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RESEARCH PAPER

Investigating the Impacts of Climate Change on Crops: A Case Study of Southern Punjab

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ABSTRACT

The study aimed to reveal the relationship between the climatic variables on agriculture of Southern Punjab, Pakistan. It explores the impacts of temperature and rainfall on rice and maize in relation to yield and production in the time span of ten years; and how to protect agriculture from extreme weather conditions through various adaptations? Agriculture of Pakistan is experiencing serious threats because of unfavorable effects of climate change.In this regard, data is collected through secondary source: meteorological and agricultural departments. Evaluation of the gathered data revealed that temperature and rainfall have minor impact on yield of crop, whereas temperature and rainfall have massive effect on production of crops. In this context, some preventative measures are suggested on national and regional level. This research will be helpful for farmers and policy makersas an assessment guide to protect their crops from intense climatic conditionsby reducing anthropogenic activities.

Introduction

The China-Pak Pakistan locates in the temperate zone. It has arid and semi-arid types of environment. Likewise, in this state four seasons are prevailing, including winter, early summer, late summer and post monsoon. Duration of these four seasons depend on climatic change impacts. Furthermore, the major economy of Pakistan is based on agriculture and considered as the backbone of economy; as well sharing 24% of Gross Domestic Product (GDP) of agricultural area as reported by Pakistan Bureau of Statistics. This state has two seasons of crops: Kharif and Rabi. The season of Kharif crops starts fromMay and ends by October, while Rabi crops period is in November to April. Kharif crops include rice, sugar cane, cotton, maize and millet, whereas Rabi crops are wheat, gram, tobacco, rapeseed, barley and mustard. Wheat, rice maize are the main food crops of Pakistan but major cash crop

is sugar cane(Ali, et al., 2017). The season of these crops are influenced by different climatic variables such as temperature and rainfall. Excess of any climatic variables lay bad impacts on agricultural crops. In addition to, farming practices in most of the regions are carried out by using irrigation methods. Indus River is the prime origin of the water which starts from China and flows all around the Pakistan territories through all provinces except Balochistan; and then falls into the Arabian Sea. This water is connected with rivers and then distributed into the canals; which is used for irrigation purposes (Kienzler, 2012). Moreover, Pakistan has been suffering from different environmental disturbances such as shifting of temperature and rainfall. According to Asif (2013), average yearly rainfall is below 240mm/year(as cited in Ahmed et al., 2008); on the other hand, 0.36°C/decade mean annual temperature has raised at all levels of country i.e.at national, regional and local time scale. From the period of industrial revolution, global warming is the significant matter throughout the world. Foremost, climate is affected by anthropogenic activities which discharge various greenhouse gases in particular carbon dioxide (CO_2), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) and these gases increase the temperature of earth(Rio, et al., 2013).

More than that, some areas of Pakistan are facing drought and flood conditions specifically in Southern Punjab. In this region, severe heat conditions went up to 51°C during summer season. After heat waves, monsoon period starts in the month of august and sometimes it forms the shape of floods because of heavy rainfall. These changes in climatic variables bring catastrophic effects on agricultural yield and production. Other than that Southern Punjab is less developed and ignored region. In this area, two-third of rainfall comes through monsoon winds which differ from June to August. Monsoon trend and western disturbances are changing constantly. These constant change in rainfall pattern gives little time to make protective measures, similarly other disaster management zones and farming activities have instant effects(S., Rehman, & Shah, 2012). In this area, the major challenge is food insecurity because of fluctuation in climatic variables as well as stress of demographic growth. The rise of temperature affects the glaciers which causes floods in plain areas. These floods increased siltation in most of the dams. In these regions, high temperature causes heat and water scarcity conditions. Other impact related to heavy rain and high temperature is migration. People moved when flood and heat waves hit their localities. This migration is also based on health risks. On the other hand, farmers being the most affected people from climate change. Due to climate change the length of growing season is likely to be reduced. Farmers in this area have no access to advance technology for that reason they cannot protect their crops from extreme weather conditions. These extreme weather events, mainly floods and droughts, can damage crops and decrease yields. For example, in 2010, economy of Pakistan was harmed by vast destruction to infrastructure and crops. Due to all these extreme issues, a great disparity is required to be observed in crop production and yield which need advanced technology as well important development in farming sector and irrigation department. This entire scenario shows that this issue is utmost serious and needs to be addressed. In this regard following

question has been generated: to what extent, temperature and rainfall effect the crops of Southern Punjab?

Literature Review

The fourth report of Intergovernmental Panel on Climate Change (IPCC) claimed that earth's climate has been varying at global and regional level. It was also observed that the mean temperature has raised from 1.4 to 5.8 degree that has been making impact on crops production (Panda, 2009).Meanwhile, considering the temperature effects, another essential element 'photoperiod' which accomplishes the growth of crops; must be examined first(Wheeler & Craufurd, 2009).Change in climate make direct and indirect impacts on crops. Direct impact pertains to effect on climate through agricultural commodities; their results can be extracted through collective usage of climatic variables: agricultural products and economic patterns. Besides this, indirect alludes to impact of snowmelt, glaciers and precipitation on crops growth which are immeasurable (Nelson, et al., 2014). To secure our food from climatic variation, some farming methods should be connected with forthcoming climatic shifts like intense rainfall, variation of temperature and droughts (Charles, 2011). Impacts of climate change in developing countries are more vulnerable because of their location on tropics. Such as India and Pakistan, these countries are agriculturally based states and experiencing adverse impact of climate change like rise in nitrogen, carbon dioxide and temperature on their crops production. On the other hand, Pakistan's food growth rate can be increased by considering the effects of climate change on Indian crop activities, according to report of Global Grided Crops Model Inter comparisons (GGCMIs) as both states are on the same latitude (Rosenweig et al., 2014).Moreover, other impacts such as long-lived greenhouse gases (LLGHGs) and short-lived climate pollutants (SLCPs) were introduced by Burney & Ramanathan (2014). In India SLCPs and carbon effusion have direct and indirect effects on crops. On contrary, in Pakistan temperature and rainfall have significant influence on agriculture, however it differs gradually for instance, with temperature uplifting the rice production will robust, although it will be harmful if it crosses particular line, contrarily surge in rainfall will not have that effects(Siddiqui, Samad, Nasir, & Jalil, 2012). With regards to Pakistan, there are two types of crop seasons, Kharif and Rabi crops. During Kharif season, increase in temperature and rainfall gives positive effect, whereas at time of Rabi season rise, in temperature and rainfall above specific threshold gives negative impacts on agriculture. To avoid this damage, governmental and private divisions should take some preventative actions such as heat and drought tolerant divergences (Hanif, Syed, Ahmad, Malik, & Nasir, 2010).In addition,(Stone & Meinke, 2005) exhibited that meteorological forecasting models, and agricultural development models need to upgrade their policy making resources since these resources are confined and not providing any benefits to crop production. Furthermore, for the improvement of seasonal predicting techniques, multidisciplinary methods are needed. Apart from that, Singarayer & Barnard (2012) presented another technique 'Bio geo-engineering' for temperature reduction. This technique is cheap as well as useful for provincial level along favorable effects on

agricultural production and food security. Several studies are carried out in different dimensions. The current study aims to investigate the impact of climatic variables on production and yield of crops of southern Punjab.

Material and Methods

In light of aim and objectives of the study, exploratory and descriptive research design is incorporated. This study is delimited to two crops; rice, and maize in South Punjab. The undertaken research incorporates quantitative approach to determine the impact of two variables: rainfall and temperature, on the yield and production of crops of arid climatic zone of three districts; Multan, Bahawalpur and Bahawalnagar. In this regard, data is gathered from the different departments of ten 10 years, 2006-2016. Data in relation to rainfall and temperature was taken from Pakistan Meteorological Department (PMD), while data with the perspective of crops was collected from Government of Punjab Agriculture Marketing Department, Directorate General Soil Survey of Punjab Agriculture Department Government of the Punjab Lahore, Punjab Food Department, whereas information regarding population was gathered from Population Welfare Department Punjab and Bureau of Statistics Punjab. Later data is statistically analyzed by using excel.

Analysis of data regarding impact of temperature and rainfall onyield and production of crops in Multan (2006-16)

Data is analyzed with reference to impact of temperature in centigrade (°C) and rainfall in millimeters (mm) on average yield of rice and maize in minimum distance separation per acre (mds/acre) and production in Multan with time span of ten years. Time duration and yearly average temperature of Multan are represented on x-axis, while average yield of rice and maize in mds/acre, production in tonnes and rainfall in millimeter of Multan are shown on y-axis. The under given tables 1 and figures1 (a & b) have been reflecting the impact of variation of temperature and rainfall on average yield and production of rice and maize of each year throughout the time span of 2006-16.

Table 1(a)Yearly Average Temperature, Rainfall, Yield of Rice and Maizein Multan (2006-2016)

	Average Temperature. (°C)	Rainfall (mm)	Average Yield (Rice) Mds/Acre	Average Yield (Maize) Mds/Acre
2006-07	27.67	21.68	16.17	25.11
2007-08	25.38	14.11	19.41	27.2
2008-09	25.84	17.75	17.42	25.52
2009-10	26.23	8.56	16.58	24.63
2010-11	25.51	23.99	17.81	25.53
2011-12	25.52	13	17.48	29.92
2012-13	25.62	28.14	18.07	44.59

2013-14	25.55	19.48	18.7	44.12
2014-15	25.41	22.45	20.72	46.28
2015-16	25.9	26.65	21.79	47.56

Table 1(b) Yearly Average Temperature, Rainfall, Production of Rice and Maize in Multan (2006-2016)

	Average Temperature. (°C)	Rainfall (mm)	Production (000) in Tonnes (Rice)	Production (000) in Tonnes (Maize)
2006-07	27.67	21.68	15.69	13.4
2007-08	25.38	14.11	22.46	13.4
2008-09	25.84	17.75	27.31	14
2009-10	26.23	8.56	21.04	13.7
2010-11	25.51	23.99	17.28	14.2
2011-12	25.52	13	16.96	17.2
2012-13	25.62	28.14	16.19	24.3
2013-14	25.55	19.48	24.43	27.5
2014-15	25.41	22.45	33.26	28.5
2015-16	25.9	26.65	24.4	38.7

In context of both tables and figures1 (a & b), the highest yearly average temperature was 27.67°C in the year of 2006-2007 in Multan with average yield of rice (16.17mds/acre) and maize (25.11mds/acre); meanwhile, the production of rice was 15.69 tonnes and maize was 13.4tonnes. On the other hand, regarding lowest yearly average temperature was 25.38°C in the year of 2007-2008, with average yield of rice(19.41mds/acre) and maize(27.2mds/acre) and production of rice was 22.46tonnes and maize was 13.4tonnes.

With the perspective of maximum yearly average rainfall28.14mm was measured in the year of 2012-13 with yearly average yield of rice (18.07mds/acre) and maize (44.59mds/acre); simultaneously, production of rice was 16.19tonnes and maize was 24.3tonnes. On the contrary, lowest yearly average rainfall in the year of 2009-10 was 8.56mm with average yield of rice (16.58mds/acre) and maize (24.63mds/acre); at the same time, production of rice was 21.04tonnes, and maize was 13.7tonnes.

With respect to the highest average yield of rice in Multan was 21.79mds/acre in 2015-16. In the meantime, the temperature was 25.9°C and the rainfall was 26.65mm. While, during 2006-2007, the lowest average yield of rice was 16.17mds/acre with 27.67 °C and 21.68mm rain fall. Comparatively rice, the highest yield of maize was 47.56mds/acre throughout 2015-16 due to temperature and rainfall that was 25.9°C and 26.65mm respectively. Moreover, with 26.23°C

temperature and 8.56mm rainfall the lowest average yield of maize was 24.63mds/acre within the year of 2009-10.

As represented in table and figure (1 b), the highest production of rice in Multan was 33.26 tonnes with 25.41°C and 22.45mm rainfall in 2014-215, whereas the lowest production of rice in 2006-2007, was 15.69 tonnes with average 27.67°C temperature and 21.68mm rainfall. Meanwhile, maximum production of maize was 38.7 tonnesin the year of 2015-2016, with temperature 25.9°C and rainfall 26.65mm. However, in the year of 2006-2008 the lowest production of maize was 13.4 tonnes; at the same time, the observed temperature was 27.67 and 25.38 °C respectively, on the other hand rainfall was 21.68 and 14.11mm respectively.

The above analysis exhibited that fluctuation in temperature and rainfall make a significant impact on the yield and production of rice and maize in Multan in the duration of ten years.

Analysis of data regarding impact of temperature and rainfall on yield and production of crops in Bahawalpur (2006-16)

Following data is analyzed to determine the impact of temperature and rainfall on yield and production of rice and maize in Bahawalpur district as mentioned below:

Table 2 (a) Yearly Average Temperature, Rainfall, Yield of Rice and Maize in Bahawalpur (2006-2016)

	Average Temperature. (°C)	**Rainfall (mm)**	**Average Yield (Rice) Mds/Acre**	**Average Yield (Maize) Mds/Acre**
2006-07	26.3	18.55	18.67	17.61
2007-08	25.53	13.69	15.54	17.41
2008-09	25.8	17.75	18.5	17.37
2009-10	26.25	9.94	15.87	17.39
2010-11	25.67	18.75	18.47	17.44
2011-12	25.51	13.84	17.31	26.79
2012-13	25.71	22.01	17.53	53.58
2013-14	25.74	5.69	14.3	54.11
2014-15	25.46	20.99	20.7	87.32
2015-16	25.75	30.16	21.98	77.05

Table 2 (b) Yearly Average Temperature, Rainfall, Production of Rice and Maize in Bahawalpur (2006-2016)

	Average Temperature. (°C)	Rainfall (mm)	Production (000) in Tonnes (Rice)	Production (000) in Tonnes (Maize)
2006-07	26.3	18.55	6.97	2.3

2007-08	25.53	13.69	5.8	2.6
2008-09	25.8	17.75	11.05	3.5
2009-10	26.25	9.94	10.66	3.7
2010-11	25.67	18.75	10.34	4.1
2011-12	25.51	13.84	6.46	6
2012-13	25.71	22.01	5.89	15
2013-14	25.74	5.69	9.61	20.6
2014-15	25.46	20.99	18.54	32.593
2015-16	25.75	30.16	29.53	41.7

In Bahawalpur district, the yearly average highest temperature 26.3°C was measured in 2006-7 with average yield of rice (18.67mds/acre) and maize (17.61mds/acre);while, production of rice was 6.97tonnes and maize was 2.3tonnes. On the other hand, least value of temperature 25.46°C was measured in 2014-15 with average yield of rice (20.7mds/acre) and maize (87.32mds/acre); on the contrary, production of rice was 18.54tonnes, and maize was 32.593tonnes.

With the perspective of highest rainfall 30.16mm was recorded during 2015-16 with average yield of rice (21.98mds/acre) and maize (77.05mds/acre); although, production of rice was 29.53tonnes and maize was 41.7 tonnes. Besides this, lowest value of rainfall 5.69mm was received in 2013-14 with average yield of rice (14.3mds/acre) and maize (54.11mds/acre); meanwhile, production of rice was 9.61 tonnes and maize was 20.6 tonnes.

With regard to the maximum average yield of rice 21.98mds/acre was calculated in the interval of 2015-16 with temperature 25.75°C and rainfall 30.16mm. While, minimum average yield of rice 14.3mds/acre was measured within the year of 2013-14 with temperature 25.74°C and rainfall 5.69mm. In contrast, throughout the year of 2014-15, the highest average yield of maize was 87.32mds/acre with temperature 25.46°C and rainfall 20.99mm. Despite of this, 17.37mds/acre was the lowest average yield of maize in the year of 2008-09 with 25.8°C temperature and 17.75mm rainfall.

In relation to peak production of rice 29.53 tonnes was measured with 25.75°C temperature and 30.16mm rainfall at the time of 2015-16. Whereas, during a period of 2007-08 least production of rice 5.8 tonnes was recorded with the 25.53°C temperature and 13.69mm rainfall8. In addition, the maximum production of maize was 41.7 tonnes with 25.75°C temperature and 30.16mm rainfall during 2015-16. Although, the minimum production of maize was 2.3 tonnes in the year of 2006-07 with 26.3°C temperature and 18.55 mm rainfall.

The above analysis showed that the average yield and production of rice and maize in Bahawalpur was affected by two variables of climate like temperature and rainfall within the duration of 2006-16.

Analysis of data regarding impact of temperature and rainfall on yield and production of crops in Bahawalnagar (2006-16)

Following data is analyzed to determine the impact of temperature and rainfall on yield and production of rice and maize in Bahawalnagar district as mentioned below:

Table 3 (a) Yearly Average Temperature, Rainfall, Yield of Rice and Maize in Bahawalnagar (2006-2016)

	Average Temperature. (°C)	Rainfall (mm)	Average Yield (Rice) Mds/Acre	Average Yield (Maize) Mds/Acre
2006-07	26.3	18.55	20.18	53.25
2007-08	25.53	13.69	18.89	57.72
2008-09	25.8	17.75	19.5	56.54
2009-10	26.25	9.94	22.51	56.6
2010-11	25.67	18.75	21.87	61.64
2011-12	25.51	13.84	21.98	66.16
2012-13	25.71	22.01	23.16	64.06
2013-14	25.74	5.69	22.7	65.08
2014-15	25.46	20.99	22.67	83.02
2015-16	25.75	30.16	21.38	86.59

Table 3 (b) Yearly Average Temperature, Rainfall, Production of Rice and Maize in Bahawalnagar (2006-2016)

	Average Temperature. (°C)	**Rainfall (mm)**	**Production (000) in Tonnes (Rice)**	**Production (000) in Tonnes (Maize)**
2006-07	26.3	18.55	118.99	31.6
2007-08	25.53	13.69	107.18	32.1
2008-09	25.8	17.75	125.92	34.4
2009-10	26.25	9.94	139.5	30
2010-11	25.67	18.75	127.35	30.6
2011-12	25.51	13.84	94.33	40.5
2012-13	25.71	22.01	106.34	42.8
2013-14	25.74	5.69	127.94	54.9
2014-15	25.46	20.99	138.74	63.831
2015-16	25.75	30.16	144.47	71.1

With the reference of highest yearly average temperature 26.3°C was recorded in the time span of 2006-07 in Bahawalnagar with average yield of rice (20.18mds/acre) and maize (53.25mds/acre); however, the production of rice was 118.99 tonnes and maize was 31.6tonnes. In that context, lowest yearly average temperature in 2014-15 was 25.46°C with average yield of rice (22.67mds/acre) and maize (83.02mds/acre); in spite of this, production of rice was 138.74tonnes and maize was 63.831 tonnes.

With respect to maximum rainfall 30.16mm was measured between periods of 2015-16 with average yield of rice(21.38mds/acre) and maize(86.59mds/acre); at the same time, production of rice was144.47tonnes and maize was 71.1tonnes. On the other hand, 5.69mm rainfall was received in 2013-14 with average yield of rice(22.7mds/acre) and maize(65.08mds/acre); simultaneously, the production of rice was127.94tonnes and maize was 54.9tonnes.

The highest (23.16mds/acre) and lowest (18.89mds/acre)average yield of rice was noticed in 2012-13 and 2007-08 with temperature 25.71°C, 25.53°C and rainfall 22.01mm, 13.69mm respectively.Moreover, the maximum yield of maize was 86.59mds/acre with 26.46°C temperature and 35mm rainfall in the duration of 2015-16. In the premises, during the interval of 2006-07, the minimum average yield of maize was 53.25mds/acre with 26.41°C temperature and 27.85mm rainfall.

In 2015-16, the maximum production of rice was 144.47 tonnes with temperature 25.75°C and rainfall 30.16mm. Whilst, the minimum production of rice was 94.33 tonnes with temperature 25.51°C and rainfall 13.84mm2011-12. Apart from this, during 2015-16, the highest production of maize was 71.1 tonnes with 25.75°C temperature and 30.16mm rainfall. On the other side, the lowest production of maize was 30 tonnes with 26.25°C temperature and 9.94mm rainfall within the year of 2009-10.

All in all, it was explored from the above interpretation that the variation in temperature and rainfall has an impact on the yield and production of rice and maize in Bahawalnagar within the duration of 2006-16.

Conclusion

The findings of the study revealed the impact of climatic variables; temperature and rainfall on the crops yield and production of three districts of Southern Punjab, Multan, Bahawalpur and Bahawalnagar. In Multan district, high temperature has not making productive impact on production of rice and maize; on the other hand, fluctuation in rainfall has dynamic effect on production of rice and maize because of the influence of other factors such as humidity, atmospheric pressure, irrigation system, fertility of soil etc. Regarding Bahawalpur district, high temperature has negative influence on maize and rice production, on the other hand, rainfall has made a positive impact on production of rice and maize. With the perspective of Bahawalnagar district, impact of temperature on the production of

rice and maize varies, whereas rainfall makes a significant impact on production of rice and maize. Overall, it is observed that temperature and rainfall have minor impact on yield of crop, whereas temperature and rainfall have massive effect on production of crops. This study will be helpful for the meteorologists and agriculturalists to take safety measures for the food security. As well as, increase in population shifts the pattern of temperature and rainfall. The increasing population of Pakistan is a major cause of climate change for example burning of fossil fuels and smoke of industries has been raising the temperature of Earth Surface. This research also raises awareness related to climate change and its impacts on crops.

Recommendations

After being familiar with the impact of climatic variables on crops, different steps must be taken by the food departments, agriculturalists, and meteorologists. Government must design policies for managing the temperature and rainfall; and then to control its effects on overall crops. In this regard, alarming system should be installed to avoid the threatening situations. As well, awareness must be raised among the landowners in regards to agricultural and education to increase the fertility, productivity, yields of crops and food security. In addition, innovative technologies and machineries must be incorporated for the progress of crop yields and production.

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