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Temporal analysis of wheat yield and climatic trends in Pakistan

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ABSTRACT

During the recent decade, the anthropogenic activities have become dominating factor towards the problem of climate variability and change. This climate variability has become the centre of many scientific studies. The objective of this paper was to investigate the total wheat yield during the time period of 1989-2009 and the overall impact of climate on the wheat yield in the provinces of Pakistan. The key meteorological variables that influenced the wheat yield were identified, the correlation and regression functions between climate relevant wheat yield and these variables were established. The correlation analysis revealed a significant relationship between wheat yield and climatic variable and regression analysis revealed that high level of variance in wheat production could be explained by climatic parameters under study. The findings of the research suggested an intensification of research as well as the appropriate measures at raising wheat yields.

Introduction

Climate is the major driving force of crop production, water use and agriculture is one of the most vulnerable sectors to climate change. Around 40% to 50% of the Earth's surface area consists of agricultural lands, comprises the land which is used for the cultivation of crops, land used as grasslands and also of stable harvest or crops which encompasses the agro-forestry and crops used for bio-energy (Cai et al., 2007).

Climate change, according to the definition by the Intergovernmental Panel on Climate Change (IPCC) (2001), refers to any change in climate over time whether due to natural variability or as a result of human activity. Many of the climate change factors affecting agriculture yield and agricultural productivity includes rainfall distribution, temperature, variation in sowing and harvesting time, water availability, evapotranspiration and land suitability. Climate change impact on agriculture is several folds, together with diminishing of agricultural output and reduction in growth period for crops (Edwards, 1999).

Wheat is such an important crop that out of total world's food requirement 21% is fulfilled through wheat and globally the area used for wheat production is 200 million. Wheat is also traded at international level and 43% of import is contributed by the developing countries, but 81% of the wheat consumed in developing countries is the production of their own (CIMMYT, 2005). In Pakistan, outstanding progress has been attained in the sector of wheat since Green Revolution. Wheat is the most important agricultural commodity of Pakistan and it accounts for 13.8% in value added in agriculture and 3.4% in GDP (GoP, 2004). Wheat is taken as targeted commodity in Pakistan mainly because it is a vital product in the diet of those who are below the poverty line, and in addition it characterizes a significant commodity in terms of its input to national food security.

Many researches have been related to climate change and latest researches have predicted that due to climate change the pattern of rain fall and variation in temperature can occur, and the temperature increase at the end of the century in South Asia is predicted to be 3-4 °C (DEFRA, 2005). Efforts to study the impacts of climate change on production pattern have employed a variety of approaches, including time series analysis (Nicholls, 1997; Thompson, 1975), crop simulation modeling (Andresen, 2001; Bell and Fischer, 1994; Pathak et al., 2003) and spatial analysis of yield trends (Lobell and Asner, 2003). Assessing climate impacts on agriculture have increasingly become major areas of scientific concerns, e.g. valuation of climate impacts on wheat production (Rajin et al., 2007; Wei et al., 2005; Yang et al., 2011).

In Pakistan, a study was conducted and Vector Auto Regression (VAR) model was used for this purpose in which trends for climate change impact on production of wheat for the period of 2010-2060 were captured. The results revealed that global climate change might influence the wheat production in Pakistan. Similarly in Swat and Chitral districts of Pakistan, potential future impacts of climate change on wheat yields were assessed (Hussain and Mudasser, 2007). The possible effects due to climate change on the production of wheat were predicted to be various, such as in India it was predicted that due to climate change, reduction in the wheat grains occurred especially in the areas of eastern plains, which had relatively lesser potential (Chandna et al., 2004).

By the help of tools of GIS (Geographic Information System), various scientists in different parts of world have predicted the yield of crops and effect of changing environmental factors on the crops and results of their findings have been represented in the form of geographical maps for the better understanding. GIS was used to predict the impact of global warming on the Middle East region, Hashemite Kingdom of Jordan through spatial analysis and meteorological data (Matouq, 2008). Liu *et al*. (2009) conducted a study to analyze the impact of climatic variables on wheat production. A study was done to quantify the production potential of winter wheat in the North China Plain (NCP) taking into account the spatial and temporal variability caused by climate (Wu et al., 2006). Similarly, crop simulation model (DSSAT) was used to assess

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the impact of different climate change scenarios on rainfed wheat and barley in the Yarmouk basin in Jordan (Al-Bakri et al., 2010). A study was done to examine how climate inconsistency influences wheat yield in China at diverse spatial scales (Li et al., 2010).

The present study involved the study of wheat production patterns in Pakistan and relationship between environmental data of the region with reference to climate change and its consequent effect on wheat production during the last two decades i.e. 1989 to 2009. The objectives of the study were i) to monitor the production patterns of wheat in Pakistan from 1989-2009 ii) detection of change in wheat production in Pakistan through map construction and visualization iii) to develop a correlation between change in production and climate changing parameters for the purpose of informing policy makers.

Materials and Methods

The data required for the study included general Pakistan map that was obtained from Survey of Pakistan (1: 50,000). There were two types of data base. Thematic map or base map was prepared using general Pakistan map on 1:50,000 scale employing the tools of ArcGIS. The map was scanned up to the resolution that made all the important features clear and vivid. It was then geo referenced by using the WGS 1984 coordinate system. Attributed data was of secondary source which was collected through published literatures, reports and online resource mainly from Ministry of Environment, Pakistan Meteorological Department and Federal Bureau of Statistics. ArcGIS 9.2 software was used to represent the change in production in provinces of Pakistan. The spatial and attribute data base were integrated through ArcGIS and maps were developed to visually display the change in wheat production in Pakistan during the analysis period of 1989 to 2009.

The data of climatic variables like temperature, relative humidity, wind speed and precipitation of each province of Pakistan was supplied by Pakistan Meteorological Department, Islamabad, and a mean was calculated for each year. Then correlation and regression analyses were both employed to analyze the data in order to establish a relationship between climatic data and crop yield; and also to show the percentage contribution of the variables in crop yield.

Results

The main objective of this study was to monitor the change in wheat production in various provinces of Pakistan. GIS tools mainly Arc Map has been adopted. The maps were generated based upon the data derived from different sources, depicting annual change during the last two decades (1989 to 2009).

Wheat Production

Wheat is the major food staple for about 150 million people in Pakistan. The wheat production system of Pakistan is one of the most dominating cropping systems. A major portion falls in the Punjab followed by Sindh. Pakistan imports wheat and it always occupies a central position in agricultural policies. Pakistan harvested a record wheat crop of about 21 million tonnes in 1999-2000, which exceeded domestic requirement and hence was available as exportable surplus (Shahid et al., 2011). The province wise distribution of wheat in Pakistan is given in Table 1.

Table 1. The province wise wheat production in Pakistan

Province/ Territory	Wheat Production (000 tonnes)				
	1989	1994	1999	2004	2009
Punjab	10518.2	12713	16480	17375	18420
KPK	1102.1	1180.2	129.2	123.2	128.2
Sindh	2130.9	2319.1	3001.3	2508.6	3540.2
	564.3	790.1	422.4	421.6	643.7
Pakistan	14315.5	17002.4	20032.9	20428.4	22732.1

Wheat as a staple food of the people of Pakistan supplies 72% of the calories and protein in the average diet. Pakistan is 8th largest wheat producer in the world and accounts for 3.17% of the world's wheat production from only 3.72% of the wheat growing area (CIMMYT, 1989). Punjab is the major producer of wheat among all provinces of Pakistan. According to the Table 1, in Punjab there was an increase in wheat production during the analysis period while in Sindh a major decrease after 2004 occurred. However, in KPK and Baluchistan the production observed a declining trend after 1994. The momentum was attained in Baluchistan till 2009 but in KPK this change was very drastic. In order to assess the change in the wheat production in Pakistan during the last two decades, the maps of 1989 and 2009 were generated for inter comparison which are shown in Fig. 1.

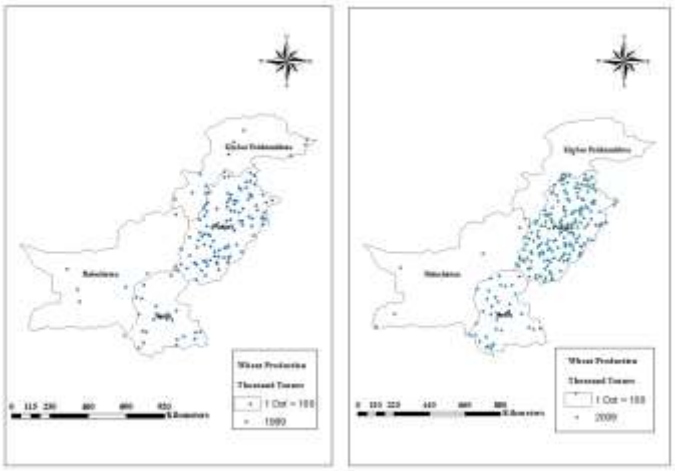

Fig. 1. Wheat production in Pakistan in 1989 and 2009

The comparison of wheat production in years 1989 and 2009 showed that the total production of wheat in Pakistan was increased by 2.9% per year (Table 2). Unlike Punjab, Sindh and Baluchistan, a decline of 4.4% per year was observed in KPK.

Table 2. Table showing the Wheat Production of Pakistan in 1989 and 2009 and Annual change (%)

Province/ Territory	Wheat Production (000 tonnes)		Annual Change rate %
	1989	2009	20 Years
Punjab	10518.2	18420	3.7 (+)
KPK	1102.1	128.2	4.4 (-)
Sindh	2130.9	3540.2	3.3 (+)
Baluchistan	564.3	643.7	0.70 (+)
Pakistan	14315.5	22732.1	2.9 (+)

In this study, the production area and the consumption patterns in this time period were also assessed. Wheat is the leading crop in Punjab occupying approximately 42% of total cropped area. The production area and consumption trends in the study period are shown in Fig. 2 and 3.

The Fig. 2 shows that in Punjab the total wheat production area followed an increasing order and also it has the highest production area among all provinces. On the other hand, the production area in KPK and Baluchistan faced a sudden decline in 1999 and Sindh also faced reduction after 2000 which was slightly increased in proceeding years. The total production area trend of Pakistan was estimated on the basis of provincial data represented with $y = 84.95x^2 - 523.0x + 8466$ and $R^2 = 0.256$.

The Fig. 3 shows that the wheat consumption in different provinces of Pakistan mostly followed an increasing trend due to population increase and this consumption was again dominated by the province of Punjab. The total consumption trend of Pakistan was also estimated on the basis of provincial data with $y = -125.0x^2 + 2326x + 13909$ and $R^2 = 0.887$.

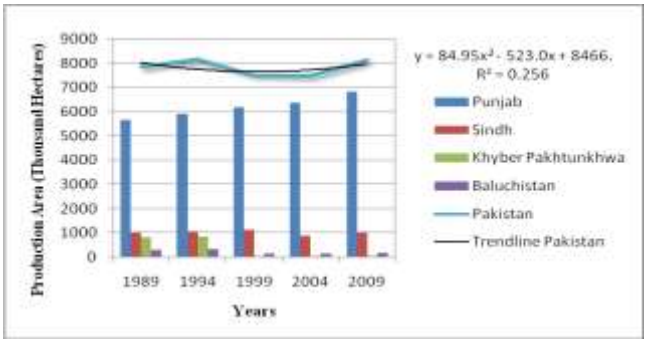

Fig. 2. Total Wheat Production Area in Different Provinces of Pakistan from 1989 to 2009

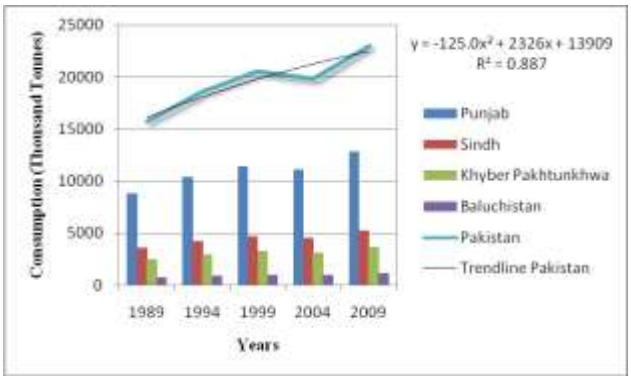

Fig. 3. Total Wheat Consumption in Different Provinces of Pakistan from 1989 to 2009

Due to high population growth in Pakistan, the food situation has always been fragile. Per capita net availability has declined in recent years by nearly 11% from 2002-2007. As a result of the reduced availability, prices of wheat and wheat flour rose by 26% and 31%, respectively from 2001 to 2007 (Mukhtar and Ilyas, 2009).

Discussion

Anthropogenic activities during the last century have resulted in the excessive emission of greenhouse gases. This has raised the temperature of the earth's atmosphere at a much faster rate than in previous centuries, resulting in global warming (Abbass, 2009). During the last 150 years, the global average surface temperature has increased by 0.76°C and the temperature increased by 1.22°C between 1955 and 2005 (IPCC, 2007).

These seemingly small changes in temperature can disrupt weather systems, resulting in distorted weather pattern such as changes in rainfall pattern and in the frequency and incidence of extreme weather events; floods, cyclones, droughts, and storms. The effects of which can be immense. Increased precipitation is likely at high latitudes, while decrease is likely in most subtropical regions such as Pakistan. Heat waves and heavy rainfall has become more frequent. Pakistan is prone to a range of natural disasters including cyclones, floods, drought, intense rainfall and earthquakes. In Pakistan 40% of the people are highly vulnerable and are frequently exposed to multiple disasters. This exposure to vulnerability is predicted to be exacerbated with impending impact of climate change (Mukhtar and Ilyas, 2009).

Climate change has been projected to increase the variability of monsoons, decrease the predictability of precipitation and exacerbate water-stress in arid and semi-arid regions (Vaughn et al., 2010). With variations in rainfall patterns, storms, floods and drought are predicted to increase and reach new locations that had not earlier experienced those. In July and August of 2010, Pakistan experienced what have been described as the worst floods in the country's history. These floods reportedly killed over 1,100 people. The 2010 wheat (Rabi crop) harvested in April/May, just before the onset of the monsoon season, estimated at 23.86 million tonnes was also affected. Not only wheat stocks estimated at 500/600 tonnes were lost but also wheat seeds, agricultural inputs and irrigation infrastructure were damaged (Vaughn et al., 2010).

Wheat plays a central role in Pakistan's food economy, both in terms of production and consumption. The present study was concerned with the determination of effect of climate on the production of wheat in Pakistan so following climatic variables were selected i-e, temperature (°C), relative humidity (%), precipitation (mm), and wind speed (knots per hour). The change in these variables in different provinces of Pakistan during the study period is shown in Fig. 4.

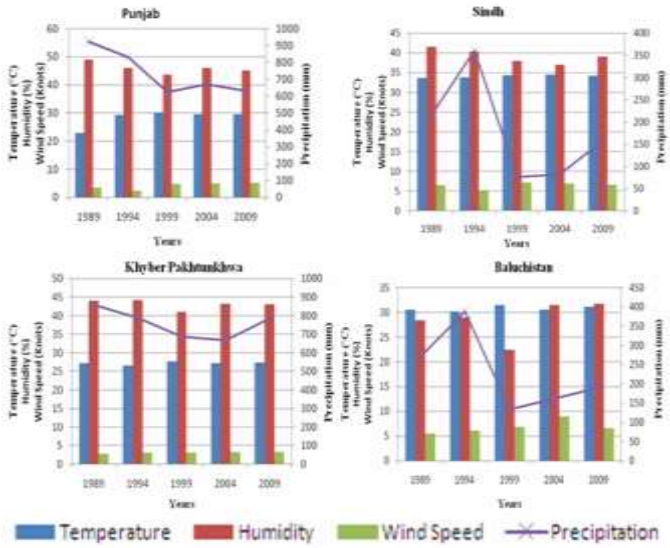

Fig. 4. Change in the selected climatic variables during the study period in different provinces of Pakistan

These climatic variables were linked with wheat production through the correlation and regression analysis of the four provinces separately which are given in Table 3 and Table 4 respectively.

Table 3. Pearson Correlation Analysis of wheat production in relation to climatic variables

	Temperature	Humidity	Wind Speed	Precipitation
Punjab				
Production	.925* .012	-.993** .000	.878* .025	-.968** .003
KPK				
Production	-.976** .002	.986** .001	-.823* .043	.875* .026
Sindh				
Production	.979** .002	-.994** .000	.811* .048	-.967** .004
Baluchistan				
Production	-.853* .033	.897* .019	-.911* .019	.929* .011

**Correlation is significant at the 0.01 level (1-tailed)

*Correlation is significant at the 0.05 level (1-tailed)

The correlation analysis of wheat production in relation to climatic variables of four provinces is shown in Table 3. In Punjab the significant association of rice production with temperature is (coefficient= .925, *P*= .012), humidity (coefficient= -.993, *P*= .000), wind speed (coefficient= .878, *P*= .025) and precipitation (coefficient= -.968, *P*= .003). In KPK, wheat production is significantly correlated with temperature (coefficient= -.976, *P*= .002), humidity (coefficient= .986, *P*= .001), wind speed (coefficient= -.823, *P*= .043) and precipitation (coefficient= .875, *P*= .026). In Sindh wheat production is significantly correlated with temperature (coefficient= .979, *P*= .002), humidity (coefficient= -.994, *P*= .000), wind speed

(coefficient= .811, *P*= .048) and precipitation (coefficient= -.967, *P*= .004). In Baluchistan wheat production is significantly correlated with temperature (coefficient= -.853, *P*= .033), humidity (coefficient= .897, *P*= .019), wind speed (coefficient= -.911, *P*= .019) and precipitation (coefficient= .929, *P*= .011).

Wheat is subjected to adverse weather conditions during much of its growth period. Increase and decrease in temperature can affect wheat in different ways. Low temperatures injure wheat by winterkilling, by early spring freezes that kill the growing point, and by late spring freezes that cause sterility of the heads. Winterkilling can be caused by direct freezing, ice sheets and desiccation (Paulsen, 1997). High temperatures severely limit wheat yield. They accelerate plant development and specifically affect the floral organs, fruit formation, and as well, the functioning of the photosynthetic apparatus. Leaf photosynthesis is negatively affected as leaf temperature rises above 25°C in cool-grown wheat leaves but leaves acclimated to warm temperature start to show a similar decline as temperatures exceed 35°C. At 45°C leaf photosynthesis may be halved (O'Toole and Stockle, 1991; Shpiler and Blum, 1986). The present analysis shows that the temperature was positively correlated with the wheat production in Punjab and Sindh, which means it remained within its optimum range during the study period. On the other hand, wheat production in KPK and Baluchistan was found to be negatively correlated with temperature due to temperature variation in these two provinces during the analysis period.

Wind injury to wheat usually is caused by blown soil that accompanies the wind. Abrasion of the soil on the leaves and desiccation of the leaves during and after the wind cause leaf burning. Wind damage also is sometimes attributed to static electricity, and wind without sand can burn margins and tips of wheat leaves. Lodging, or falling over of the wheat plant, is another form of wind injury. Lodging is most common after heading and when growth has been over stimulated by excess nitrogen fertilizer or moisture, high temperatures, or over planting (Paulsen, 1997). In the present study it was observed that wind was positively and significantly correlated with wheat production in Punjab and Sindh. However, in KPK and Baluchistan this relationship was negative, which might be attributed to the intensity of wind.

Like temperature, very high or very low relative humidity is not conductive for high grain yield. The wheat grain yield is reduced in high relative humidity. Grain yield can be attributed to bad effect of relative humidity on pollination and high incidence of pests. With similar amount of solar radiation, crops that are grown with irrigation gives less yield compared to those grown with equal amount of water as rainfall. This is because the dry atmosphere, which is little affected by irrigation, independently suppresses the growth of crops (Pidwimy, 2006). In present study, this relative humidity was found to be significantly negatively correlated with wheat production in Punjab and Sindh where the yield was higher and followed an increasing order while positively correlated with wheat production in KPK and Baluchistan where the yield followed a declining trend especially in KPK.

Variability in amount and distribution of rainfall is the most important limiting factor for wheat production. Pakistan often gets inadequate or excessive rainfall during the rainy season. As a result, drought or flood, or sometimes both cause excessive damage to wheat production. Therefore, the observed relationship with rainfall/precipitation was significantly negative in Punjab and Sindh where the production of wheat followed an increasing trend while positively correlated with wheat production in KPK and Baluchistan where a declining trend was observed.

A few similar studies have been conducted all over the world which studied the effect of climatic variables on the crop yield. Ahmed et al. (2011) studied the effect of temperature and solar radiation on wheat yield and found a direct relationship of yield with solar radiation and inverse relationship with temperature. The effect of climatic variables like temperature, relative humidity and rainfall on crop production in Nigeria was also studied by Tunde et al. (2011). Ajewole and Iyanda (2010) studied the effect of climate change on cocoa yield with the use of correlation analysis and concluded that optimal temperature and minimal rainfall would give better yield of cocoa in Nigeria. The regression analysis computed for the crop production and climatic variables revealed that the wheat production have coefficient of determination of 0.98, 0.97, 0.99 and 0.85 for Punjab, KPK, Sindh and Baluchistan respectively. This indicates that 98, 97, 99 and 85% of the variance in wheat production can be explained by the climatic parameters under study (Table 4). The implication is that 2, 3, 1, and 15% of the variance in wheat production can be respectively explained by other factors not included in the study. Climatic variables therefore, have impact on selected crop yield over the years under study. The study has actually revealed that other factors, such as solar radiation, type of soil, soil fertility and farm methods may also be responsible for crop yield (Gifford et al., 1998; Lobell and Asner, 2003). Lobell et al. (2005) observed 69% variance in wheat yield.

Table 4. Regression Analysis for Wheat Production and Climatic Variables

	R	R^2	Adjusted R^2	Std. Error of the Estimate
Punjab				
Production	0.995[a]	0.989	0.957	6.91
KPK				
Production	0.983[a]	0.966	0.863	2.06
Sindh				
Production	0.997[a]	0.993	0.989	5.58
Baluchistan				
Production	0.920[a]	0.847	0.387	1.22

[a]Predictors: (Constant), Wind Speed, Temperature, Humidity, Precipitation

In the present study, analysis of the change in the production of wheat was done with the help of ArcGIS and correlation and regression analysis were used to study the relationship of climatic variables with the wheat production. Through this study, it was inferred that the change was positive for Punjab and Sindh and negative for KPK and Baluchistan. Similarly, Lobell et al. (2005) studied the relationship among wheat yield and climatic variables in Mexico. The results revealed that average wheat yield was positively related to maximum temperature. This finding is similar to that of Peng et al. (2004), who showed a negative response of rice yields to increased minimum but not maximum temperature. Some studies by the Indian Agricultural Research Institute (IARI) indicate the possibility of loss of 4-5 million tonnes in wheat production with every rise of 1º C temperature throughout the growing period. Other crops such as mustard, tomato, onion, garlic and other vegetable and fruit crops also suffered losses (Aggarwal, 2008).

Moreover, in each province the amount of wheat consumption was far more than the wheat production except in the province of Punjab. The reasons behind this low productivity are various, such as the soil and climate of each province vary from the other. The soil and climate of the province Punjab is considered more suitable for wheat production than the other provinces. The water availability is also more suitable for wheat irrigation in Punjab than other provinces. Some of the major

reasons for low production of wheat and instability include the late harvesting of wheat, inaccessibility to better inputs that includes seeds etc, unproductive use of fertilizer, plagues and crops diseases, deficiency of water for irrigation purpose, drought in the rain fed areas, soil degradation and deviating temperature and floods. In addition, the farmers are not using the modern technologies that can enhance the production of wheat.

Conclusion

Climate change is adversely affecting the abiotic as well as the biotic components of the environment of our Earth. This adverse effect has posed a serious threat to the agricultural system among the other life processes. This study was conducted to analyze the effect of climate change on wheat crop in Pakistan as it is a major food crop and recent studies have shown that its yield is affected by the climate change either positively or negatively all over the world. The aim of this study was to analyze the variation in the yield of wheat in Pakistan due to climate change for the time period of 20 years i.e. 1989-2009. The wheat production was correlated with four climatic variables which included temperature, precipitation, wind speed and humidity. The study showed that from 1989 to 2009 in the provinces of Pakistan the variation in wheat yield was diverse. It showed increased yield manner in Punjab and Sindh but a huge reduction in the province of Khyber Pakhtunkhwa and to some extent in Baluchistan and the yield of wheat was affected negatively by the climate. This study would provide information to other researches, policy makers and analysts about the status of wheat yield and climate change in Pakistan and by the analysis of wheat yield with varying climate, the production of wheat could be improved.

The recommendations in the light of the study for better wheat production and yield are:

1. Cultivar selection is one of the most important considerations in risk management and maximizing yields. The cultivar should be selected keeping in mind the soil and climate of the area where cultivation has to be done. Hence high yielding wheat varieties resistant to rusts, smuts, etc should be sown in sufficient amount.
2. The selection of a suitable planting date is one of the aspects within the farmer's control and the most important determining factors with regards to the optimum planting date are soil and air temperature.
3. The conservation of groundwater is the most important objective for successful dry land wheat production such as Baluchistan and Sindh, because some areas of these regions receive a very minimal annual rain fall and also under the climate change scenario the pattern of rain fall has been distorted. Therefore, the conservation of ground water can support the irrigation of wheat during droughts or unavailability of sufficient water supply.

References

1. Abbass Z. Climate change, poverty and environmental crisis in the disaster prone areas of Pakistan. ln: Oxfam GB Regional Research Report; 2009.
2. Aggarwal PK. Global Climate Change and Indian Agriculture: Impacts, adaptation and mitigation. Indian J Agr Sci. 2008; 78: 911-919.
3. Ahmed M, Fayyaz-ul-Hassan M, Aslam A, Akram MN, Akmal M. Regression model for the study of sole and cumulative effect of temperature and solar radiation on wheat yield. Afr J Biotechnol. 2011: 45: 9114-9121.
4. Ajewole DO, Iyanda S. Effect of Climate Change on Cocoa yield: A case of Cocoa Research Institute (CRIN) Farm, Oluyole Local Government Area, Ibadan Oyo State. J Sust Dev Afr. 2010: 12(1): 350-358.
5. Al-Bakri J, Suleiman A, Abdulla F, Ayad J. Potential impact of climate change on rainfed agriculture of a semi-arid basin in Jordan. Phys Chem Earth 2010; 35: 125–134.
6. Andresen JA, Alagarswamy G, Rotz CA, Ritchie JT, LeBaron AW. Weather impacts on maize, soybean, and alfalfa production in the Great Lakes region 1895–1996. Agron J. 2001; 93: 1059–1070.
7. Bell MA, Fischer RA. Using yield prediction models to assess yield gains – a case study for wheat. Field Crops Res. 1994; 36: 161–166.
8. Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Sirotenko O. Agriculture. In: Climate Change 2007: Mitigation. United Kingdom; 2007.
9. Chandna P, Hodson DP, Singh UP, Gosain AK, Sahoo RN, Gupta RK. Increasing the productivity of underutilized lands by targeting resource conserving technologies, a GIS/Remote sensing approach. In: A Case Study of Ballia district, Uttar Pradesh in the astern Gangetic plains. Mexico; 2004.
10. CIMMYT. Wheat Research and Development in Pakistan. Pakistan Agriculture Research Council /CIMMYT Collaborative Programme; 1989.
11. CIMMYT. International Maize and Wheat Translating the Vision of Seeds of Innovation into a Vibrant Work Plan, CIMMYT Business Plan 2006–2010. El Batan: Centro Internacional de Mejoramiento de Maı´z y Trigo; 2005.
12. Department for Environment, Food and Rural Affairs (DEFRA). India-UK collaboration on impacts of climate change in India. India; 2005.
13. Edwards PN. Global Climate Science, Uncertainty and Politics: Data-Laden Models, Model- Filtered Data. Sci as Culture 1999; 8: 437-472.
14. Gifford R, Angus J, Barrett D, Passioura J, Rawson H, Richards R, et al. Climate change and Australian wheat yield. Nature 1998; 391: 448–449.
15. Government of Pakistan (GoP). Economic Survey 2003–2004. Islamabad: Finance Division, Economic Adviser's Wing; 2004.
16. Hussain SS, Mudasser M. Prospects for wheat production under changing climate in mountain areas of Pakistan -An econometric analysis. Agr Syst. 2007; 94: 494–501.
17. Intergovernmental Panel on Climate Change (IPCC). Climate change: impacts, adaptation, and vulnerability, Contribution of Working Group II to the Third Assessment Report. Cambridge UK: Cambridge University Press and New York; 2001.
18. Intergovernmental Panel on Climate Change (IPCC). Climate Change: The Impacts, adaptation and vulnerability (Working Group III) 4th Assessment report. Cambridge UK: Cambridge University Press and New York; 2007.
19. Li S, Wheelerb T, Challinorc A, Lind E, Jud H, Xu Y. The observed relationships between wheat and climate in China. Agr Forest Meteorol. 2010; 150: 1412–1419.
20. Liu DL, Mob J, Fairweatherc H, Timbald B. A GIS tool to evaluate climate change impact: functionality and case study. Australia: 18th World IMACS / MODSIM Congress, Cains; 2009.
21. Lobell D, Asner G. Climate and management contributions to recent trends in US agricultural yields. Science 2003; 299: 1032.
22. Lobell DB, Ortiz-Monasterio JI, Asner GP, Matson PA, Naylor RL, Falcon WP. Analysis of wheat yield and climatic trends in Mexico. Field Crops Res. 2005; 94: 250–256.

23. Matouq M. Predicting the impact of Global Warming on the Middle East Region: Case Study on Hashemite Kingdom of Jordan Using the application of Geographic Information System. J Appl Sci. 2008; 8: 462-470.
24. Mukhtar T, Ilyas M. Co-integration and error-correction modeling of wheat consumption in Pakistan. J Econ Coop Dev. 2009; 30: 87-104.
25. Nicholls N. Increased Australian wheat yield due to recent climate trends. Nature 1997; 387: 484–485.
26. O'Toole JC, Stockle CD. The role of conceptual and simulation modeling in plants breeding. In: Acevedo EF, Gimenez C, Srivastava JP, editors. Improvement and Management of winter Cereals under Temperature, Drought and Salinity Stresses. Madrid, Spain: National Institute for Agricultural Research; 1991.
27. Pathak H, Ladha JK, Aggarwal PK, Peng S, Das S, Singh Y, et al. Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic plains. Field Crops Res. 2003; 80: 223–234.
28. Paulsen GM. Wheat Production Handbook. Kansas: K-State Research & Extension Manhattan; 1997.
29. Peng S, Huang J, Sheehy J, Laza R, Visperas R, Zhong X, et al. Rice yields decline with higher night temperature from global warming. P Nat Acad Sci. 2004; 101: 9971–9975.
30. Pidwirny M. Atmospheric Humidity. In: Fundamentals of Physical Geography, 2nd Ed.; 2006. Available online at: http://www.physicalgeography.net/fundamentals/contents.html (Accessed 15 June 2011).
31. Rajin AM, Leary GO, McNeil D, Hossain H, Nelson R. Climate change impact on rainfed wheat in south-eastern Australia. Field Crops Res. 2007; 104: 139–147.
32. Shahid MA, Pervez MA, Balal RM, Abbas T. Wheat and Rice of Pakistan in the Scenario of WTO. 2011. Available online at: http://www.agrihunt.com/horti-industry/267-wheat-and-rice-of-pakistan-in-the-scenerio-of-wto.html (Accessed 15 June 2011).
33. Shpiler L, Blum A. Differential reaction of wheat cultivars to hot environments. Euphytica 1986; 35: 483-492.
34. Thompson LM. Weather variability; climatic change; and grain production. Science 1975; 188: 535–541.
35. Tunde M, Usman BA, Olawepo VO. Effects of climatic variables on crop production in Patigi L. G. A., Kwara State, Nigeria. J Geogr Regional Plan. 2011; 4(14): 695-700.
36. Vaughn B, Carter NT, Sheikh PA, Johnson R. Security and the Environment in Pakistan. 2010. Available at: http://www.fas.org/sgp/crs/row/R41358.pdf (Accessed 23 July 2011).
37. Wei X, Yinlong X, ERDA L. The simulation of yield variability of winter Wheat and its corresponding adaptation options under climate change. Chinese Agr Sci. 2005; bulletin 05.
38. Wu D, Yu Q, Lua C, Hengsdijk H. Quantifying production potentials of winter wheat in the North China Plain. Eur J Agron. 2006; 24: 226–235.
39. Yang X, Chen CH, Luo Q, Li L, Yu Q. Climate change effects on wheat yield and water use in oasis cropland. Int J Plant Prod. 2011; 5(1): 83-94.