Spatio-temporal impact of climate variability on crop production of Potohar Region, Pakistan (1990-2017)

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Abstract. Climate variability is a major challenge for humanity, especially in agricultural countries, like Pakistan. Crop production in Pakistan is particularly vulnerable to climate variability. The current research addresses the Spatio-Temporal impact of climate variability on crop production using the Mann-Kendall trend model (MKTM) within the Potohar region, Pakistan. The trends in temperature and resulting changes in rainfall patterns and crops production in this region have a strong relationship with temperature changes, as the agriculture of the Potohar region depends solely on rainfall. There are no alternative means of cultivation in the area so agriculture depends only on the amount and duration of rainfall. To conduct this study, metrological data was collected from the Pakistan Meteorological Department for the three meteorological stations located in the Potohar region. ArcGIS software was used to analyze the satellite images from four different times to observe changes in vegetation cover during this period. Normalize difference vegetation index (NDVI) and Soil adjusted vegetation index (SAVI) from Landsat 5 and 8 were used to assess the levels of vegetation and soil moisture. The MKTM method was applied to demonstrate the fluctuations in annual temperature and rainfall. Rainfall data showed a decrease in annual rainfall and rise in temperature in Rawalpindi and Chakwal districts. The Mann Kendall trend model indicated that there is no significant trend detected in both rainfall and temperature data. The combination of indices identified periods where drought is affecting cultivation. The results showed that significant changes occurred in vegetation cover, with image classification showed the low vegetation cover in recent years. The analysis further explains that the observed deviation in climate data is attributed to the climate variability in this region. Weather factors such as air temperature, humidity, and soil temperature also support the normal growth of crops, ensuring normal crop yields. However, significant changes in rainfall and temperature will affect crop yield in the future.

Keywords: crop production, climate variability, Mann–Kendall trend model, NDVI, SAVI.

1. Introduction

Agriculture, an essential part of the economy is highly dependent on the climate in most developing countries. Climate variation and its variability have become foremost defies for agricultural development. The increase in irregular and unpredictable weather conditions places an additional burden on food security and rural livelihoods. In most cases, climate variability has a direct adverse impact on crop production (Bonsu et al., 2022). The climate of an area is strongly connected to crops, and the reliability of the climate is essential for the forecasting of agricultural processes (Nkuba et al., 2023).

Climate variability is expected to rise with global warming. Over the last 50 years, it has been observed that global temperature is increasing because of the rise of greenhouse concentrations in the atmosphere (Dawood et al., 2018; Al-Ghussain, 2019). Changes in local rainfall patterns, warming of the seas, and melting of ice sheets have been observed (Golledge et al., 2019). Moreover, the global average temperature is projected to be increase by 1.4°C to 6.4°C by 2100 (Singh & Singh, 2012; Zachariah et al., 2022). This upsurge exceeds the 3°C threshold beyond which it becomes impossible to avoid dangerous interference with the global climate system. Globally, the temperature rise may have mixed effects, potentially increasing agricultural production in temperate regions while reducing yields in tropical regions (Lahn & Shapland, 2022).

Changing climate is a major challenge for society, especially in a world with growing population. Climate change has a significant negative influence on agricultural yield and associated developments because one of the most sensitive sectors to climate change is agriculture (Mojanaga, 2022). Particularly, in tropical countries and lowland areas that are plagued by reduced snow and melting glaciers, these impacts are expected to be severe (Shivanna, 2022; Haq et al., 2025). The heat tolerance and drought threshold have already been reached, any further increase in temperature will contribute to a significant reduction in crop yield in tropical countries (Tesfaye et al., 2018; Rahman et al., 2025). Climate change is considered a universal occurrence, but its effects are felt more extensively in emerging countries because of higher vulnerability and less capability to cope with climatic impacts. Changes in precipitation patterns, floods, temperature, droughts, and climate change are a major impact on agricultural production and have adverse effects on water and land resources (Lemi & Hailu, 2019). Crop productivity will be affected by climate change and may therefore pose food security problems. Although global warming is expected to increase yields due to “fertilizer effect’, it will harm poor agrarians (Tutal, 2022)

Changes in temperature and rainfall are the potential effects of climate variability on agricultural production. The effect of climate variability on agricultural production can be direct or indirect. The timing of the crop development is directly affected by changes in temperature and precipitation (Grigorieva et al., 2023). Over the years, both temperature and rainfall patterns have changed. At crop maturity, droughts occurrence at critical stages of crop growth are common along with instances of heavy rainfall (Rahman et al., 2025). Particularly by reducing the number of days of suitable for agricultural growth, rising temperatures may reduce agricultural production in the long term, while changes in rainfall patterns are likely to increase temporary crop failures and decline long-term production. Ultimately, climate variability along with population and the proliferation of pests, insects, weeds, and diseases make crop management challenging and expensive. Such circumstances are likely to harm agricultural production (Grigorieva et al., 2023).

The climate of a region is a product that is contingent on the aggregate performance of land use or land cover types in the environment and the interaction between people. Vegetation cover in geographic areas helps us understand the causes and effects of climate change (Li et al., 2023; Haq et al., 2024). The role and behavior of agricultural land cover are unique. It not only helps to provide food but also naturally absorbs greenhouse gases such as CO_2. According to reports, because of overgrazing and removal of vegetation for fuelwood purposes have caused Potohar's productivity to drop by about 2.5 to 7 times. Water erosion affects the agricultural environment and this degradation is evident in the result (Gong et al., 2015; Amir et al., 2019).

Agriculture production is affected by various aspects of climate variability resulting mainly in an increase in temperature and changes in precipitation patterns, the increase in atmospheric CO_2 absorption, the increase in extreme weather events, and the upsurge in seawater levels (Sivakumar, 2021). In mountainous areas, it may be beneficial to extend the growing season while restricting the time for plants to grow to maturity. Winter crops will mature at the ideal time has a positive impact on crop yields. Not only rainfall but the temperature is also important for the healthy growth of crops mainly in rain-fed areas. Pakistan's climate restrictions and insufficient water supply for agriculture remain hostile realities. To conduct more accurate and comprehensive agro-meteorological research throughout Pakistan, consistent evidence on atmospheric and hydrological parameters is needed (Hafeez et al., 2024)

Precipitation is the utmost vital climatic variable that has an impact on the growth and development of field crops (Dawood et al., 2020). In the growth and development of crops, water serves as a means of transporting nutrients. Therefore, water scarcity can directly hamper crop growth and productivity (Mulla et al., 2023). The seasonal details of rainfall are an essential climatic element that affects the productivity and potential production of crops in existing farming systems. The current warning of climate variations in the availability of precipitation can have a major effect on crop yields (Kukal & Irmak, 2018). An important role in the productivity of rain-fed agriculture is the accessibility of soil moisture. In small-scale rainfed farms, the productivity and production potential of land resources are determined by the seasonal variability of rainfall. Crop production volume is based on the accessibility of water in the soil from planting to the crop harvesting stage (Alemu & Desta, 2017).

Pakistan`s agriculture is an important economic and cultural activity that contributes substantially to the domestic and international production of many commodities. The economy of Pakistan is heavily reliant on agriculture (Hussain et al., 2016; Rahman et al., 2017), from agriculture and agriculture-related industries, a substantial portion of the country's GDP comes. Pakistan is based on agriculture, covering a locality of almost 796 Mha with a semi-arid and arid climate. In the 796 Mha, about 23 Mha are felicitous for agricultural engendered and proximately total 25% area under cultivation is for rainfed agronomy. Unluckily, rainfed farming faces multiple difficulties such as hydro stress, crust and soil erosion, depletion, deficiency of nutrients, the poor utilization efficiency of nutrients, and weed influx restricting the possible yield in this land (Baig et al., 2013).

Pakistan`s climate is mixed and nearly two-thirds of the country experiencing a dry climate (Rafiq et al., 2024). The slender mountainous region brings a humid climate. Most parts of southern and central Pakistan are very dry, although the country`s north side is humid, except for the relatively dry north extreme mountains (Hina & Saleem, 2019). Punjab is the most populated and established region, accounting for 59% of GDP and 76% of the country's annual food grain production (Hussain et al., 2012; Rahman et al., 2017). The scarcity of rainwater is the main drawback for growing crops in a rain-fed agro-system. So, short-term crops such as chickpea, groundnuts, barley, and millet are grown only through the wintertime preferably in the rain-fed agro-system (Naz et al., 2010; Baig et al., 2013). The Potohar Plateau lies in northern Punjab. The Potohar area lies between almost 32.5ºN and 34.0ºN latitude and between almost 72ºE and 74ºE longitude. The Study includes the area of Chakwal, Rawalpindi, and Jhelum Districts. These districts are called Barani areas because agriculture depends heavily on rainfall. Climatically, the Potohar Plateau is situated semi-arid region, with the summer monsoon (July-September) mostly influenced and partially by winter precipitation. The first rainfalls in winter are favorable for the sowing time of wheat in the Potohar region. Besides, early spring rains lead to healthier final growth and improved wheat yield in the region. It obtains about 1000 mm of precipitation per year, of which 63 to 67% in the monsoon season (Hassan & Goheer, 2021)

2. Material and Method

Two types of data collection were used i.e. primary and secondary data. Secondary data on climate was collected from PMD, Islamabad, and crop data was collected from PCRS, agriculture department, Lahore. Almost 28 years of data on climate and agriculture were collected Secondary data was analyzed by using excel and excel state software to generate maps. Primary data sources are ground base satellite data of the required region collected from the USGS website (https://earthexplorer.usgs.gov/). The data was integrated with ArcGIS software and maps were generated to show the indices of affected areas of the region.

Study Area

The Potohar lies between 32.5ºN and 34.0ºN latitudes and between 72ºE and 74ºE longitudes. Potohar Plateau is surrounded by Kala Chitta and Margalla ranges on the north side, by the Jhelum River on the east, by the Salt Range on the south, and by Indus on the west (Kazmi & Rasul, 2009). This area has an elevation of about 500 to 1000 m above than mean sea level. Potohar region is around 13,000 km^2 and located at an elevation of about 350 to 575 meters. Most plateaus are tilted from north to east and empties into the Soan River in the Indus River. Nevertheless, the southeastern part of the plateau slopes east and empties into the Jhelum River. To the east and south, the basin margins are associated with Sohawa, Chakwal, Choa Saidan Shah, Kalaral Kahar, and Mianwali areas.

The Study includes the area of Chakwal, Rawalpindi, and Jhelum Districts (Figure 1). These districts are called Barani areas because agriculture depends heavily on rainfall (Rashid & Rasul, 2011). As a result, it exhibits considerable temperature variations that create satisfactory conditions for extreme weather conditions. It obtains about 1000 mm of precipitation per year, of which 63 to 67% in the monsoon season.

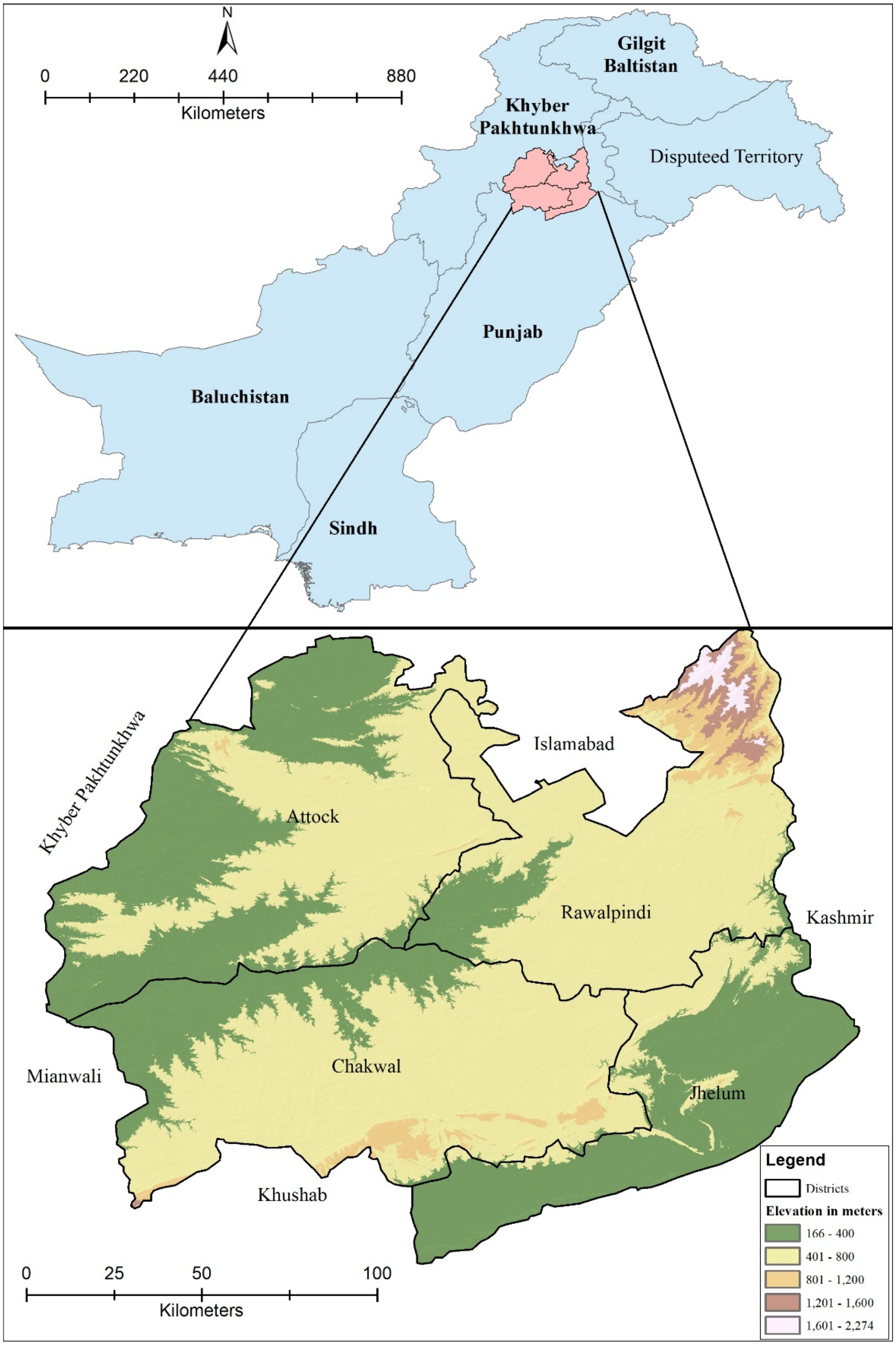


Figure 1. Study Area Map-Potohar Region-Pakistan

Data Collection

Six meteorological stations operate in the Potohar region. These stations collect data for various climatological parameters like maximum temperature, minimum temperature, dry bulb temperature, wet bulb temperature, wind speed and direction, atmospheric pressure, precipitation, sunshine duration, and relative humidity.

The study covers the period 1990–2017 crop production analysis. The observations within the present study lie on satellite images derived from Landsat 5 & Landsat 8. Rainfall and Temperature estimates measure derived from ground-based information for the year 1990–2017. Completely altered satellite-based vegetation indices have successfully been applied to assess drought conditions. The vegetation index was used to measure the state of the vegetation (Aziz et al., 2018).

The Landsat 5 & 7 data were used to calculate the Vegetation Indices. Ground-based rainfall & temperature and crop data are used to measure the influence and severity of vegetation conditions. Excel software was used to make the graphs of annual rainfall and an average temperature of 28 years. Excel state software is used to calculate the Mann-Kendall trend test.

Secondary Data

Secondary Data include the maximum and minimum temperature and precipitation data from four weather stations, Attock, Rawalpindi, Jhelum, and Chakwal, which were used for the period 1990-2017 from the PMD statistics archive. The actual performance data of crop production for that period is used as received from the Punjab Crop Reporting Service, Agriculture Department, Lahore Pakistan.

Mann–Kendall Trend Model

The mean and maximum daily temperature and precipitation for all stations were analyzed using the Mann–Kendall trend mode (MKTM). To find the trends in metrological time-series data MKTM is extensively used (Dawood et al., 2023).

MKTM is derived as:

$$S = \sum_{i=j}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(xj - xi),$$

$$\text{where } \operatorname{sgn}(xj - xi), = \begin{Bmatrix} +1, & xj > xi \\ 0, & xj = xi \\ -1, & xj < xi \end{Bmatrix}$$

Eq. (I)

The Normalized Difference Vegetation Index

NDVI is an index of vegetation photosynthetic activity and is one of the most commonly used vegetation indexes. By assessing the variance between near-infrared (a strong reflection of vegetation) and red light (vegetative absorption), the Normalized Vegetation Index (NDVI) computes vegetation (Table 1).

Table 1. Classification of NDVI Range.

Vegetation Classes	**Description**	**NDVI Value**
1 Non-Vegetation	Barren areas,	-1 to 0.199
2 Low Vegetation	Shrub and grassland,	0.2 to 0.5
3 High Vegetation	Green land,	0.5 to 1.0

NDVI = (NIR–R) / (NIR+R)   Eq. (II)

where NIR (Near-Infrared) and RED - RED is reflected in the visual cues. It is a good indicator of vegetation, crop production, forest cover, and seasonal trends. The NDVI values range from –1 to +1 (Vani & Mandla, 2017).

Soil Adjusted Vegetation Index (SAVI)

SAVI is alike NDVI but is used in those areas where vegetative coverage is low (<40%). When a substantial quantity of the soil surface is visible, the soil reflection can affect the NDVI values. On NDVI values Light reflected from the bottom have a significant Effect (the values can be changed by up to 20%).

$$\mathbf{SAVI} = \frac{(\mathbf{NIR} - \mathbf{Red})}{(\mathbf{NIR} + \mathbf{Red} + \mathbf{L})} * (1 + L) \qquad \textbf{Eq. (III)}$$

"L" is a modification factor that varies from zero for very high vegetation coverage to 1 for very low vegetation coverage. An "L" value of 0.5 is used typically for middle vegetation coverage, at which time "L" equals zero SAVI becomes the same as NDVI. The modification factor L was found by trial and error until a factor was found that gave equal results for the vegetation index for the dark and light soil.

The Climate of the Potohar Region

Climatically, the Potohar Plateau is situated semi-arid region, with the summer monsoon (July-September) mostly influenced and partially by winter precipitation. The first rainfalls in winter are favorable for the sowing time of wheat in the Potohar region. Besides, early spring rains lead to healthier final growth and improved wheat yield in the region (Kazmi & Rasul, 2009). However, the potash level is appropriate. The pH level of soils is 7.5 to 8.5 (Rashid & Rasul, 2011).

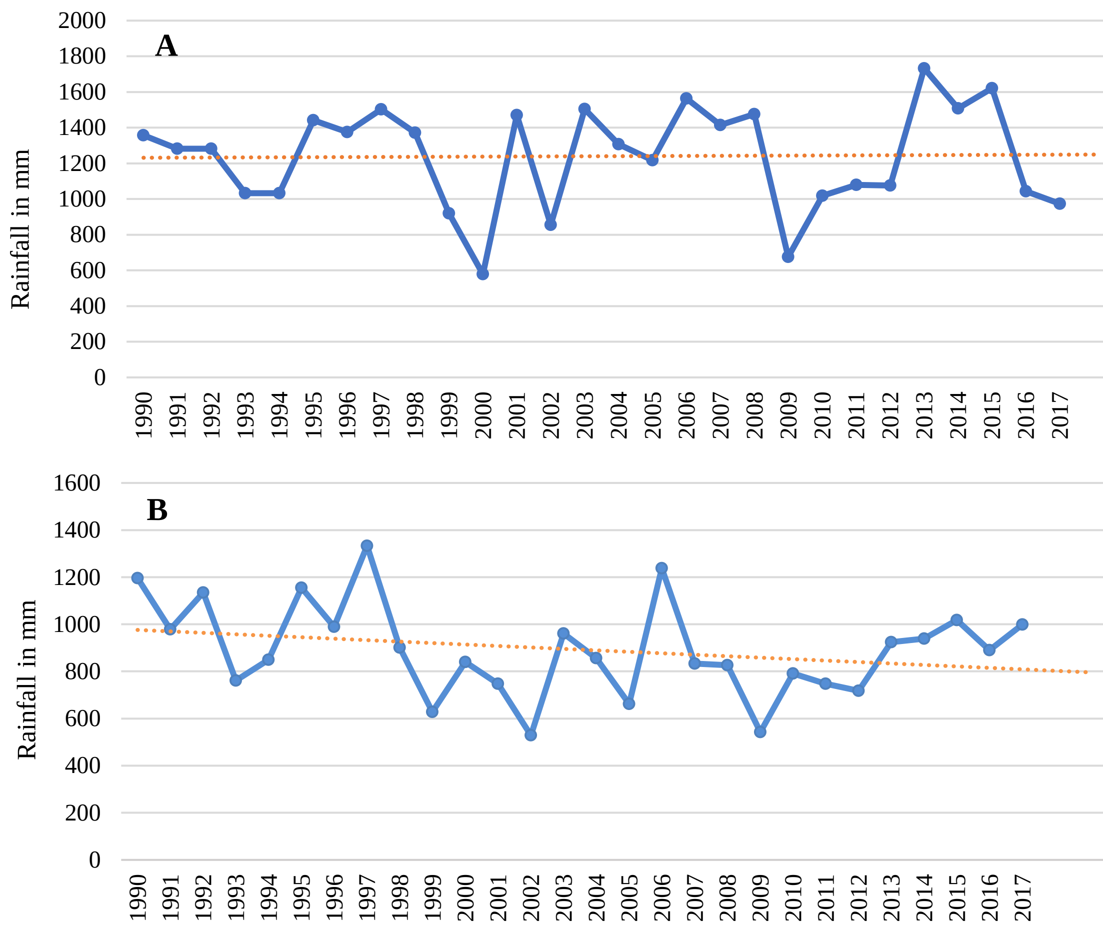
3. Results and Discussions

Continuous and abnormally dry weather causes water shortages, which may cause natural catastrophes, such as agricultural droughts, hydrological disparities, and many other serious ecological glitches. Here is a summary of crop production and climate fluctuation in the Potohar region.

Rainfall Data Analysis

The annual rainfall data from 1990 to 2017 is required from PMD. The data is first shifted into excel to make high and low peaks in the graph. It has been observed that the seasonal pattern is strong and stable as shown in Figure 2, showing the annual rainfall of Rawalpindi, Jhelum and Chakwal respectively.

The fourth-largest city in Pakistan is Rawalpindi which is a rain-fed area in the Potohar Plateau. The cultivation method of Rawalpindi depends entirely on rainfall. Rawalpindi is located at an altitude of 517 meters. Rawalpindi has a humid climate with moderate temperatures throughout the year. The annual rainfall in Rawalpindi shows great fluctuations.



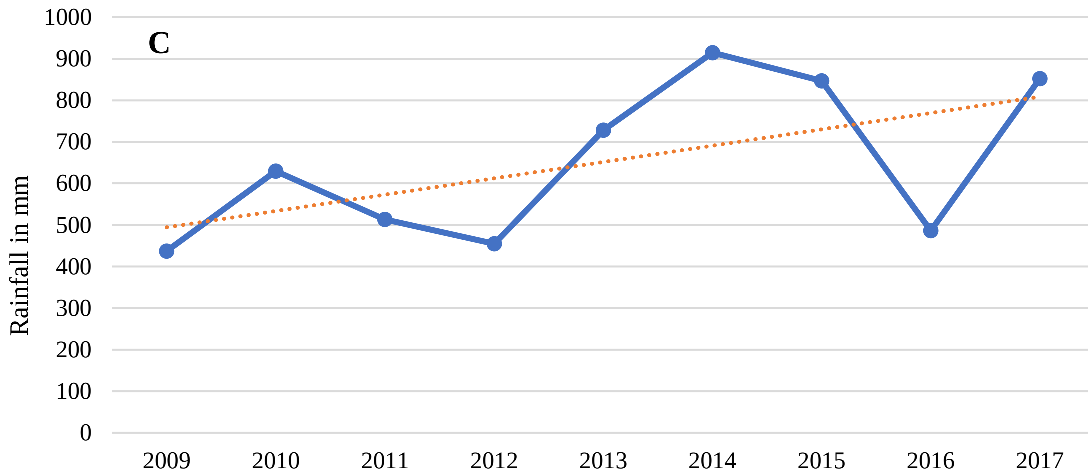


Figure 2. Temporal annual rainfall distribution. A - Annual Rainfall in Rawalpindi, B - Annual Rainfall in Jhelum, C - Annual Rainfall in Chakwal

Figure 2A shows the annual rainfall of Rawalpindi. The highest rainfall is observed in 2013 i.e. 1734 mm and the lowest rainfall is observed in 2000 i.e. 855 mm. Furthermore, rapid changing behavior is observed in 2013, from the lowest in 2000, 2002, and 2009 as well. Whereas, the fluctuation in the rainfall pattern has been observed throughout the time series. The trend line slightly inclines through the series data.

Jhelum is the regional headquarters of the Potohar region. The weather observatory in the region has been working for five eras, but the data used in this study covers 28 years. It denotes the southeast agricultural plain of the plateau. The Jhelum River passes through the zone, but due to its uneven altitude, it cannot be used for crop cultivation. Thus, agriculture depends entirely on rainfall.

Figure 2B shows the annual rainfall of Jhelum. The highest rainfall is observed in 1997 i.e. 1333 mm and the lowest rainfall is observed in 2009 i.e. 542 mm. Furthermore, rapid changing behavior is observed from 2005 to 2006, from lowest in 2002, 2005 and 2009 as well. Whereas, there is no such fluctuation in the rainfall pattern has been observed throughout the time series. The trend line has been shown to continue the declining trend in the data.

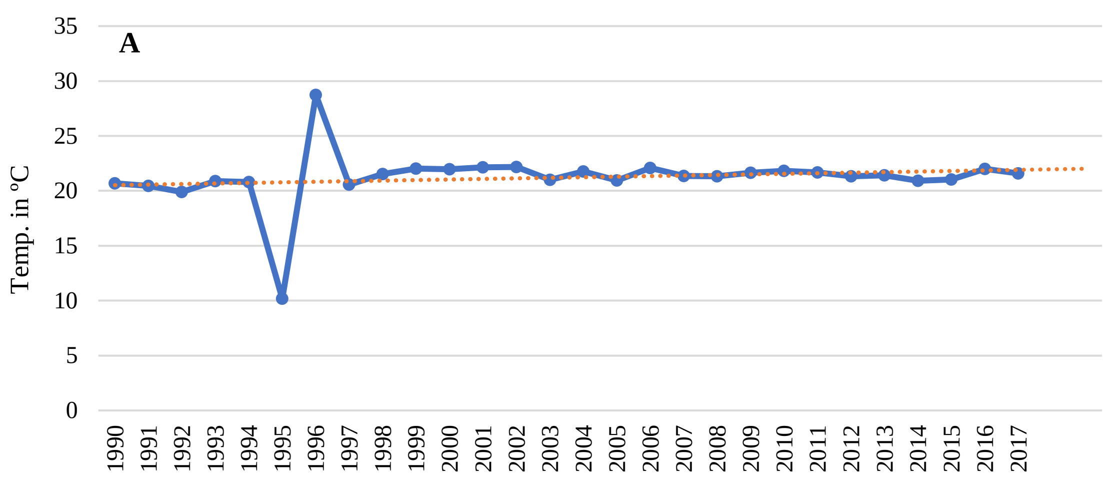
Chakwal is located on the south side of the Potohar plateau, at 33°N latitude and 73°E east longitude. The rainfall fluctuates greatly. During the study period, most of the rainfall was less than normal rainfall. Rain upsets the harvest of crops in this case the harvest is not good.

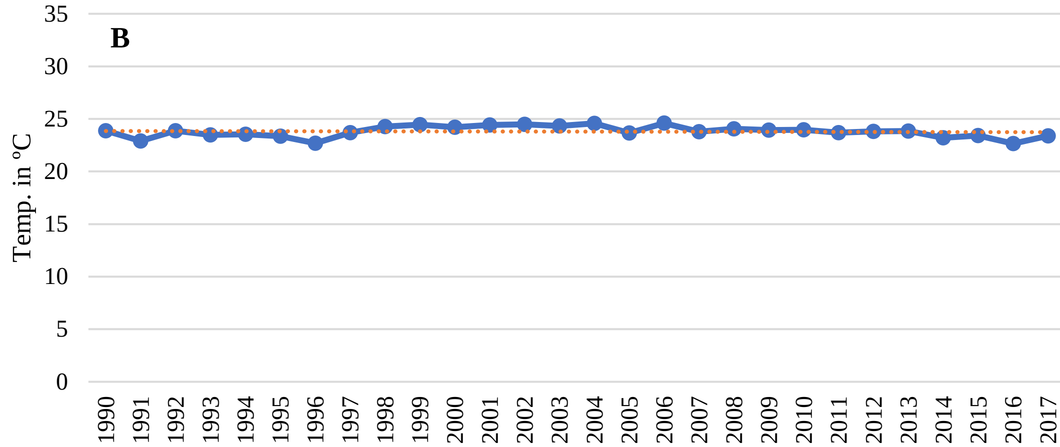
Figure 2C shows the annual rainfall of Chakwal. The highest rainfall is observed in 2014 i.e. 915 mm and the lowest rainfall is observed in 2009 i.e. 437 mm. Furthermore, rapid changing behavior is observed in 2012 and onward, and stability in the pattern has been observed from 2010 to 2012 and 2016 as well. Whereas, the fluctuation in the rainfall pattern has been observed throughout the time series. The trend line has been showing a continuing incline trend in the series of data.

From the above figure, it can be concluded that Rawalpindi and Chakwal show similar fluctuating behaviors to rainfall. On the other hand, Jhelum has an unpredictable pattern. This is because Jhelum's crops are not entirely dependent on rainfall.

Temperature Data Analysis

The annual average temperature data from 1990 to 2017 is required from PMD. The data is first shifted into excel to make high and low peaks in the graph. It has been observed that the seasonal pattern is strong and stable as shown in Figure 3, showing the annual rainfall of Rawalpindi, Jhelum, and Chakwal respectively.





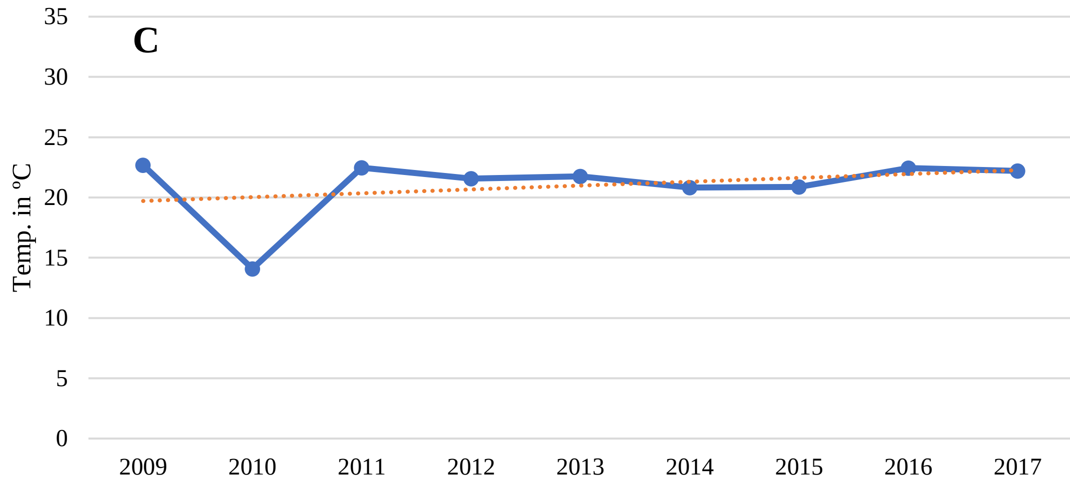


Figure 3. Temporal Distribution of Annual Average Temperature. A - Annual average temperature in Rawalpindi, B. Average annual temperature in Jhelum, C - Annual average temperature in Chakwal

Figure 3A shows the annual average temperature of Rawalpindi. The highest temperature is observed in 1996 i.e. 29 ºC and the lowest temperature is observed in 1995 i.e. 10 ºC. Furthermore, rapid changing behavior is observed from 1995 to 1996. Therefore, stability in the pattern has been observed from 1997 onward. The trend line slightly inclines through the series data.

Figure 3B reveals the annual average temperature of Jhelum. There is no fluctuation in the temperature of Jhelum in these periods. The average temperature of Jhelum has been observed between 22 to 24 ºC. Therefore, stability in the pattern has been observed the same throughout the period. The trend line remains the same throughout the series of data

Chakwal metrological station has been established in 2009. So that the ground base data has been collected from 2009 to 2017. Figure 3C shows the annual average temperature of Chakwal. The highest temperature is observed in 2009 i.e. 23 ºC and the lowest temperature is observed in 2010 i.e. 14 ºC. Furthermore, rapid changing behavior is observed from 2009 to 2010. Therefore, stability in the pattern has been observed from 2011 onward. The trend line slightly inclines through the series data.

Crop Data Analysis

The annual average temperature data from 1990 to 2017 is required from PMD. The data is first shifted into excel to make high and low peaks in the graph. It has been observed that the seasonal pattern is strong and stable as shown in Figure 4, showing the annual rainfall of Rawalpindi, Jhelum, and Chakwal respectively.

Figure 4A depicts the production of wheat, gram, and maize in the study area. Wheat crop production in the Rawalpindi district from 1990 to 2017, shows less production in 2001 and 2010. The wheat crop production was affected by drought during 2000-2004 and by flood during 2009–2014 as compared to other usual years.

Gram crop production in the Rawalpindi district from 1990 to 2017 shows remain the same production. The gram crop production remains constant throughout the spell there are no major improvements in the production. There is almost no cultivation of gram in this area.

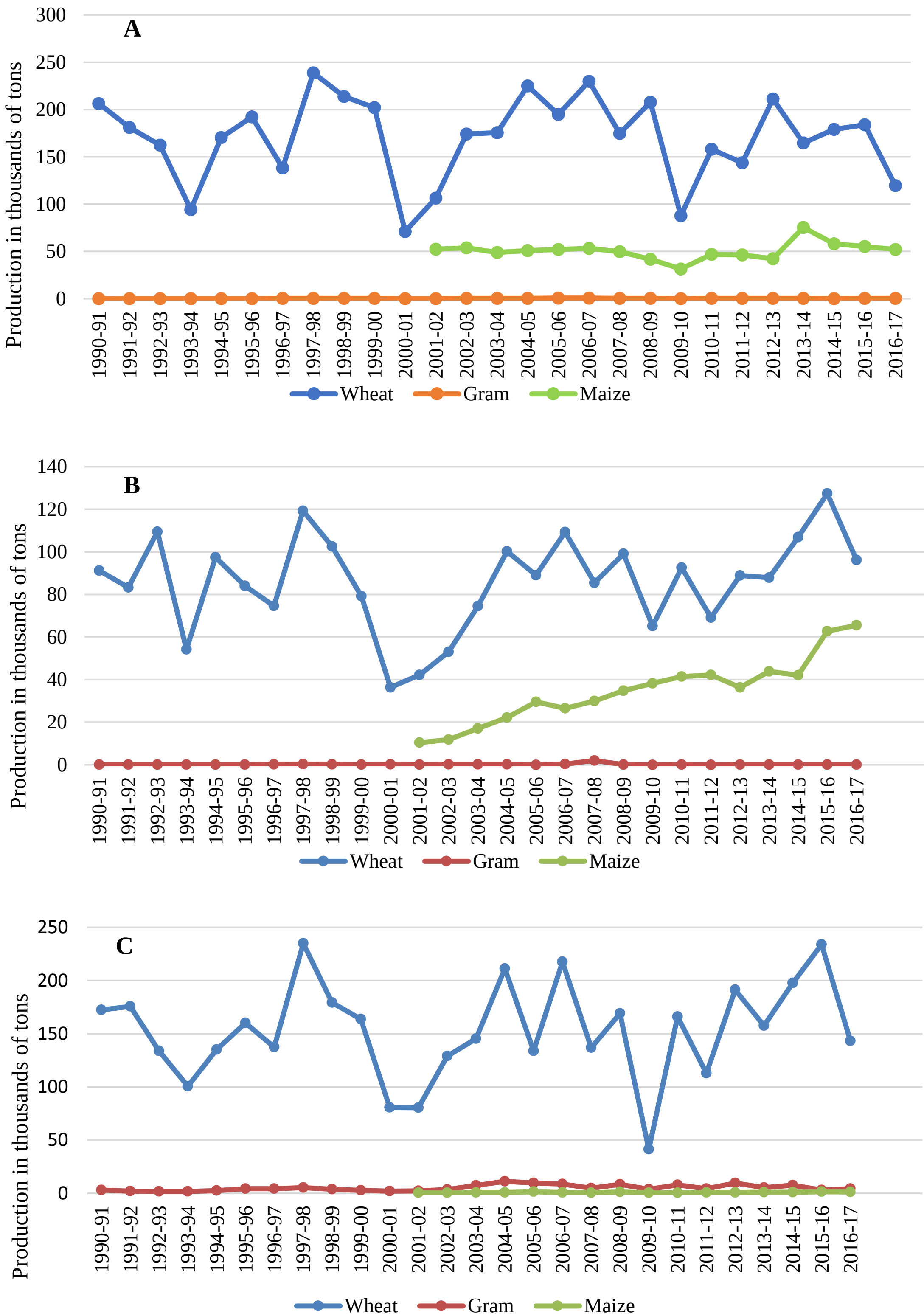


Figure 4. Crop Production in the study area. A - Rawalpindi, B - Jhelum, C - Chakwal districts

Maize crop production in the Rawalpindi district from 2001 to 2017 shows less production from 2001- 2010. It is obvious the wheat crop production during 2001-2013 that drought spell (2010) disrupt the crop production as compared to other normal years. In 2014, there was a little surge in production, but in 2015, it dropped again. Due to data limitations couldn`t get data from past years.

Wheat crop production in the Jhelum from 1990 to 2017 shows less production in 2001 and 2010. It is obvious from the wheat crop production during 1999-2004 and 2009–2014 that a drought spell disturb the crop production as compared to other usual years. After 2014, there was a little rise in production that dropped again in 2017.

Figure 4B depicts the gram crop production in the Jhelum district from 1990 to 2017. Data shows a similar production. It is evident from data that the gram crop production remains constant throughout the spell there are no major improvements in the production. There is almost no cultivation of gram in this area.

Maize crop production in the Jhelum district from 2001 to 2017 shows an increase in production in 2014- 2017. It is obvious from the maize crop production during 2008-2017 that continue an upsurge in crop production as compared to previous years. Due to data limitations couldn`t get data from past years.

Figure 4C reveals wheat crop production in the Chakwal from 1990 to 2017, which shows great fluctuation during the whole spell. It is obvious the wheat crop production during 2001-2004 and 2009–2010 that drought spell affected the crop production as similar to other usual years. After 2014, there is a little rise in production that dropped again in 2017.

Gram crop production in the Jhelum district from 1990 to 2017 shows less production. The gram crop production remains constant throughout the spell (1990-2003). There is slightly rise in production after 2004-2007. After 2015, it dropped again.

Maize crop production in the Jhelum district from 2001 to 2017 shows no production. It is obvious from the maize crop production during 2008-2017 that no changes in crop production. There is almost no cultivation of maize in this area. Due to data limitations couldn`t get data from past years.

Crop Indices

For any improvements and monitoring of the drought conditions, an accurate estimation of vegetation is essential. It is difficult to obtain the data for whole areas by using traditional methods where the need for highly qualified people with immense information from the area. Remote sensing tools can give vegetation information in sequential data over time. Remote sensing figures were used to display vegetation bio phenology and health eminence. It is economically viable to measure vegetation production in large areas.

Satellite data of Landsat 5 and 7 were used to obtain the data, this data is accused of ArcGIS software to get the results. Five images are taken with a gap of 10 years respectively to analyze the changes that occur during these years. All these images are collected during the month of crop harvest like April.

Normalize difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is an extensively used vegetation quality and spread area index. Rouse is the first who used Normalized Difference Vegetation Index. The potency of vegetation is measured with NDVI. Regarding the NDVI, the obtained value ranges from −0.45 to 1 (Figure 5). The positive values shows the healthy vegetation areas. The results revealed in 1990 followed by 2017 while the years 1999 and 2009 showed low vegetation cover as it these were dry years in Pakistan as reported by different researchers (Rahman et al., 2018; Rafiq et al., 2022; Rafiq et al., 2023).

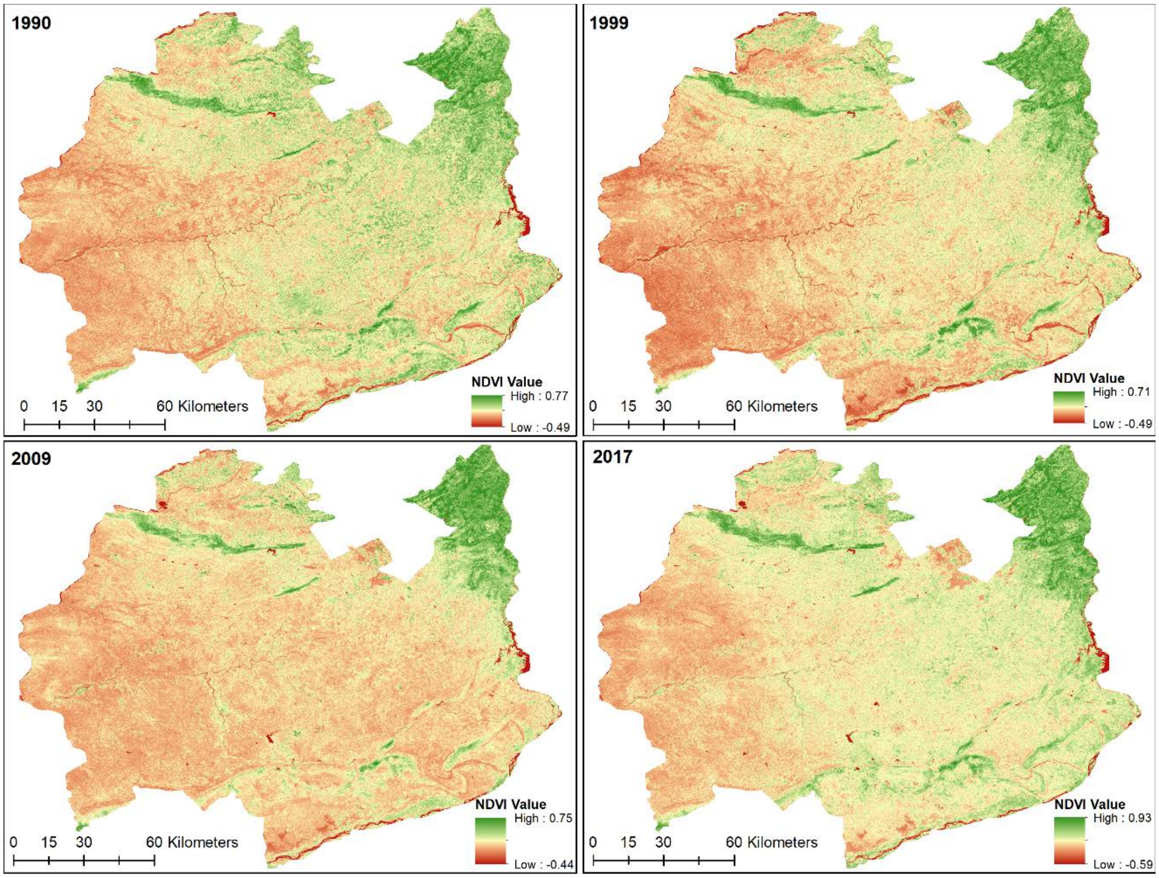


Figure 5. Spatial distribution of Normalize Difference Vegetation Index

Soil Adjusted Vegetation Index

SAVI is used to precise the Normalized Vegetation Index (NDVI) for the effects of soil intensity in areas with low vegetation coverage. Figure 6 shows the classification of SAVI in the area. The SAVI derived from Landsat surface reflectance is the ratio of R and NIR values, and the soil brightness correction factor (L) is distinct as 0.5 to suit most land cover types. The value of L varies with the quantity of coverage of green vegetation: in very high vegetation areas, L = 0; in areas without green vegetation, L = 1. Usually, L = 0.5 works well in most cases and is the default value used. When L = 0, then SAVI = NDVI.

SAVI and NDVI are highly allied with vegetation values. SAVI foils NDVI, which has vegetation and forest cover on the land cover. The background soil affects NDVI values, which are subjected to bare vegetation in the land cover. The higher the SAVI value means more vegetation; moderate greenish color means normal vegetation, and purple color means no vegetation. In 1990, the Rawalpindi district shows the highest values, Jhelum shows moderate values, and Chakwal and the lower Jhelum shows the least values.

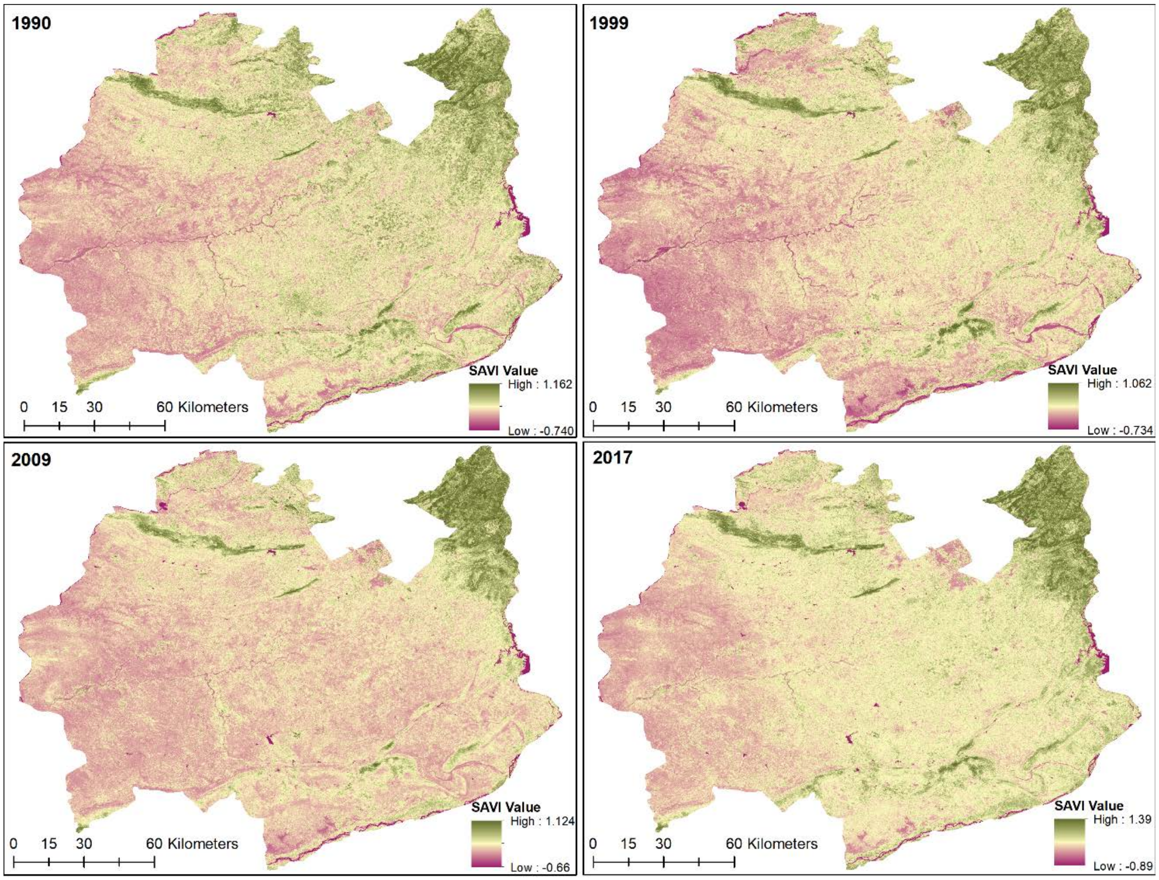


Figure 6. Spatial distribution of Soil Adjusted Vegetation Index

After 10 years in 1999, there is some difference observed in Chakwal district vegetation which shows moderate values, Rawalpindi and Jhelum shows more vegetation. Here Reflectance of settlement can also change the values of SAVI. Forest values are similar in both NDVI and SAVI (Figures 5&6). In 2009, only the Rawalpindi district shows the highest values SAVI as compared to other. However, the other two districts Chakwal and Jhelum show the least values and drought prevailing conditions with low vegetation. In 2017, the vegetation condition looks better, both Rawalpindi and Jhelum shows healthier vegetation condition. Rawalpindi shows high values and Jhelum shows moderate values. On the other side, in Chakwal district most of the areas show moderate values but the western part shows the least values.

Spatio-statistical trend analysis of Annual mean temperature and rainfall using Mann-Kendall Trend Test

The Mann-Kendall trend is a rank-based statistical technique used to assess the significance of trend in time series data. The Mann-Kendall trend test is employed to identify significant decreasing or increasing trends in long-term temporal data such as, rainfall, temperature, evapotranspiration, humidity, pressure and streamflow.

The MK trend lies on 2 hypotheses; one is the null (Ho) and also the alternative is the various (H1) hypothesis. The Ho existence of no trend whereas H1 explains important rising or decline in precipitation or temperature information.

The temperature, Rainfall data sequence was analyzed by using MS Excel and Addinsoft XLSTAT. Addinsoft XLSTAT (2012) has been used to perform MKTM, and for the null hypothesis (Ho), the significance level is 95%. Use non-parametric MKTM for analyzing time series data from selected weather stations. The MKTM was applied to statistical temperature data of all distinguished met stations. The Mann-Kendall model noted that if the p-value ≤ the importance level ($\alpha = 0.05$), then Ho is going to be refused. Refusing Ho means there is a transparent trend within the statistical data. On the opposite hand, if the p-value is bigger than the importance level (0.05), Ho is accepted. Accepting Ho means no obvious trend has been detected. By refusing the null hypothesis, the result is going to be statistically substantial.

The results of both rainfall and temperature detected no significant trend which means the p value was greater than 0.05 at 95% significance level. This indicate that both rainfall and temperature shows variation in the study area but these changes are not exhibit any significance as shown in Table 2.

Table 2. Mann–Kendall trend test results of annual average temperature and annual rainfall for all the met stations.

	Annual Rainfall					Annual Average Temperature				
Name of met station	Mann–Kendall statistics	Kendall's Tau (τ)	Variance (S)	p-value (two-tailed test)	Model interpretation	Mann–Kendall statistics	Kendall's Tau (τ)	Variance (S)	p-value (two-tailed test)	Model interpretation
Rawalpindi	57	0.16	2301	0.246	Accept Ho (NSTD)	29	0.08	2301	0.563	Accept Ho (NSTD)
Jhelum	-19	-0.05	2301	0.711	Accept Ho (NSTD)	-52	-0.13	2562	0.317	Accept Ho (NSTD)
Chakwal	6	0.21	65.33	0.548	Accept Ho (NSTD)	8	0.28	65.33	0.399	Accept Ho (NSTD)

4. Conclusion

The trends in temperature and resulting changes in rainfall patterns and production of crops especially in Potohar region have a robust relationship with temperature changes because the agriculture of the Potohar region depends on rainfall. There are no other means of cultivation in the area so agriculture in this area depends only on rainfall intensity. The study reveals that the crop situation of this region is at high risk as seen from 1998 to 2001 and then from 2009 to 2014 the situation of crops indicates drought situations. As seen the rainfall of the region was in a huge fluctuation. Rainfall in Rawalpindi met station showed the drought prevailing condition from 1998 to 2005 then 2009 to 2014; same as for district Jhelum the rainfall conditions are not favorable for the crops. For the Chakwal district data was limited so it`s hard to predict the situation of rainfall and temperature situation. On the other hand, in the temperature scenario of Rawalpindi, the trend is to increase for temperature rise yearly. The temperature trend of Jhelum is slightly increasing but in Chakwal, district data shows the increasing temperature trend situation. Crop production was affected by the drought and flood of 2010.

The study also focused on the vegetation indices to detect the vegetation or crop condition by satellite images with a gap of 10 years. The images show the vegetation cover with different periods from 1990 to 2017 images, there is a huge difference that occurred in 27 years of data. Low vegetation cover was detected in 1999 and 2017. There is no irrigation system in the area, crops are dependent on rainfall. Therefore, crop production may be affected by climate variability.

Future efforts to make situations for crop conditions will not only provide useful information for meteorological science research platforms in Pakistan and even in South Asia. In further research, the results need to be linked with the output of other models to make an ample assessment and achieve higher reliability in future predictions.

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