Article

Climate change impacts on rain water availability during Rabi Cropping season in Pothwar region of Pakistan

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Abstract: One of the most important topics in the modern age is climate change. Due to changing climate, changes in the patterns of rainfall and temperature highlighting the need to analyze the consequences of such changes on different sectors such as on food production, ecosystem, and water availability. This study aims to investigate the climate change and its consequences on the rain water availability in the Pothwar regions of Pakistan, which is a rainfed agricultural region of the country. Historical changes in the rain water availability during Rabi cropping season was assessed over the period of 1985-2014. The modified Mann-Kendal (MMK) test was used to check the trends in the rainwater water availability during the entire season and during the different stages of wheat crop in the region. In this region, four irrigations are normally applied to the wheat crop, therefore, entire cropping season was divided into four stages, namely (1) crown root initiation stage; (2) tillering stage; (3) late jointing stage; and (4) flowering stage. It was found the overall water availability during the Rabi season was decreasing in the region. In case of 1st and 3rd stages, the water availability does not change. In case of 2nd stage, the water availability was significantly decreased, however, the water availability was increasing during the 4th stage. These findings might be useful for the growers of wheat crop as well as regional policy makers.

Keywords: Climate change; Water availability; Rabi cropping season; Pothwar region: Pakistan

1. Introduction

Climate change is defined as any major change in regional climate patterns that occurs over an extended period; this definition does not limit changes to those that are due to human agency. It has become a global threat to food and nutrient security all over the world. The temperature is also increasing due to the greenhouse effect because greenhouse gas emissions in the atmosphere continuously increasing. The global temperature is increasing averagely and it is predicted to rise by 2 ◦C until 2100, which is more harmful at the global level. The concentration of CO2 in the greenhouse is increased at an alarming rate. Climate change has significant impacts on the Earth's environment, while some effects are more evident than others. Significant regional climates can result in different extremes of precipitation events, which could have direct consequences on the number and types of crops that grow in these regions. Only significant and immediate reductions in greenhouse gas emissions can stop warming of 1.5 or 2 degrees Celsius, according to the IPCC's 6th assessment report.

Pakistan has a very diverse topography. As demonstrated by the past 30 years' rise in temperature and variations to monsoon rainfall, Pakistan is one of the many nations that has been significantly impacted by climate change [1]. The country is divided into

plain areas in its central and southern regions and high mountain ranges in its northern and northeastern regions. The plain-land-dominated Punjab and Sindh provinces have semi-arid to arid climates with little precipitation and high temperatures, the Pothwar region is one of them.

The Pothwar Plateau has a height that undulates and an irregular pattern of precipitation. For agriculture in this region, precipitation, which ranges from 380 to 500 mm annually, is essential. Semi-arid to sub humid conditions prevail on the plateau. Despite having a drier climate than the southwest, the northwest receives the most precipitation. The monsoon season accounts for nearly 80% of precipitation (July to September). Winter temperatures range from 4 to 25 degrees Celsius, while summer temperatures are between 15 and 40 degrees Celsius [2]. The landscape of the area is described as undulating, with an average slope of 8 to 40 percent and an inclination of 32.5 to 34.0 degrees north latitude and 72 to 74.0 degrees east longitude. The monsoon season is responsible for 70% of the region's annual precipitation, which ranges from 450 mm in the south-west to 1750 mm in the north-west. The two seasonal stream courses that crossed this region were the Haro River and the Soan River.

Crop water availability and crop production are significantly impacted by climate change. It has been observed that the reduction in water availability and rise in temperature during crop flowering have a significant impact on crop yield. This result has been observed throughout the world, including in Pakistan [2,3]. The impacts of climate change are not limited to the agricultural production; they also have an impact on other dependent industries, such as forage cultivation for livestock that depends on agricultural products.

Although some studies [4] has assessed the effect of changing climate on water requirement and productivity for different crops. But climate change under different future concentration scenarios specially related to rain water availability of wheat crop in the Pothwar Plateau of Pakistan is not properly documented. Moreover, the effects of climate change, the Modified Mann-Kendall (MMK) test, the Sen's slope estimator (SS) test and the Innovative Trend Analysis (ITA) were used to water the crop in stages, using all the available rainwater. For a variety of sowing/transplanting dates for the locations and crops listed above, the historical and predicted crop period wise aggregated effective rainfall, total net irrigation demand, and total crop water requirement were also investigated. The important environmental parameters will be quantified in this study along with their effects on the water supply for the wheat crop in Pakistan's Pothwar region.

2. Materials and Methods

2.1. Study Area

The Pothwar region is situated between the Indus River and the Jhelum River at 33°30'0" N and 73°0'0" E and stretches from the salt range northward to the foothills of the Himalayas. As a result, the majority of Attock, Jhelum, Rawalpindi, and Chakwal are included in the Pothwar region shown in (Figure 1). Northern Punjab province in northeast Pakistan that's where you'll find the Pothwar Plateau. The western portion of Azad Kashmir and the southern portion of Khyber Pakhtunkhwa provinces border the 22,254 km^2 study zone. Jhelum River on the east, Indus River on the west, Kala Chitta Range on the north with the Haro and Soan rivers and agricultural Margallo hills, and salt mountains on the south constitute the Pothwar Plateau. Because of ongoing renewal, the streams are deep-set and not very useful for irrigation. Rainfall, which is crucial to agriculture and averages 589 to 1682 mm yearly mention in (Figure 2), is highest in the northwest and decreases to arid conditions in the southwest and the mean temperature varies from 13 °C to 24 °C shown in (Figure 3). The main crops are wheat, barley, and sorghum.

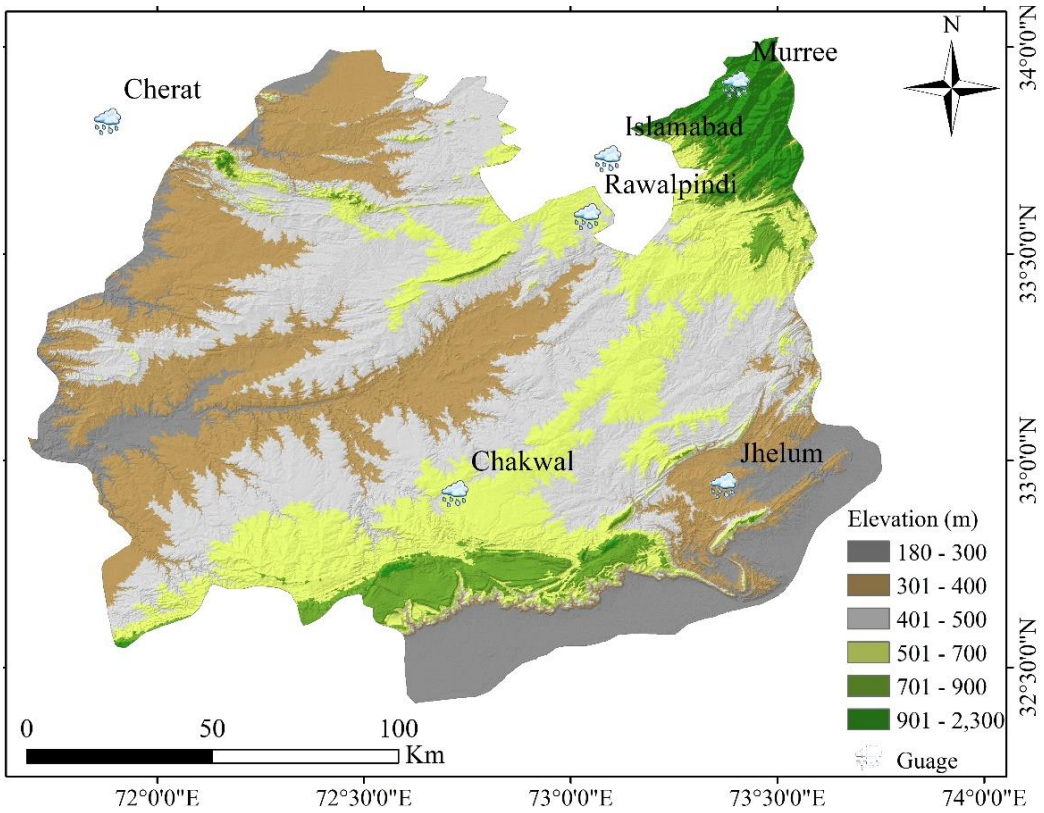

Figure 1: Location map of study area

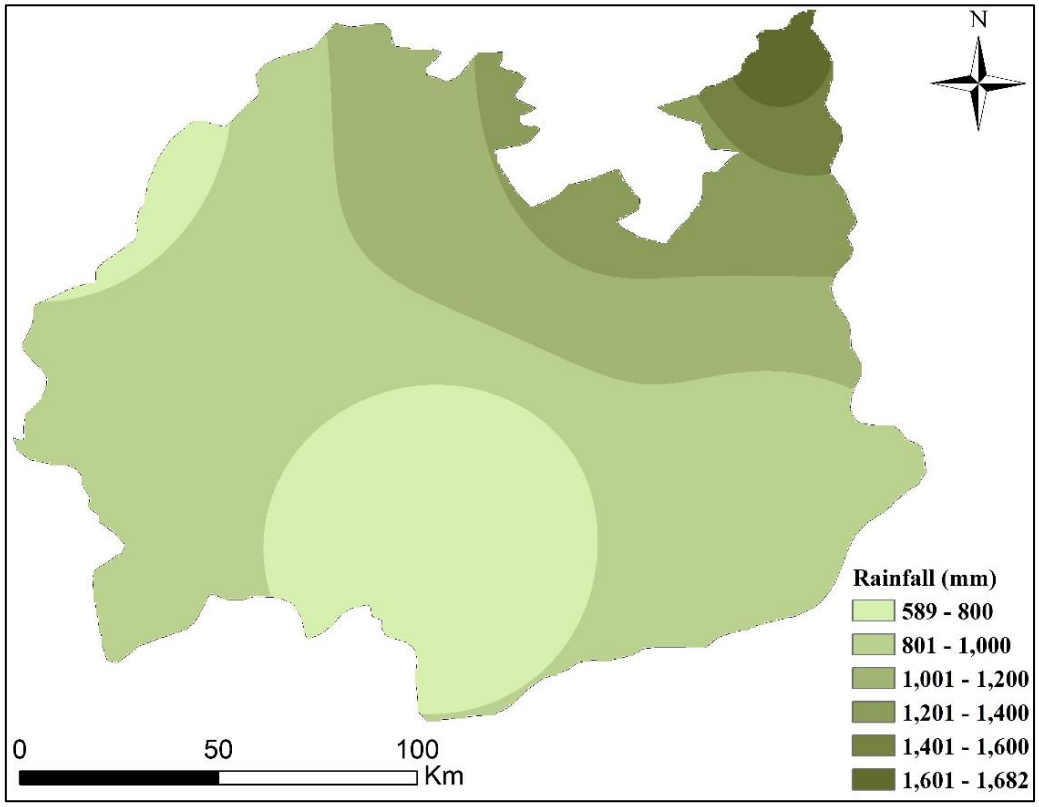

Figure 2: Spatial variability of annual average rainfall over the Pothwar region of Pakistan

The spatial variability map of annual average rainfall shows that the western parts of the study area receive more rainfall than the northern areas. The average rainfall varies from 589 to 1682 (mm) (Figure 2).

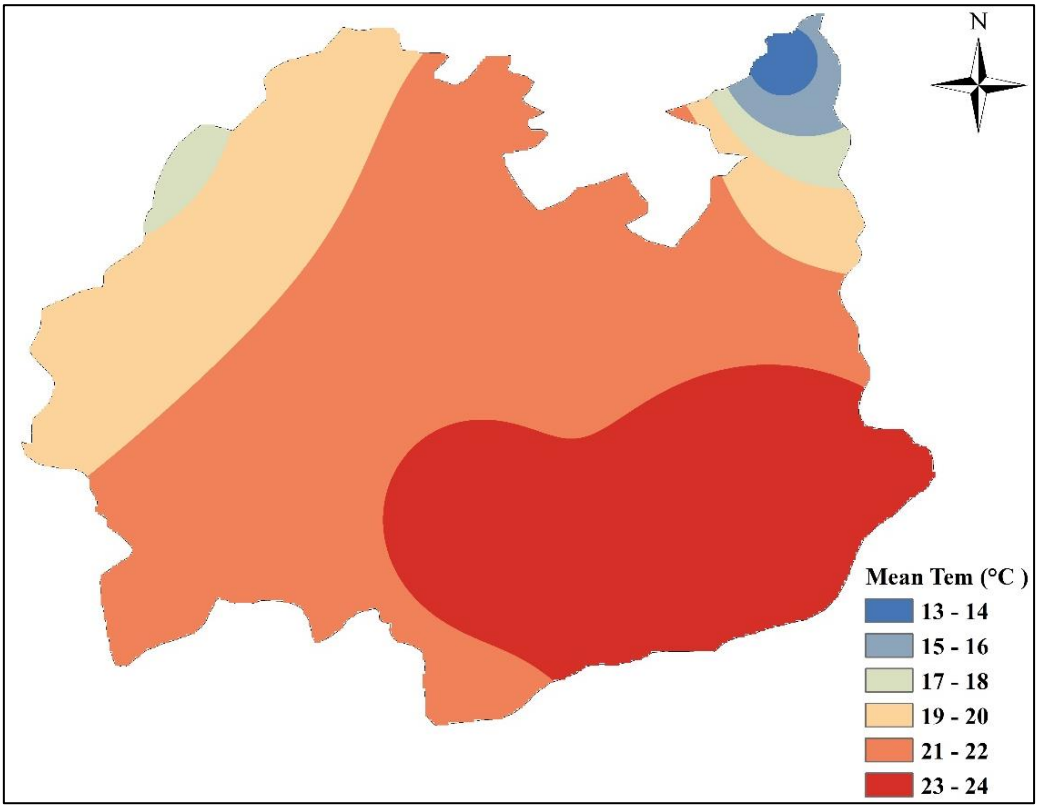

Figure 3: Spatial distribution of annual average temperature in Pothwar region of Pakistan.

For this analysis, daily data of six meteorological stations were used. Data of five stations was obtained from the Pakistan Meteorological Station and observations of one station (Chakwal) was obtained from Barani Agricultural Research Institute (BARI). The modified Mann-Kendal test was used to check the significance of trends and Sen's Slope estimator was used to estimate the rate of change in the rainfall timeseries. The details of considered stations is presented in Table 1.

Table 1. Details of weather stations used for this analysis.

Stations	Lat (DD)	Long (DD)	Elevation (m)	Annual average precipitation (mm)	Annual average temperature (C°)
Cherat	33.82	71.88	892	661	17
Jhelum	32.94	73.37	287	854	24
Murree	33.91	73.4	2025	1682	13
Rawalpindi	33.59	73.04	540	1239	22
Islamabad	33.73	73.09	569	1255	22
Chakwal	32.92	72.72	522	589	22

3. Results and Discussion

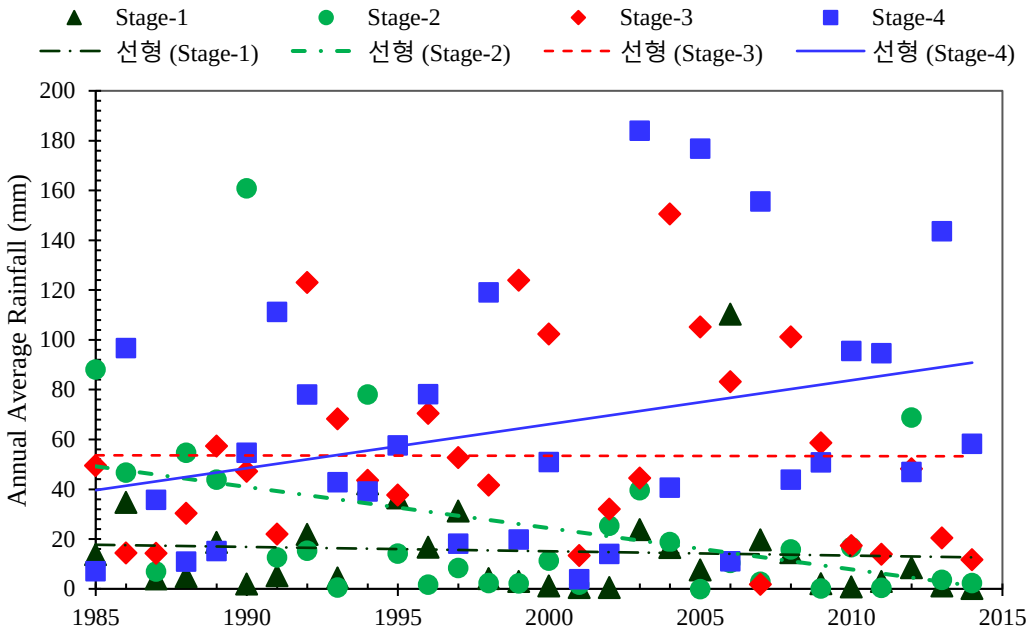

Figure 4: Annual average rainfall of different stages

Figure 4 shows the trends of rain water availability during four different crop stages (Stage-1: Crown root initiation stage; Stage-2: Tillering stage; Stage-3: Late jointing stage; Stage-4: Flowering stage) during 1985-2014 in the Rabi cropping season. Black color line shows the 1st stage annual average rainfall, no considerable increasing or decreasing trend of rain water availability was detected for this stage. Green color line shows the 2nd stage annual average rainfall, a significantly decreasing trend of average rainfall was detected during this stage. Red color line shows the 3rd stage, that also represent no considerable trend in the rain water availability during this stage. The blue color line shows the 4th stage, in contrast to the other three stages, the rain water availability was significantly increased during this stage.

4. Conclusions

The trends in rainwater availability during different stages of wheat crop in the Pothwar region of Pakistan were assessed using the Modified Mann-Kendall (MMK) test. The analysis covered the periods from 1985 to 2014, focusing on four distinct stages: Crown root initiation (Stage-1), Tillering (Stage-2), Late jointing (Stage-3), and Flowering (Stage-4). The results indicate varying patterns in rainwater availability across the stages.

For the first stage (Crown root initiation), no significant increasing or decreasing trend in average rainfall was observed. During the second stage (Tillering), there was a noticeable and statistically significant decrease in average rainfall. However, for the third stage (Late jointing), no significant trend in rainwater availability was detected. In contrast, the fourth stage (Flowering) exhibited a significant increase in rainwater availability compared to the other stages.

These findings highlight the heterogeneity of rainwater availability during different stages of the wheat crop in the Pothwar region. Understanding these trends is crucial for effective water resource management and sustainable agricultural practices in the region.

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