Research Article

Impacts of Spatio-Temporal Changes in Rainfall and Temperature on Different Crops in Selected Districts of Punjab, Pakistan

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Abstract | This study ponders the effect of changes in rainfall and temperature of Punjab, Pakistan on the production of five major crops viz. wheat (*triticum*), maize (*zea mayes*), cotton (*gossypium*), sugarcane (Saccharum officinarum) and gram (*Cicer arietinum*). Firstly, changes in mean temperature and rainfall from 1951 to 2015 were assessed at district level. Secondly, the changes in crop performance were computed through remote sensing and crop reporting data obtained from the agriculture department, Government of Punjab, Pakistan. Lastly, changes in crop performance (what does performance mean here!!) were compared with changes in studied climate variables (temperature and rainfall). It was found that increased in mean annual temperature decreased the crop yield. In addition, the climatic variation imparts negatively on studied crop production in the Central Punjab (i.e. Jhang) and southern Punjab (i.e. Bahawalnagar) parts and a positive effect in the northern Punjab (i.e. Attoack and Chakwal) Parts. It is therefore, suggested that various agriculture departments be educated regarding outcomes / conclusions of this paper so that formers be trained to take necessary precautions while looking after their crops at different stages of crop cycle regarding these climatic variables i.e. temperature and rainfall.

Received | February 28, 2018; **Accepted** | April 10, 2018; **Published** | May 29, 2018
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Citation | Yasin, M.Y., M.R. Khan and M. Amin. 2018. Impacts of Spatio-Temporal Changes in Rainfall and Temperature on Different Crops in Selected Districts of Punjab, Pakistan. *Sarhad Journal of Agriculture,* 34(2): 400-413.
DOI | http://dx.doi.org/10.17582/journal.sja/2018/34.2.400.413
Keywords | Agriculture, Temperature, Rainfall, Punjab, Punjab crops

Introduction

Variations in temperature and precipitation are adversely influencing land resources such as water, farming systems, beach front areas, freshwater territories, vegetation, and topographical features (Malla, 2009). The climatic variation is a worldwide phenomenon. Worldwide ratio of increment in temperature is about 1.4-5.7°C which is due to increments in ozone depleting substances before the end of current century (Houghton et al., 2001). Climatic modification is leaving an effect on nutrition safety at all levels viz., global, vicinity, and near-by levels (Cell, 2009). This change can aggravate food openness, diminish access to nutrition, and impact food worth. For example, probable augmentations in temperatures, changes in precipitation designs, changes in uncommon environment occasions and decline in water receptiveness may all outcomes in diminished crops productivity (Wheeler and Von, 2013).

Pakistan has limited arable land with farming segment's contribution of 21% in GDP out of which about 7.84% is from crops and remaining comes from livestock sector (Usman, 2016). Rabbi (winter) and Kharif (summer) are Pakistan's two prime harvest seasons demanding optimal levels of precipitation and temperature which if surpass or diminish from the required levels, our agrarian profitability is adversely affected (Naheed et al., 2010). The impact of such changes can be both damaging and helpful. For instance, no basic adverse impact of weather change on wheat in Pakistan (Hussain et al., 2007) but 2011 destructive effect was demonstrated because of rise in temperature on farm production (Xin et al., 2011). Thus, relationship between such environmental changes and yield needs to be explored (Patwardhan et al., 2007). It has also been reported that rain fall changes in Pakistan affected agricultural production. The already dwindling agrarian economy of Pakistan needs attention of decision makers particularly in the wake of consistent floods in the years 2010, 2011 and 2012 (Schütte et al., 2012). The decision makers need to know whether the implemented levels of modification are adequate to deal with the probable effects of environmental changes on agricultural productivity. Climate change has adversarial results on Pakistan although with 135th level on the globe with respect greenhouse gasses (GHG) discharge per capita with 7th position among the countries affected by climate change (Asif, 2013; Hoyt and Schatten, 1997). Climate change poses significant risks across diverse divisions and groups, for instance, sustenance, water, forests, biodiversity, oceanic and marine with related hazards such as floods and drought (Khan et al., 2016).

Environmental change is the critical driver of nutrition security, since climate change controls the benefit of farming industry not only its firmness but also distinctive sections of food structure, including size, access, and utilization (Gregory et al., 2005). This is, additionally valid if such changes occur in technologically developed or undeveloped nations to lessen adverse impacts of environmental change. As countering the adverse impacts requires searching for different adjustment methodologies to changing climates in all spaces of existence (Abid et al., 2016). Assessing the outcomes of climatic variations on foremost agrarian yields (e.g. wheat, cotton, rice and sugarcane) utilizing a board information from 1980-2008 on designated areas of Punjab. The investigation was huge as it considered the effect of environmental change at four germination phases of the harvests. The analysis established a helpful effect of climate change on wheat creation and has an adverse effect on rice, cotton and sugarcane generation. A few studies have demonstrated that in Pakistan the agriculture sector is especially incapable against climate change. An investigation on outcomes of environmental variations of wheat growth in Punjab was directed. The goal of the analysis was to discover the mean greatest temperature, mean least temperature, sufficient precipitation and other financial aspects that affects wheat generation in the amalgamated zone of Punjab territory. The analysis demonstrated that climate change affects wheat efficiency at the seeding, vegetative and enlargement phases of wheat development (Ashfaq et al., 2011). An additional investigation in Rawalpindi division evaluating the effect of climate on agrarian estate incomes was accomplished (Aamir et al., 2015). Climate change disorders are caused from high heats, fluctuations in rainfall, and complex climatic CO_2 fixation. There are three options by which the greenhouse gases result might be vital for agricultural business. At to start with, expanded normal CO_2 can have a direct effect on change rate of item floras. Also, CO_2-incited alterations of air may alter levels of temperature, rainfall and daylight that can influence vegetable and plant growth (Mahato, 2014).

Heat waves are reason for crazy warm stress in crops that can diminishes crops when they are in critical periods of their growth (Jovanovic and Stikic, 2012). In agricultural structures, crop biodiversity might stretch the association among strain along with adaptability as better assortment of living is required for natural agendas (Heal, 2000). Since, Pakistan is not technologically advanced country at this moment. Hence, at this stage it is more appropriate to look for adaptability measures rather than implementing counter climate change measures. This requires to look for various components of climate change not only through quantifying but also estimating their impact on agriculture. This will help in identifying hotspot areas as well as resilient areas. Keeping this in view, the study aimed at recognizing changes in two parameters of climate (i.e. temperature and precipitation) at regulatory intervals across Punjab (1980 - 2015). Moreover, varying temperature and precipitation is correlated with crop performance (profiles) to quantify the impact of these changes on crop production.

Materials and Methods

Study area description

Punjab, province of eastern Pakistan lies on the edge of the monsoon climate (31.1704° N, 72.7097° E). Province can be divided into three distant parts i.e. northern, central and southern. The temperature is by

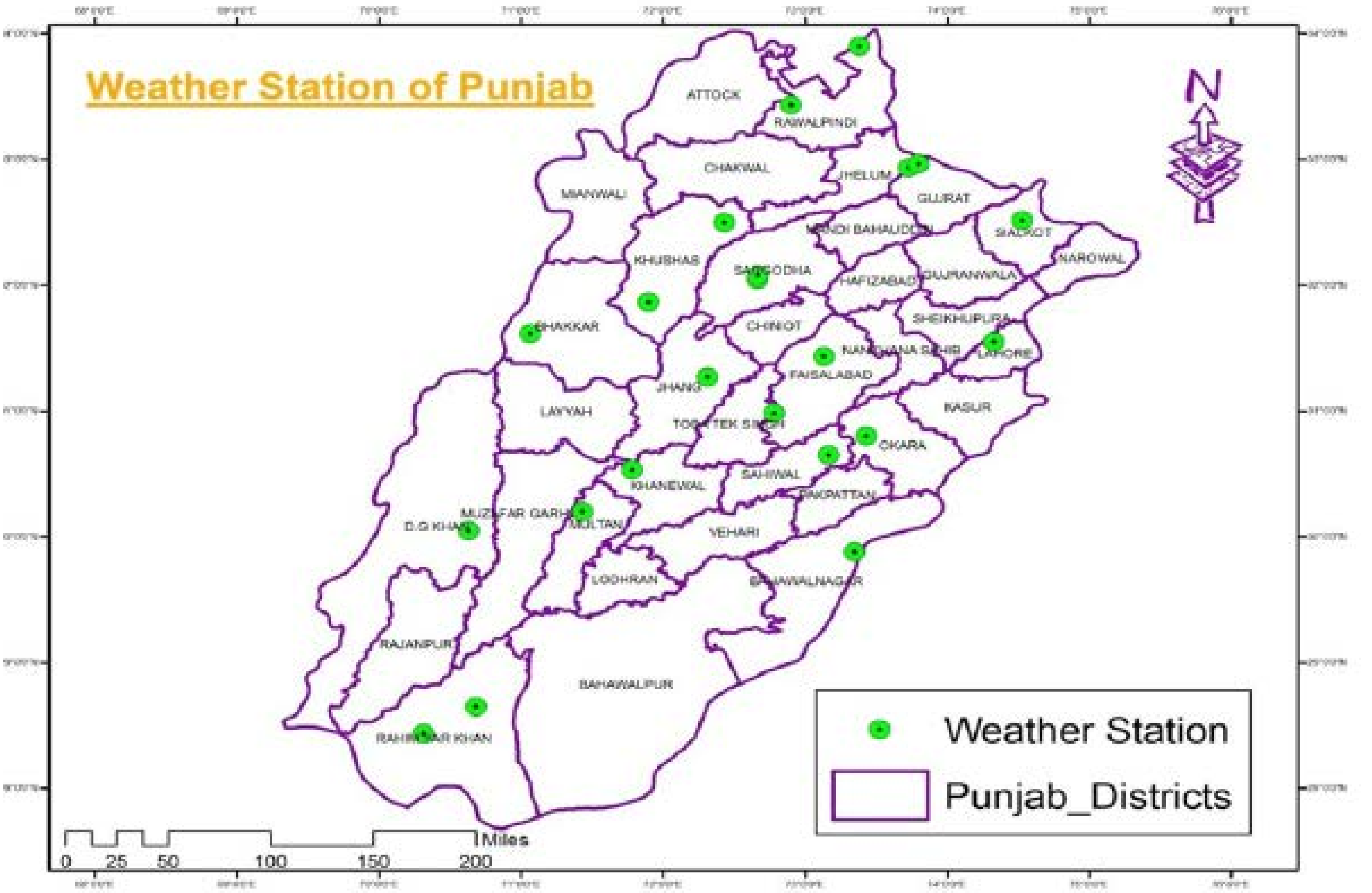


Figure 1: *Pakistan Metrological Department Weather Stations which observe and record continuously temperature, rainfall and many other type of climatic data and are located mostly in every district of Punjab.*

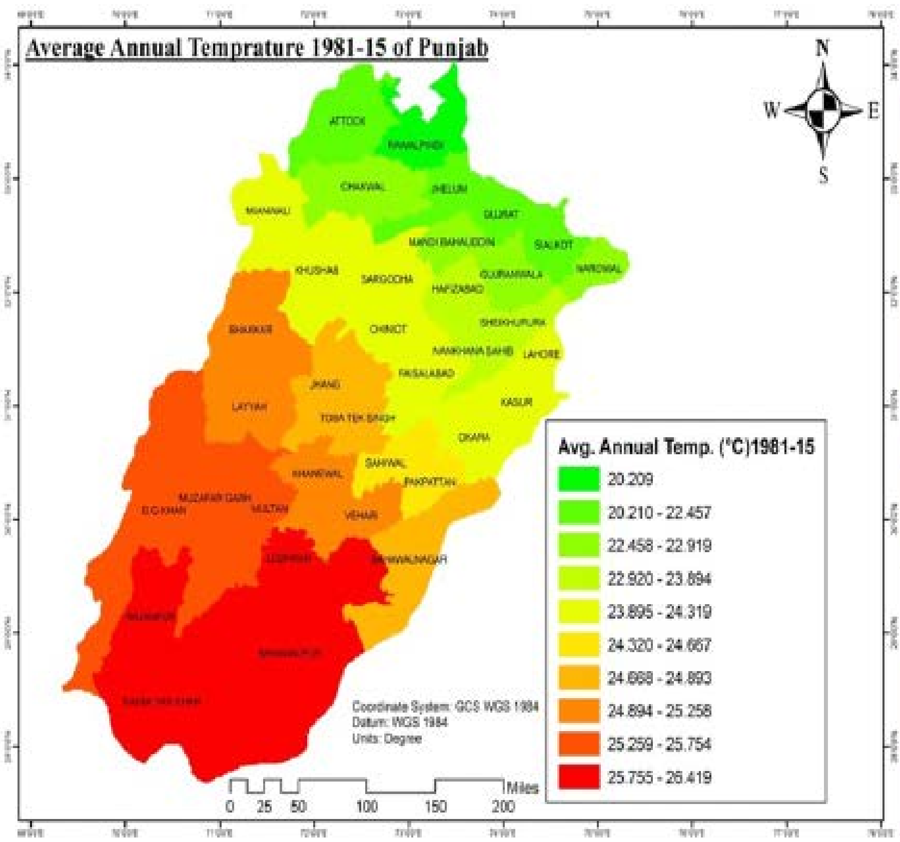
and large sweltering, with checked varieties amongst summer and winter. In June the average temperature achieves the mid-89s F (mid-30s C), whereas in January the average temperature is in the mid-49s F (low 10s C). Important crops are wheat and cotton in central and southern Punjab. Different products developed incorporate rice, sugarcane, millet, corn (maize), oilseeds, heartbeats, organic products, and vegetables. Domesticated animals and poultry are brought up in extensive numbers. Total number of weather stations working in Punjab Province is shown in (Figure 1) which shows the location of these stations that are stretched across the province.

Temperature and Rainfall change in Punjab

Climatic data (Rainfall and Temperature) was obtained from weather stations of Pakistan Meteorological Department (PMD) across Punjab. The data included temperature (°C) and rainfall (mm) for different regions in District Punjab for (a) Average data for two normal periods (1955 to 1985 and 1985 to 2015). The data were used to compute the climatic change occurred in the study area since last 60 years and (b) the monthly average data from 2000 to 2014. The last fifteen years climatic data was used to observe the impact of changing climate on crop producing areas of Punjab. These two parameters (Temperature and Rainfall) have the longest and largest information scope.

Figure 2 demonstrates the annual average temperature in the time of first climate normal in district Punjab from 1951 to 1980 introduces that the coldest locales are Rawalpindi 19.61°C, Attock 21.72 °C, Jehlum 22.61 °C and Gujrat 22.93 °C. While, the most sweltering areas of Punjab are Lodhran 25.81 °C, Bahwalpur 25.42 °C, Multan 25.33 °C and Rahim Yar Khan 25.11 °C.

Figure 3 demonstrates the time of second climate normal of average temperature in district Punjab (1981-2015) which demonstrated that the hottest areas are Rahim Yar Khan 26.41 °C, Multan 26.11 °C, Bahwalpur 26.06 °C and Lodhran 26.10 °C. While, the coldest among the areas of Punjab include Rawalpindi 20.22°C, Attock 21.72 °C, Jehlum 22.42 °C and Gujrat 23.82 °C.



Districts	Temp °C
Rawalpindi	20.2
Attock	21.7
Jhelum	22.4
Gujrat	23.8
Rahim Yar Khan	26.4
Multan	26.1
Bahawalpur	26.0
Lodhran	26.1

Figure 2: *Average temperature Map (0C) 1951 – 1980 map of Punjab.*

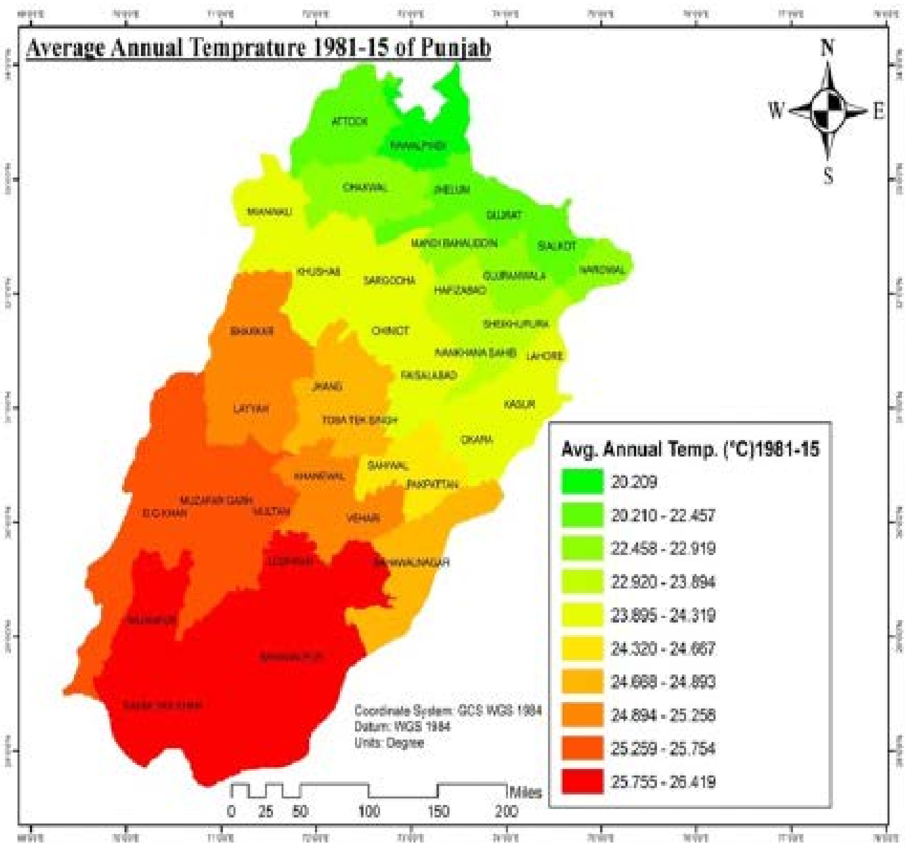


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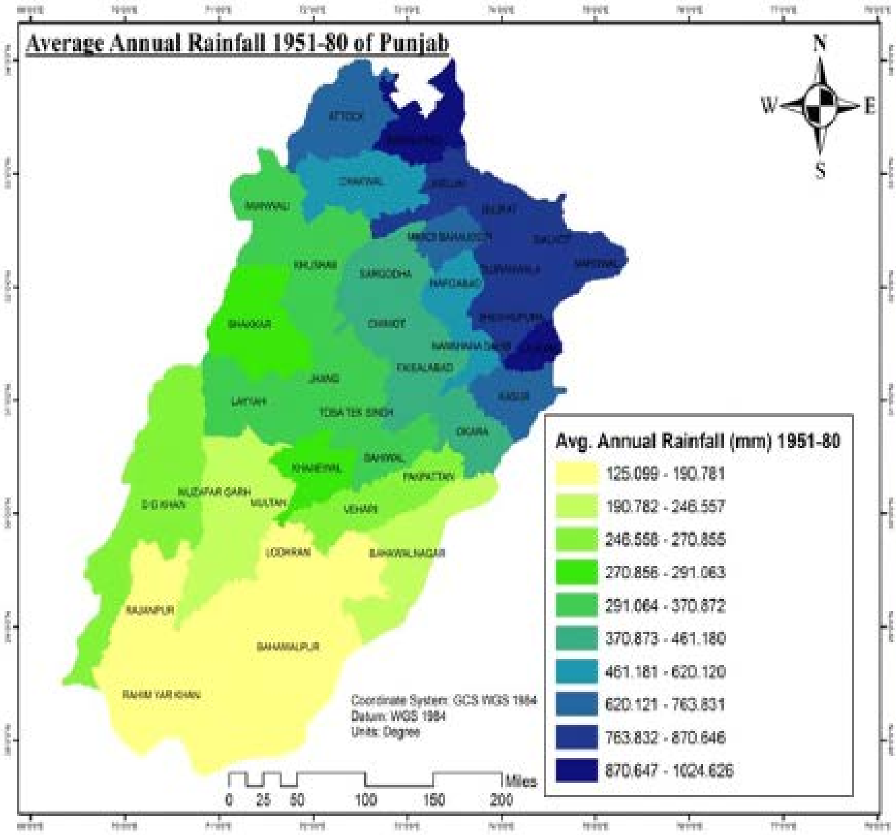
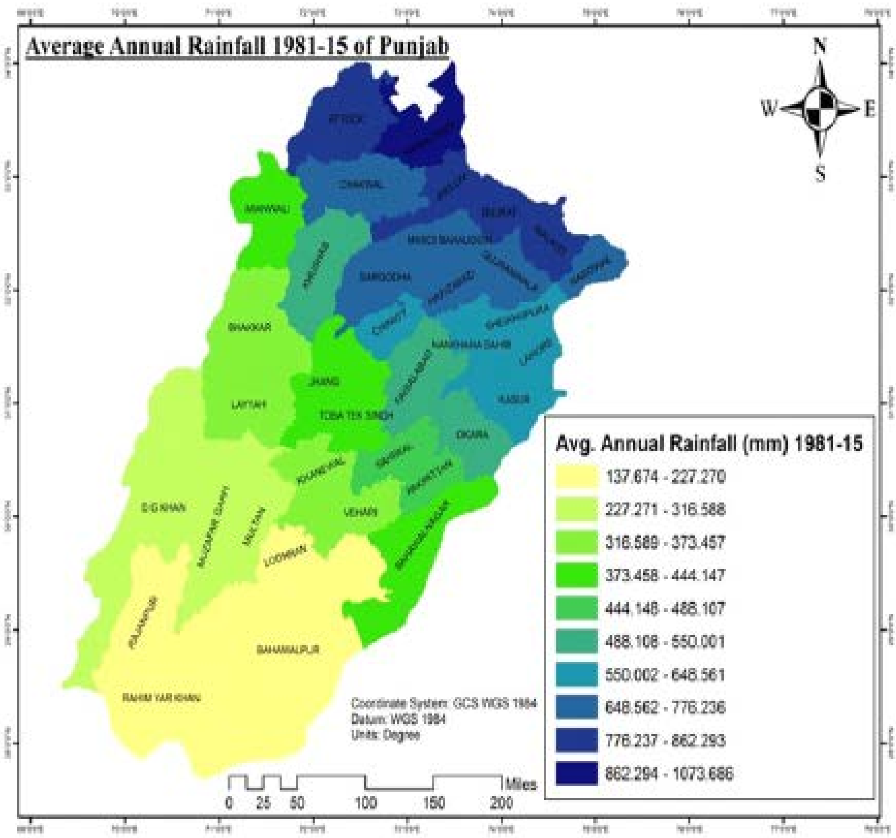
Figure 3: *Average temperature Map (°C) 1981 – 2015 map of Punjab.*

Average precipitation in the time of first normal climate (1951-1980) shows that district Rawalpindi 1073.7 mm, district Attock 862.3 mm, district Jhelum 829.1 mm and district Gujrat 808.8 mm were the rainy locales of Punjab province. While, district Rahim Yar Khan 137.7 mm, district Rajanpur 197.1 mm,



Districts	Rainfall (mm)
Rawalpindi	1073
Attock	862
Jhelum	829
Gujrat	808
Rahim Yar Khan	137
Rajanpur	197
Bahawalpur	227
Lodhran	205

Figure 4: *Average rainfall (mm) 1951 – 1980 map of Punjab.*

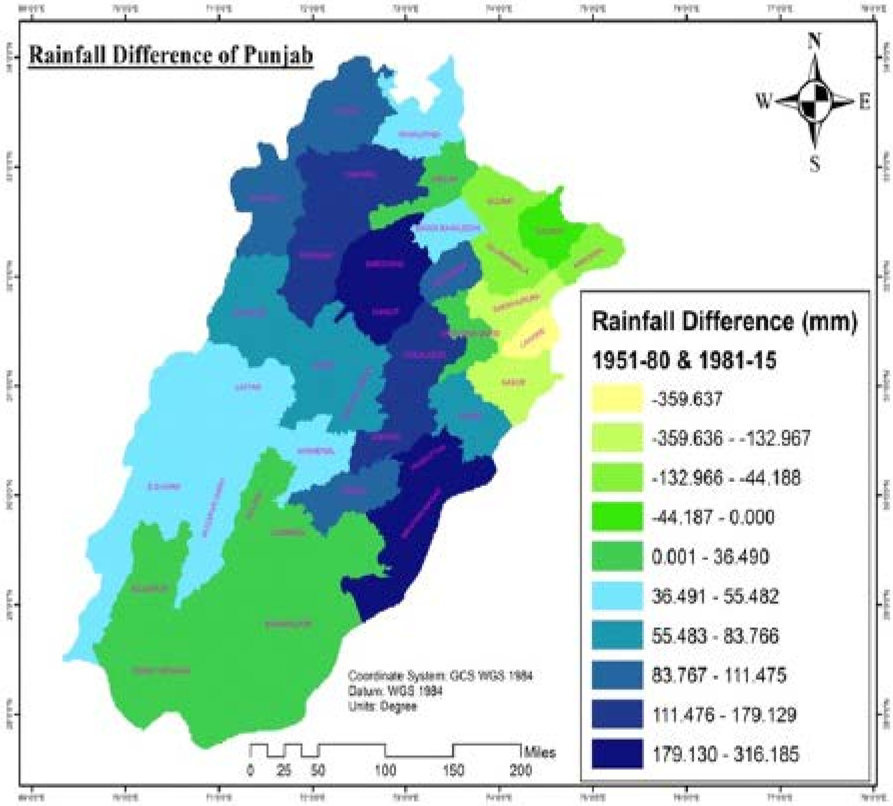


Districts	Rainfall (mm)
Rawalpindi	1024
Lahore	960
Sheikupura	827
Gujrat	870
Rahim Yar Khan	125
Rajanpur	171
Bahawalpur	190
Lodhran	187

Figure 5: *Average rainfall (mm) 1981 – 2015 map of Punjab.*

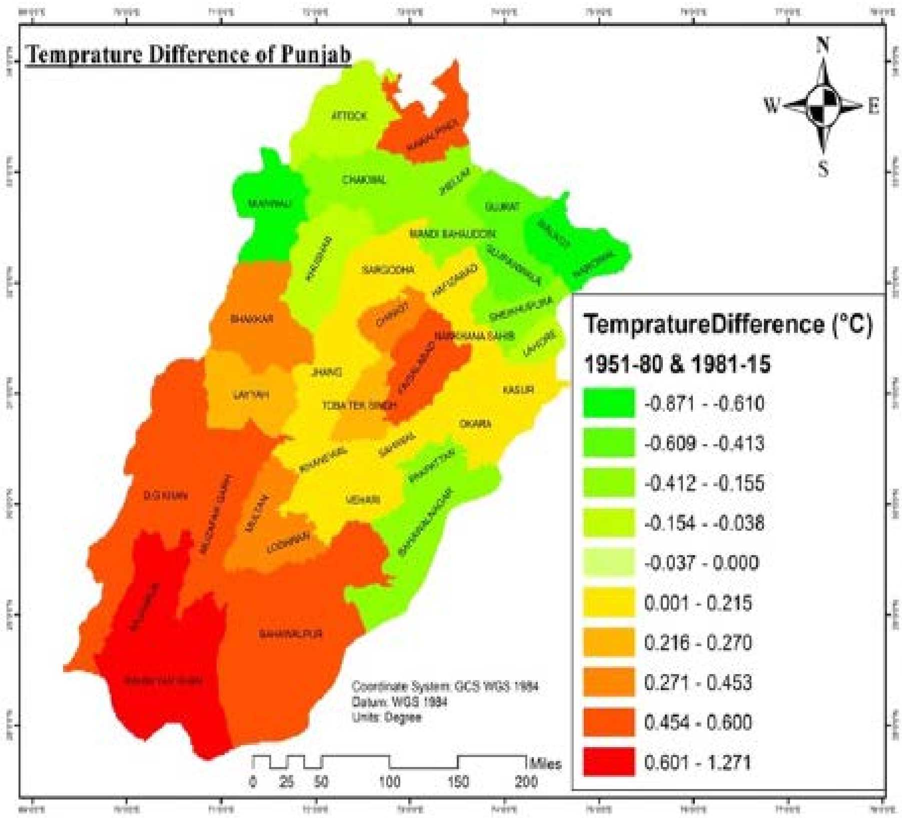
district Lodhran 205.3 mm and district Bahawalpur 227.3 mm were the dry out areas of the Province (Figure 4).

The normal rainfall in the time of second climate normal (1981-2015) in the districts of province (Figure 5) occurred that district Rawalpindi 1024.1 mm, dis-



Districts	Rainfall Increase
Lahore	359.6
Sheikhupura	178.6
Kasur	132.9
Gujrat	61.8
Districts	**Rainfall Decrease**
Sargodha	316.2
Chiniot	225.7
Pakpattan	225.7
Bahawal Nagar	205.1

Figure 6: *Rainfall change (mm) 1951 – 2015 map of Punjab.*



Districts	Temp (°C) Decrease
Sialkot	0.871
Narowal	0.616
Mianwali	0.610
Gujrat	0.477
Districts	**Temp (°C) Increase**
Rahim Yar Khan	1.27
Rajanpur	0.987
Faisalabad	0.600
D.G Khan	0.582

Figure 7: *Temperature change (0C) 1951 – 2015 map of Punjab.*

trict Lahore 960.2 mm, district Sheikhupura 827.3 mm and Gujrat 870.2 mm were the most rainy districts. While, district Rahimyar Khan 125.2 mm, district Rajanpur 171.3 mm, district Bahwalpur 190.4 mm and district Lodhran 187.2 mm were the driest area of the province of Punjab.

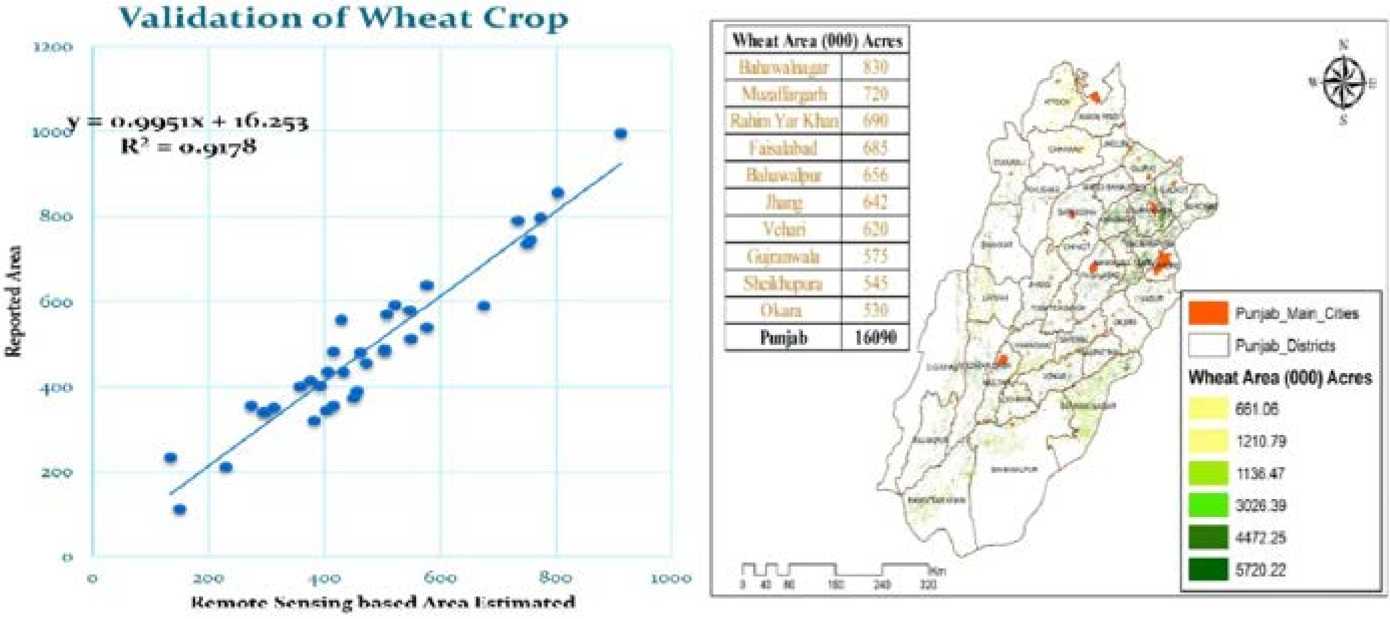


Figure 8: *Validation – Remote sensing vs reported data of wheat crop.*

Figure 6 shows the maximum increment in precipitation was seen in Lahore 359.62 mm, Sheikhupura 178.64 mm, Kasur 132.92 mm and Gujrat 61.83 mm. While, Sargodha 316.21 mm, Chiniot 230.82 mm, Pakpattan 225.72 mm and Bahwalnagar 205.12 mm, demonstrated the most extreme decline in precipitation.

Figure 7 demonstrates the difference in temperature of Punjab region. Most extreme increment in temperature was seen in Rahim Yar Khan 1.27 °C, Rajanpur 0.98 °C, Faisalabad 0.600 °C, and D.G. Khan 0.582. °C.While, greatest decline in temperature was seen in Sialkot 0.871 °C, Narowal 0.616 °C, Mianwali 0.610 °C & Gujrat 0.477°C.

Crop identification and monitoring performance with remote sensing

After obtaining the spatio-temporal changes in temperature and rainfall the next requirement was estimating the impact of these changes on crop performance. This required the spatial knowledge of various crop grown in the study area for the studied period. For this purpose remote sensing was used to map various crops in space and time. Firstly, MODIS NDVI (MOD13Q1) data available after every 16 days with 250 meter resolutions was acquired from glovis website to prepare spatially explicit crop maps. Secondly, unsupervised classification was implemented using ISO DATA clustering method to identify of crop patterns. ISODATA clustering has minimum user inputs which are number of iterations (set to 50) and convergence threshold (set to 0.95) for every classification run (Khan et al., 2010). A total number of 20 classification runs were executed starting from 5 classes till hundred classes with an increment of 5 classes in each run. The output of each classification run was a classified image and its corresponding signature. Optimal classification was selected by using Divergence statistics (Sawin, 1973).

Thirdly, after selection of optimal classification the corresponding signature was used and matched with practiced crop calendar of the study are and each class was related with the crop calendar. Individual crop areas were then identified both in Rabi and Kharif seasons by linking the results of image processing and the crop calendar information along with crop area statistics obtained from crop reporting service. Fourthly, the crop profiles identified through afore mentioned signatures were linked with changes in temperature and rainfall. Lastly, changes in temperature and rainfall at district level were correlated with reported yield data to quantify the impact of these weather changes over the period of time on crop production

Results and Discussion

Comparison – Satellite remote sensing vs. survey of wheat crop

Figure 8 shows that accuracy of remote sensing based wheat crop map is 91%. The results show that remote sensing results were very accurate with respect to the survey data collected from agriculture directorate of Punjab for the same time span as acquired date of satellite imagery. The comparison Figure reveals that escalating pattern of the precipitation has extremely dense effect on the wheat crop production. The zone

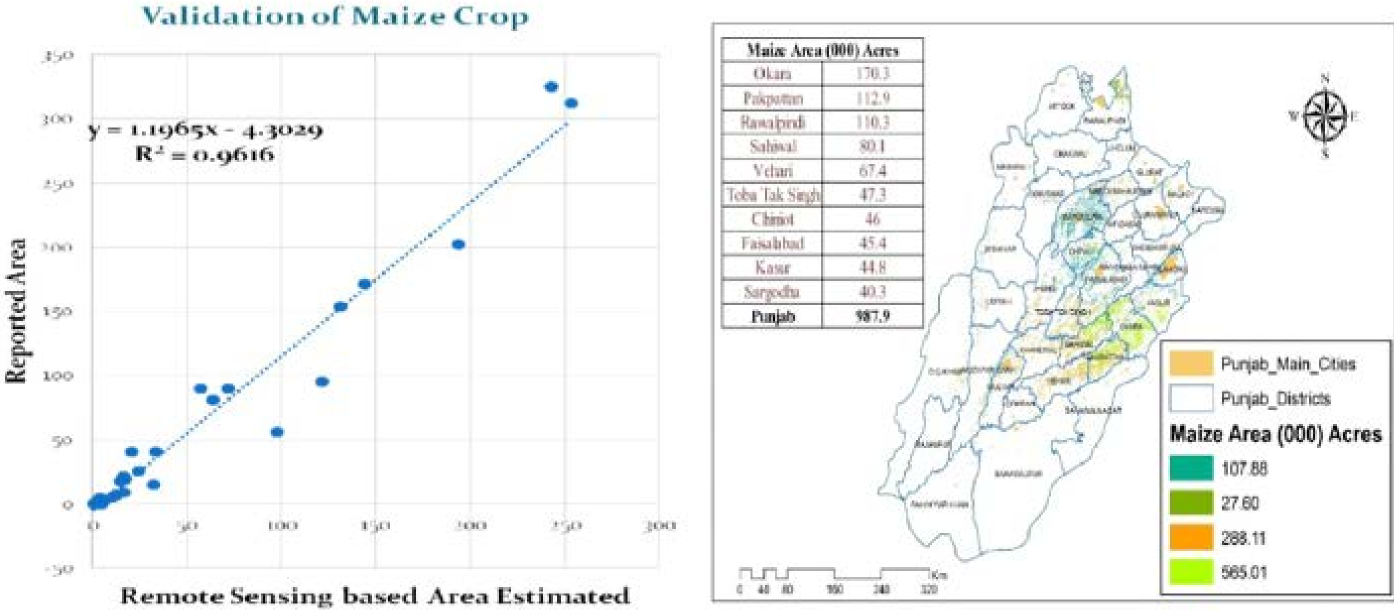


Figure 9: *Validation – Remote sensing vs reported data of maize crop.*

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Comparison – Satellite remote sensing vs. survey data of maize crop

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Comparison–Satellite remote sensing vs. survey data of maize crop

Figure 9 demonstrates that the validation of Maize crop map which shows that data collected from survey and satellite-based crop area estimates have correlation of 96%. Regression line goes almost through the origin with a very small constant of 4.3 acres. Remote sensing results were extremely exact concerning the survey information. The result shows that spatial analysis were in high agreement with those were accumulated from Punjab directorate of same time course of action as got due of satellite imagery.

Comparison – Remote sensing data vs survey data of cotton crop

For cotton crops the approximate analysis shows that the authentication of cotton crop is also high as it shows 94 % correlation of remote sensing based cotton area estimate and the crop reporting data of agriculture department of Punjab. The approximate information was based on satellite information and crop calendar. Moreover, the regression line passes almost through the origin with a small amount of constant i.e. 9.98 acres. This shows that area of classified NDVI data sufficiently represented the variability in the cotton crop area.

Comparison – Satellite remote sensing vs survey data of sugarcane crop

Approximate analysis of sugarcane crop shows the authentication which imprints to 94% correlation of remotely sensed crop areas with the crop reporting data. The relapse data was pointed from audit and through satellite view; because of gigantic determination, satellite information was utilized for the approximate examination. The output dictates that stunningly correct correlation of remote sensing with the audit analysis, which were accumulated from Punjab agriculture directorate. There was a negligible constant of 0.31 acres of constant and regression line is passing almost through the origin.

Comparison – Satellite remote sensing data vs survey data of gram crop

For Gram crops the approximate analysis shows that the authentication is 94 % of remote sensed outcomes and of overview information also. The result shows that the generated gram crop map was extraordinarily

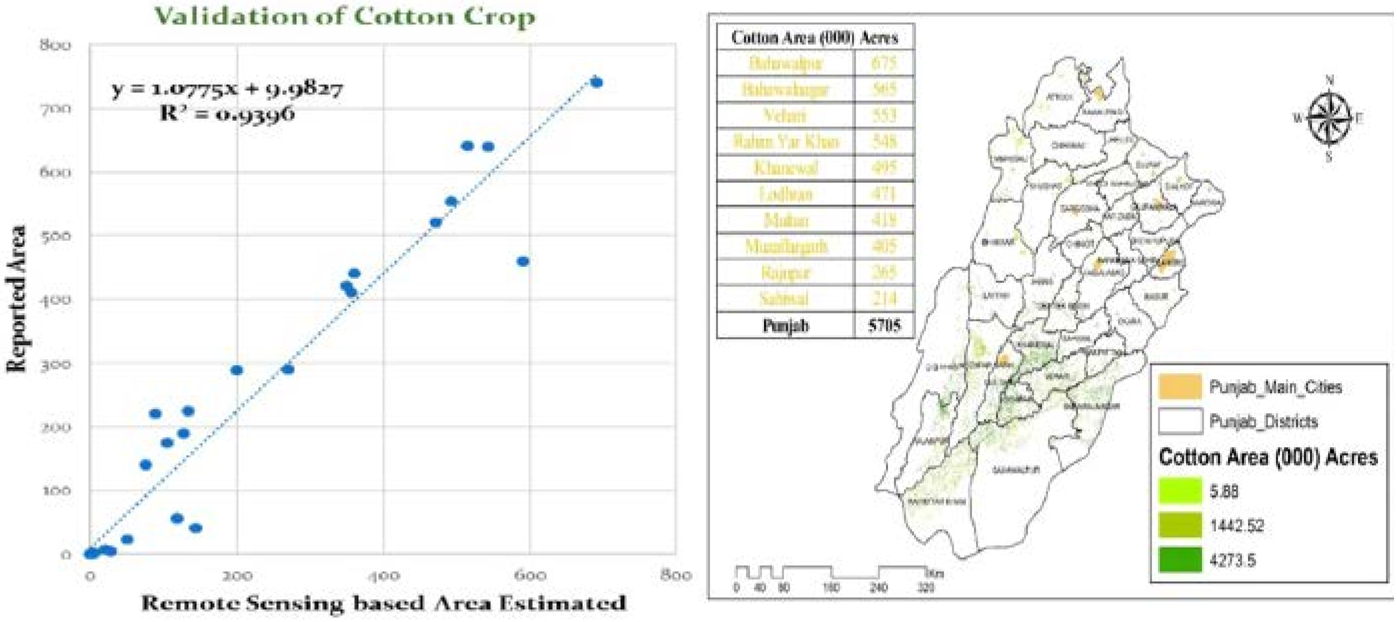

Figure 10: *Validation – Remote Sensing vs Reported Data of Cotton Crop.*

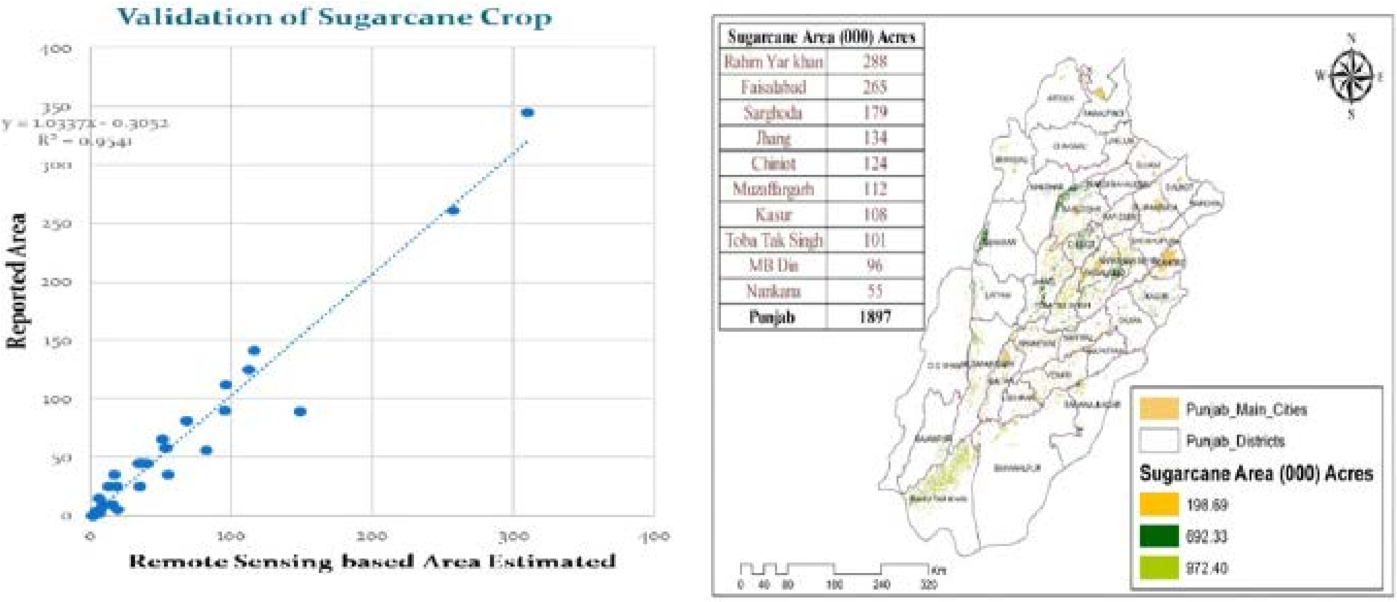

Figure 11: *Validation – Remote Sensing vs Reported Data of Sugarcane Crop.*

correlated (94%) with the data obtained from agriculture directorate of Punjab. concerning the investigation data. The regression line passes almost through the origin with a small value of constant (9.98 acres). Strong correlation among the satellite derived crop areas and the crop reported area (or field data) have also been reported by various studies. In these studies, researcher have used vegetation indices computes from multitemporal satellite images (Asgarianet al., 2016; Wardlow and Egbert, 2008) values are enough to ensure that the satellite-derived maize distribution can be distinguished from other land cover types in study area. Due to high temporal resolution of Satellite data and linking of crop phenology with the remote sensing data, the generated map showed high accuracy with respect to the data obtained from agriculture directorate of Punjab.

The Figures 8, 9, 10, 11 and 12, show that the generated crop area maps have strong correlation with the area of these crops reported by the agriculture department of Punjab. The remote sensed NDVI data are therefore, strong predictors of crop area as there is a very small amount of constant in the aforementioned figures. This clearly depicts that no other explanatory variables are not needed in the presence of remotely sensed NDVI data.

Impact of the rainfall on wheat vegetation

The effect of the precipitation on vegetative period

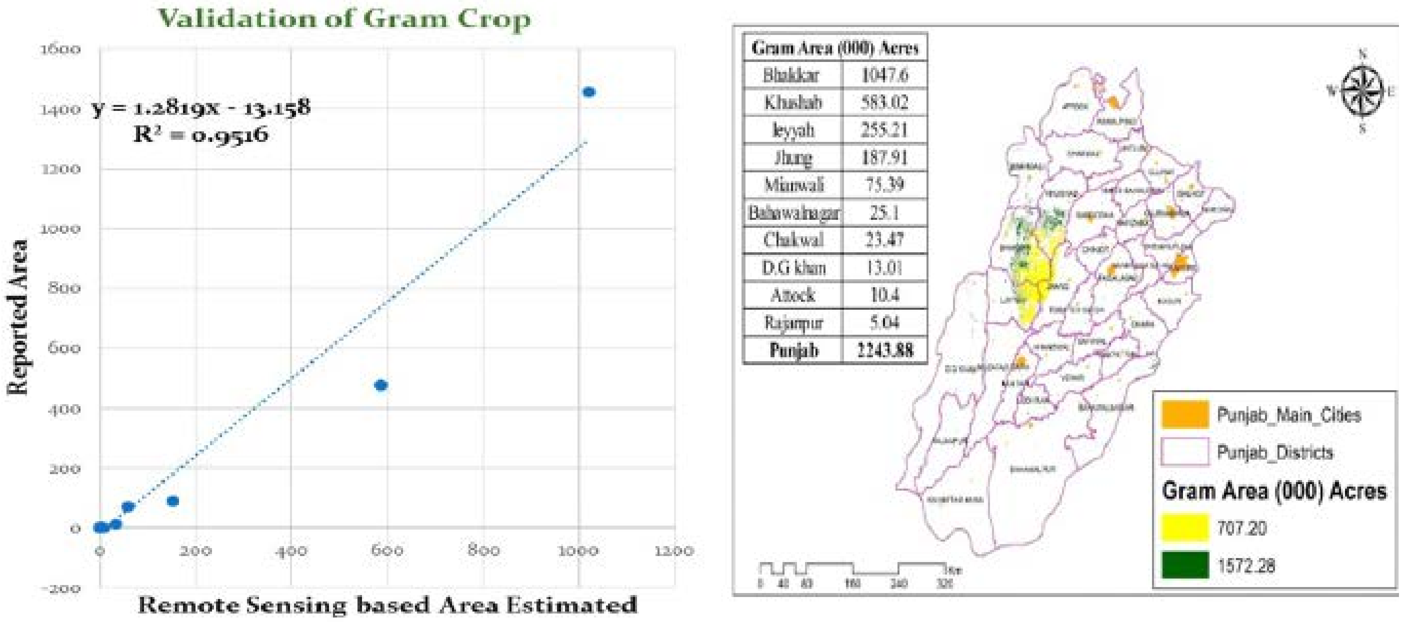

Figure 12: *Validation – Remote Sensing vs Reported Data Gram Crop.*

through regression analysis demonstrates that vegetation i.e. NDVI is 27% correlated with the rainfall. So the precipitation factor is vital for production of wheat especially northern areas of Punjab where surface water is not supplied. Upper part of Punjab is absolutely reliant on precipitation factor which included the studied districts of Attock and Chakwal whereas, central and southern districts have the supply of surface water for irrigation.

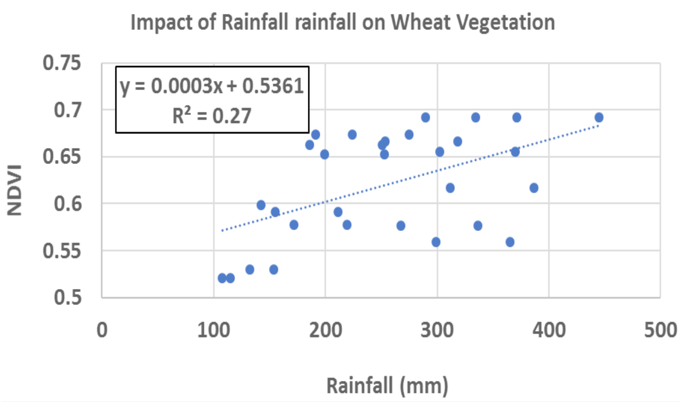

Figure 13: *Impact of Rainfall on wheat Vegetation.*

Impact of temperature on wheat vegetation

The effect of the temperature on vegetative period through regression analysis demonstrates that authentication of analysis for wheat is 21%. Thus, temperature is vital for growth and development of wheat as with increasing temperature, the NDVI decreases. Temperature affect is extremely huge between the month of March and April for development level of crops as show by Table 1.

This is because of the reason of wheat being at critical stage of maturity and slight increase in temperature causes browning of the crop and hence less values of NDVI.

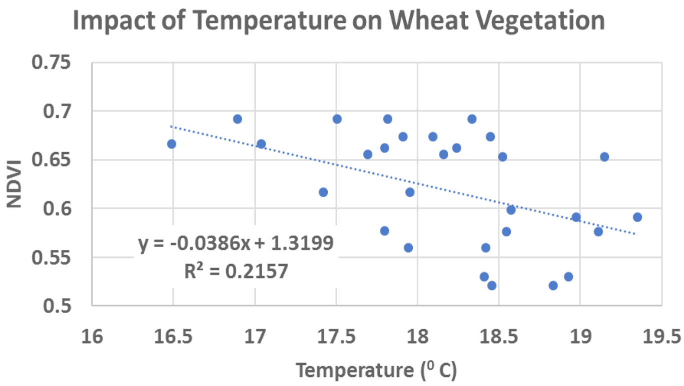

Figure 14: *Impact of Temperature on wheat Vegetation.*

Impact of rainfall and temperature in irrigated districts

Following two irrigated districts were chosen to study the influence of rainfall and temperature on wheat vegetation and production.

District Bahawalnagar: One of the most profitable regions for growing wheat is District Bahawalnagar (Figure 15). The significances of wheat NDVI as for the climatic variables of Precipitation and temperature were examined with crop generation (Figure 16). As indicated by the aftereffects of Bahawalnagar, wheat production is equally better regarding precipitation. The connection amongst precipitation and wheat crop is 34% and additional aspect of climate i.e. temperature is 0.023%. (Figure 17). The maximum increase in the rainfall was calculated to be 140mm in the year 2005 and it has simultaneously effected the growth of wheat in the respective and the following years.

Table 1: *Showing Impact of climate variables on Kharif crop production.*

	Regression Statistics			Coefficients	P-value
Cotton	R square	0.428	Intercept	9183.309	0.007
			Temp July	-199.159	0.014
			Temp Aug	-183.409	0.031
			Rain Kharif	-5.864	0.042
Maize	R square	0.43	Intercept	812.184	0
			Temp May	-6.058	0
			Rain Sep	0.406	0.025
			Rain kharif	-0.347	0.053
Sugar-cane	R square	0.366	Intercept	1317.704	0.003
			Temp Sep	26.128	0.008
			Rain Aug	0.593	0.013
			Rain Sep	0.604	0.004
			Rain kharif	-0.42	0.021
Wheat	R square	0.505	Intercept	28.672	0.001
			Rain Jan	-0.034	0.004
			Rain Feb	-0.024	0.003
			Temp Oct	1.674	0
			Temp Nov	0.663	0.041
			Temp Dec	-1.006	0

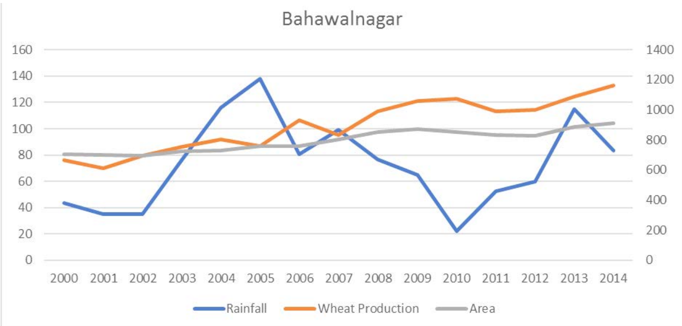

Figure 15: *Impact of climate change on crop performance in District Bahawalnagar.*

As Bahawalnagar is an irrigated district of Punjab, therefore, though the rainfall decline was observed from 2006 -2010 but the production of wheat did not decline because of additional water was available for irrigating the wheat grown fields.

District Jhang: For wheat growing district Jhang is moderate productive area (Figure 19). The aftereffects of wheat NDVI as for the climatic variables of temperature and precipitation were investigated with crop production. As indicated by the outcomes of Jhang District wheat production regarding precipitation is 15% and added factor of climate i.e. temperature is 0.0266%.

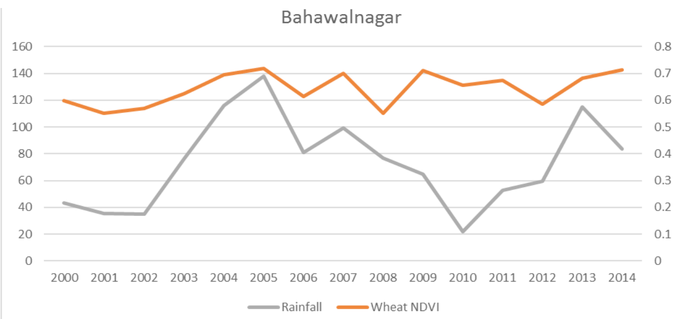

Figure 16: *Impact of climate change on wheat NDVI in District Bahawalnagar.*

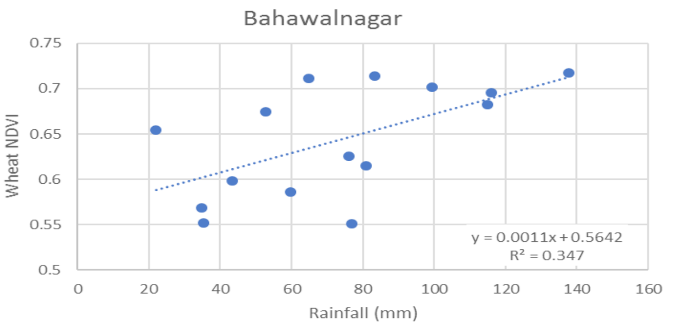

Figure 17: *Impact of rainfall on crop performance in District Bahawalnagar.*

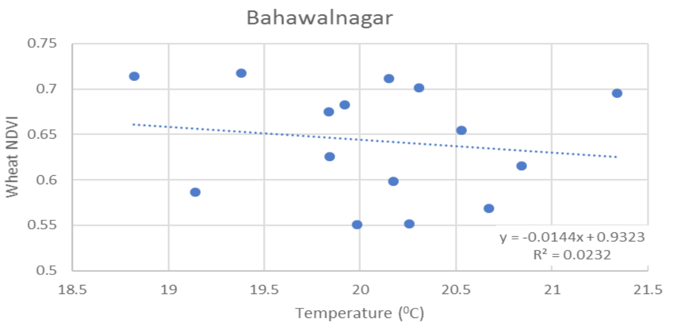

Figure 18: *Impact of temperature on crop performance in Bahawalnagar.*

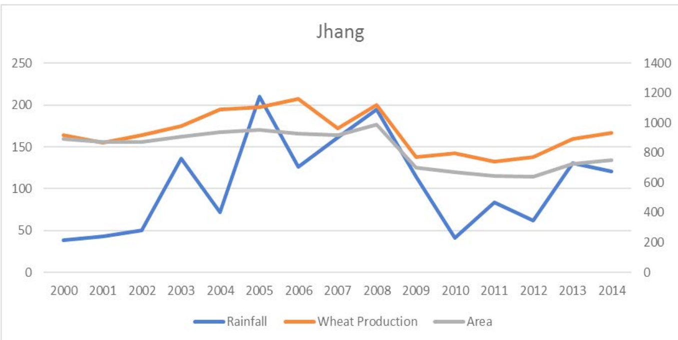

Figure 19: *Impact of climate change on crop performance.*

In wheat areas of Jhang, temperature and rainfall both have minute impacts of the wheat production and NDVI values. The reason for the week affect is because like Bahwalnagar it is also an irrigated area and water requirements are fulfilled by additional supply of water through surface water irrigation.

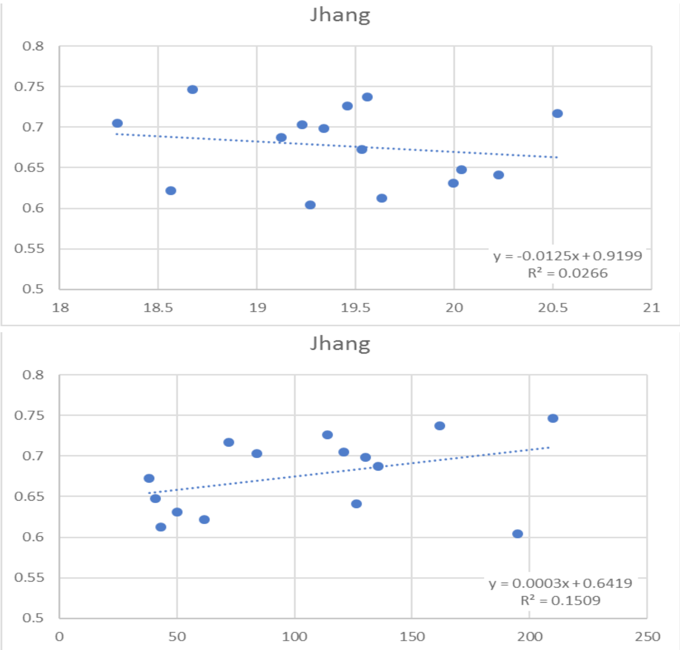

Figure 20: *Impact of climate change on crop performance in Jhang.*

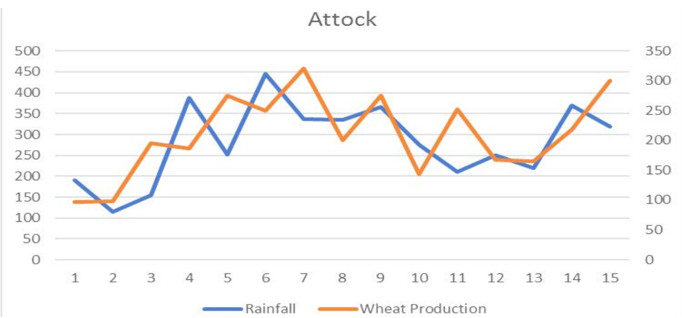

Figure 21: *Impact of climate change on crop Performance.*

Impact of rainfall and temperature in rainfed districts

Following two rainfed districts were chosen to study the influence of rainfall and temperature on wheat vegetation and production.

District Attock: District Attock has rain fed territory and greater crops rely upon precipitation. Here behaviour of crops and its production is specifically relative to the precipitation even from sowing season to development of the crops. (Figure 21). Moreover, in this district the temperature in the months of March and April has very strong impact due to ripeness of the crops. Out of 692000 hectares of geographical area in Attock, 318000 hectares is cultivated area.

From 2007 to 2010, there has been a decline in the amount of rainfall in district Attock which adversely impacted on wheat production. Whereas, in 2011 there was increased amount of rain which consequently improved the production of wheat.

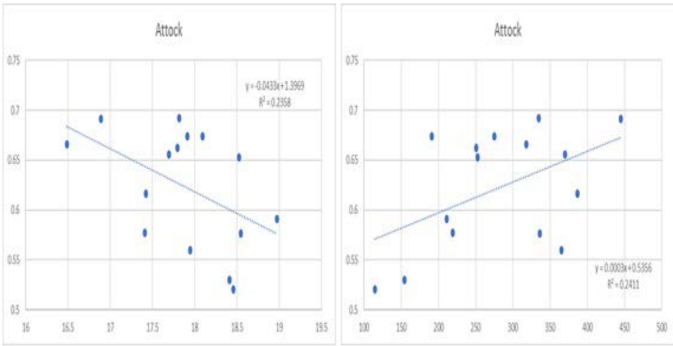

Figure 22: *Impact of climate change on crop performance in Attock.*

District Chakwal: The crop behaviour and area production in district Chakwal is directly proportional with respect to the precipitation from spreading season to availability of the crops. As indicated by the results of District Chakwal wheat production as for precipitation is 33% and other factor of atmosphere i.e. temperature is 0.0293%.

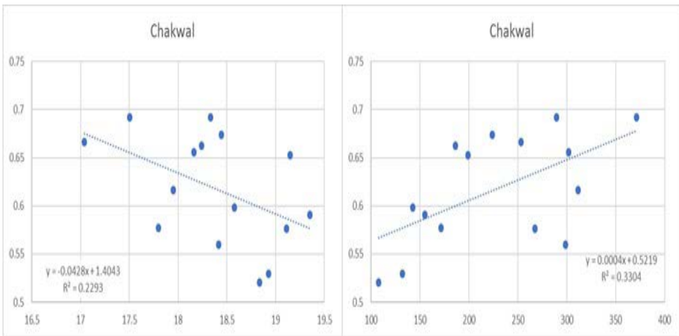

Figure 23: *Impact of climate change on crop performance in Chakwal.*

Both the rainfed districts, had close positive association of wheat production and the amount of rainfall. High temperature during the growing season decreases wheat production by increasing evaporation rate which is in agreement with the findings of the previous literature. Furthermore, other studies have also indicated that seasonal precipitation and temperature significantly affect grain yields. With increasing temperature, evapotranspiration is increased and hence production is reduced if sufficient amount of water is not supplied in time. Several researchers have described the relationship between ET and a crop yield a linear or curvilinear (Tolk and Howell, 2008). Furthermore, other studies have also indicated that seasonal precipitation and temperature significantly affect grain yields. Climate variability and changes are expected to adversely affect crop productivity and yields in the rainfed regions mainly because of the crop water stress (Asgarian et al., 2016; Sarkar and Kafatos, 2004).

The results show that changing temperature and rainfall have significant correlation with the yield of above mentioned crops. For cotton, it is observed that increasing temperature by the months of July and august cause's decline for the yield and similarly rainfall has negative but very less impact on the cotton yield. In case of Maize crop, rainfall in the month of September contributes positively on yield. Whereas, temperature in the month of May shows negative correlation with yield. Sugarcane yield shows positive correlation the temperature in the month of September, rainfall in the months of August and September. Wheat crop yield showed considerable negative correlation with temperature in the month of December.

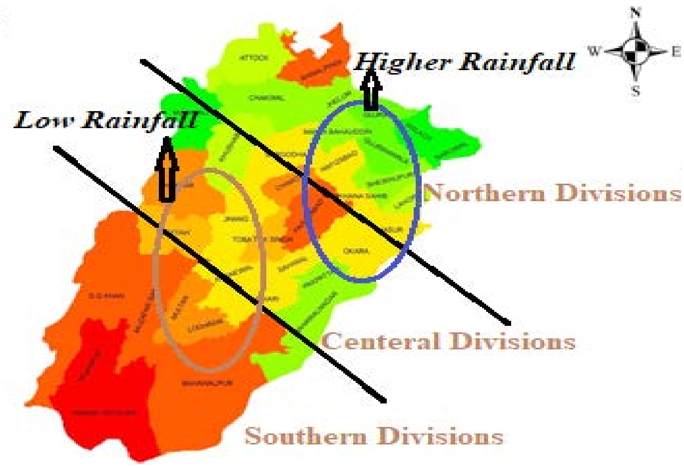

Figure 24: *Zoning of Punjab with regards to temperature and rainfall.*

Conclusion

The study derived the effect of changes in climate on major crops (wheat, maize, cotton, sugarcane, gram) in Punjab. The outcomes demonstrated that increase in temperature influences production of crops, as critical adverse relationship on yield and production is found with temperature what rise or fall. Allocating area of Punjab into three equivalent parts (Northern, central and Southern divisions). It is apparent that the most extreme increment in the temperature which happened in the southern division i.e. Lower Punjab (DG Khan, Rahim Yar Khan, Rajanpur). In context with central portion i.e. Faisalabad likewise raised temperature is inspected. Most extreme lessening in temperature that occurred just in Northern Punjab, while thinking about the Precipitation, greatest increment happened in centre eastern segment and Northern segment i.e. Gujrat, Lahore, Sheikhupura and Kasur; where most extreme decline happened in central western and Southern potions i.e. Bahawalnagar, Sargodha, Chiniot and Pakpattan. Huge negative effect of temperature increment for cotton crop in July and August is appeared. For maize a vast adverse effect of expanding temperature in the month of May; while rain in the period of September vigorously contributed. November temperature has helpful effect for wheat crop, however December temperature has adverse effect on it what production or yield. Precipitation in February has unimportant negative effect on wheat production. Above discussion may be taken as guide line for various agriculture departments to predict their crop production / yield very accurately at every stage of crop cycle through remote sensing images. Also farmers and agriculturists may be educated about the effects of these climate variables i.e temperature and rainfall on crop growth from sowing to harvesting, even on monthly basis. This would entail better crop monitoring, requirement of water at every stage of crop cycle, accurate estimation of yield and better adaption / mitigation strategies for the future.

Author's Contribution

Muhammad Waqar Yasin: Did all the work related to satellite data processing and analysis including crop mapping, validation of remote sensing results and comparison of remote sensing data with survey data along with report writing was also executed by him.
Mobushir Riaz Khan: Carried out statistical data analysis of crop production with respect to climatic variable.
Muhammad Amin: Performed analysis on climatic variable data processing and mapping results.

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