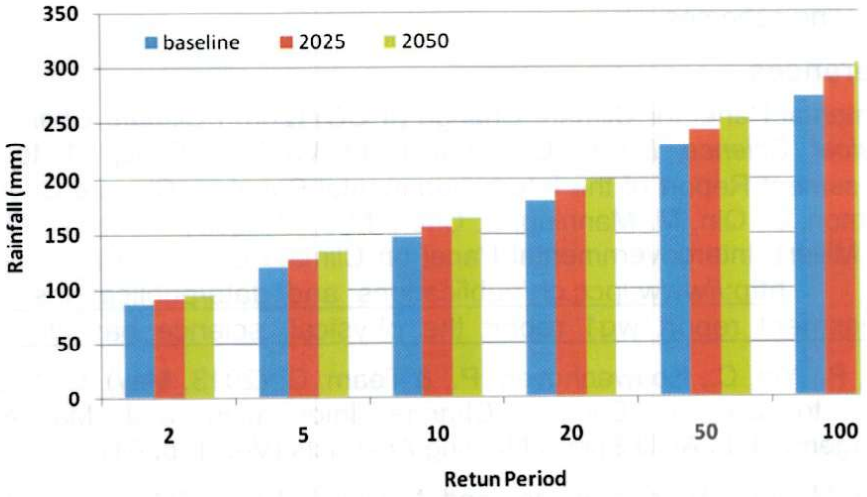



***Figure 1-9:*** Extreme Event Analysis for Various Return Periods

## 4.2 Impacts of climate change

As discussed in the previous section that there is likely to be increase in the temperature and rainfall in the project area with more extreme events will be the characteristics of the future weather.

Higher temperatures could increase evaporation leading to drier soils. Moreover, due to shift in rainfall patterns will reduce water availability in the winter season. As a result of climate change, rainfall events which are the same size as the historic 1-in-100 year rainfall event are expected to occur more frequently in the future. In addition to the potential for more frequent flooding, this shift in the characteristics of rainfall events is also likely to:

- Increase runoff and associated pollutants
- Increase soil erosion
- Impact on vegetation cover which provides soil stability.
- These shifts in environmental flows and water quality are expected to impact on waterways and biodiversity.

## 4.3 Conclusion and Recommendation

The impact of climate change will further aggravate the situation as there will be more droughts and extreme events in the coming years (IPCC, 2007). The farmers in the region already rely on rainfed water and almost 67% of rain occurs in monsoon months (July to September). Therefore, it is very necessary to conserve the water in the form of small dams and water harvesting schemes. Pothohar total cultural able area is about 1.92 million acre At the moment, there are only 55 small dams that are irrigating about 67,000 acre of land of cultural able land and about 1000 mini dams/harvesting schemes ( Irrigation scheme with few acre feet storage) irrigating 86,470 acres of land (less than

10%). The undulated Pothohar land provides a very good opportunity to develop small dams/ harvesting schemes.

## 4.4 References

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