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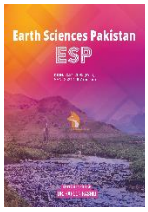

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RESEARCH ARTICLE

IMPACT OF CLIMATE CHANGE ON CITRUS PRODUCTION IN MOUNTAINOUS VALLEYS OF KHYBER PAKHTUNKHWA, PAKISTAN

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ABSTRACT

Climate change is a universal phenomenon which has impacted several aspects of farming such as seasons, crop production, land fertility as well as trees health. The climate change has been observed overtime, reportedly affecting agricultural production in various regions in several countries. The impact of climate change has been more widespread in Pakistan and the country has proved to be more vulnerable. The economy of Pakistan is mainly driven by agriculture-related activities. Pakistan is among the top exporter countries of Citrus fruit and the demand of this product is higher across the world. However, there has been an increasing concern of low Citrus production in Pakistan, as compared to the neighboring countries, an aspect which necessitates the salience of studying Citrus production in Pakistan. To this end, this study examines the effects of rainfall, temperature, humidity and wind speed on Citrus production to identify the Citrus orchards change as a result of climate change. To achieve this goal, this study makes use of various data collection techniques, data sources and different statistical analysis tools such as SPSS to investigate the impact of climate change on Citrus production in the selected area. The findings suggest that there exists a significant correlation between Citrus production and change in temperature ($p=0.039$), rainfall ($p=0.048$) and wind speed ($p=0.001$). In addition, the correlation coefficient between rainfall and Citrus production is positive with a value of 0.341. Mitigating the impacts of climate change has never been so simple and thus a holistic approach is always needed to attain the sustainability status. This study offers recommendations for policymakers to formulate the future policies of the country.

KEYWORDS

Climate Change, Citrus Production, Citrus Quality, Khyber Pakhtunkhwa, Pakistan.

1. INTRODUCTION

Climate change pertains to an important, long-term change within the world climate, and almost every part of the world has been impacted by the vulnerabilities of climate change, one way or another (Ahmad et al., 2017). Among other impacts, climate change has proved to be increasing the greenhouse emissions and pollution across the globe (Field et al., 2014). Though climate change has existed for a long time, its impact has been more widespread over the past few decades, primarily due to deforestation, industrial revolution, burning of fossil fuel and land degradation. Consequently, there has been more greenhouse emission in the atmosphere (Baig and Amjid, 2014). Pakistan is drastically impacted by the negative consequences of climate change as it lies in a geological zone where it is forecasted that the change in temperature is increasing (Rasul et al., 2012).

As Pakistan is an agriculture country, its economy is primarily driven by returns from agricultural-based products. Pakistan currently produces agricultural products of around 550 billion (PRs) per year (Shahbaz et al, 2017). The Citrus fruit produced in Pakistan has a very good standing globally; it is demanded world-wide and the country is among top 10 citrus fruit exporters across the world. The quantity of Citrus produced in Pakistan rose to 20180 tons in 2015 from 1970 tons of Citrus in 1991-1992 (Tahir, 2014; Muchuru and Nhamo, 2019). It is the largest producer of an indigenous high quality "Citrus Reticula" also known as Kinnow and Pakistan produces 95% of the total Kinnow produced globally (Farooq et al., 2018). There has been research focus on fruit production, especially the production of Citrus in Pakistan (Ahmad et al., 2017; Joshi, 2016). The country is the 12th largest producer of Citrus fruit with 200 ha area and 2.32 million tons production (Nasir et al., 2016) and Citrus is almost 40% in quantity among other fruits produced in Pakistan (Khalid et al., 2016). It is the major fruit and is grown in all four provinces of the country and it has one-third share in the total value of fruits export (khan et al., 2012; GOP, 2006). However, the country national normal yield is 10.6 tons/hectare which is low compared to different Citrus growing nations (Jabeen et al., 2016). The country yield per hectare is even less than the neighboring nations, including India and Iran (Iqbal et al., 2009; Ghani, 2017).

The production of Citrus requires specific climatic condition, so that an improved yield and quality can be ensured (Ahmad et al., 2017). Any change in temperature can potentially impact the plant growth, fruit setting, flowering and speed in which the fruits reach their maturity (Zabel et al., 2014). The global normal temperature over the mainland broke a record of + 1.89°C, and it is assumed that if temperature were to rise by 2.5°C- 4.9°C by the end of the current century, the damage to crops will increase by 10-40 percent (Birthal et al., 2014). It is emphasized that the normal yearly temperature shows a higher increase than the worldwide normal temperature (Zouabi and Kadria, 2016). The major effects of such changes are more prominent on agriculture crops in developing countries (Redden et al., 2014). Changes in temperature will affect fruit quality as rise in temperature will accelerate fruit maturity, less content of sugar and lower acidity levels because of low levels of acids (Zabel et al., 2014). However, high temperatures during specific development periods such as

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the fruit-drop stage may have a harmful effect on Citrus production (Qin et al., 2016). Variation in temperature is the major proponent with a strong impact on Citrus production (Melgar, 2014). Optimum temperature between 22-27°C is required for Citrus fruit production and fruit drop occur in Citrus if it reaches 30°C.

During the development of fruits, if the temperature goes beyond 33°C, there is a decline in sugar and acid contents, size and fruit drops (Luo, 2011). Variation in temperatures also plays important role in causing Citrus canker disease in Citrus (Ference et al., 2018). The ideal temperature for infection was found to be ranging between 25-35°C (ConceišŃo et al., 2017). For Citrus production, long term reduction in rainfall can have either positive or negative effect. Longer dry periods encourage drought induction of flower buds. Also, extreme drought can reduce tree efficiency and make irrigation necessary for citrus or other crop production (Albrigo, 2008).Wind speed is an important factor in the deterioration of Citrus quality and friction between the skins of one fruit with another can cause discoloration of the peel (Zhang et al., 2018). In an artificial simulation experiment conducted in Florida, higher wind speed resulted in increase in incidence and severity of Citrus production (Rasoulnia et al., 2018). One of the main effects of wind on Citrus plant is to act as dispersal agent, either individually or in arrangement with rain, for several plant pathogens. Humidity is another factor that can demoralize the pace and quality of Citrus production (Al-zoubi and Normah, 2012). The production of Citrus is reduced, and the produced fruit will be unfit for export if the concentration of humidity and rainfall is high seasonally or during the whole year. Consequently, the fruit will be consumed locally due to adverse effects of hot, humid climatic condition (Ochuodho and Lantz, 2015).

The production of Citrus fruit plays important role in the economy of a country. In accordance with the contribution of climatic factors in the ongoing global warming scenarios, this research is designed to analyze the effect of climate change in terms of assessing the effects of temperature, rainfall, humidity and wind on the quantity of Citrus production. Swat valley of Pakistan has been serving as a fertile land for production of various crops and fruits for its adoptive climate conditions. It has been producing Citrus fruit on commercial basis over decades. However, the quantity of Citrus production in Swat valley has been changing over time. To the best of our knowledge, the impact of temperature, wind speed, humidity and rainfall on Citrus production in the context of Swat has not been studied before. Thus, it provides an opportunity for examining it to advance the body of knowledge.

To this end, this research examines the impact of climate change on Citrus production over time and identifies the land use change as a result of climate change adaptation by farmer. It models the future projection of Citrus production using various statistical tools and recommends a holistic perspective based on the analysis and synthesis of the results for Citrus producers, exporters and policy makers. The agriculture sector has been highly affected by climate changes and this research focuses on the shift in Citrus production and its relationship with climate change over time in the Swat valley of Khyber Pakhtunkhwa, Pakistan.

The rest of the study is organized as follows. Section 2 provides the methodology comprising the details of questionnaire, pilot study, sample frame, regressions analysis, research framework and hypotheses. Section 3 provides the results and analysis concerning correlation analysis, regression analysis and hypotheses testing. Section 4 discusses the implications of results and Section 5 provides the conclusion of the study.

2. Methodology

This research uses a methodological framework for analyzing the relationship between climate change and Citrus production. To perform the analysis, rainfall, humidity, wind speed and temperature are considered as proxies for assessing the effects of climate change. The independent variables in this analysis are rainfall, humidity, wind speed and temperature, while the dependent variable is the quantity of Citrus production. A survey collection method was used to collect the primary data for analysis. This data was collected from farmers and field expert/horticulturist of Swat valley of Khyber Pakhtunkhwa. The research framework is provided in Figure 1.

Following hypotheses for the study analysis were formulated;

H_1: Change in Rainfall has a significant impact on Citrus Production.

H_2: Change in Humidity measure has a significant impact on Citrus Production.

H_3: Change Wind Speed has a significant impact on Citrus Production.

H_4: Change in Temperature has a significant impact on Citrus Production.

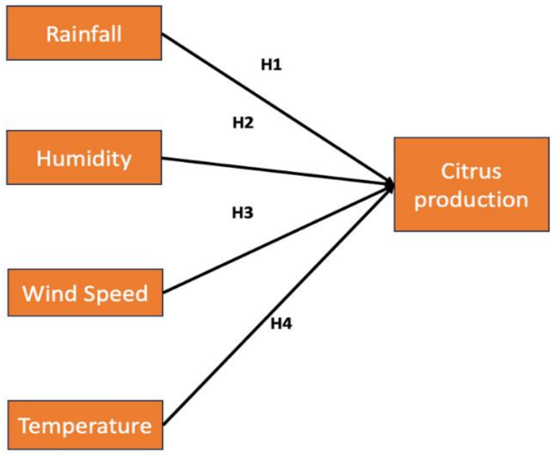

Figure 1: Proposed research framework

The dependent variable for the study analysis was Citrus Production which is a quantitative measure while in independent variables, rainfall, humidity, wind speed and temperature were considered. In this study, multiple linear regression analysis is used in which each variable was entered in the model incrementally to check its significance in explaining the variance produced in the dependent variable of Citrus production.

2.1 Pilot study

Before going to the field for data collection, a pilot study was conducted to the strengthen the applicability of the questionnaire. The questionnaires were distributed among seven field experts, and they were requested to return them in one week. In the pilot study, the field experts suggested that the developed questionnaire needs some corrections in specific questions and their feedback was incorporated. Corrections were made after meeting with field experts and some of the questions were replaced by adding and removing unnecessary questions. Initially, a Likert scale-based questionnaire of five variables comprised thirteen questions, which were extended to twenty-one questions as a result of the pilot study.

The finalised quantitative based questionnaire consisted of questions regarding four independent variables including rainfall, temperature, humidity, wind speed and Citrus production as a dependent variable. The questionnaire was divided into two sections where the first section comprised six questions concerning the demographic information of the respondents such as name, age, address/contact number, qualification, main source of income, owner/tenant (of the orchard). The second section comprised five sub-sections which contained questions concerning four independent variables (rainfall, temperature, humidity and wind speed) and one dependent variable. The second section consisted of five question each for Citrus production, rainfall, temperature and three questions each for humidity and wind speed. All questions in the questionnaire were based on the impact on citrus production due to climate change. A 5-point Likert Scale based was used for all items of the questionnaire.

2.2 Sample frame

A good sample should include each unit in the target inhabitants to have the same chances of selection. Sampling technique has two main categories such as probability and non-probability techniques. In probability sample technique, data is collected by the method of probability from a larger population. The main requirement of this technique is that everyone should get a chance to be selected. This type of technique shows the true representation of the selected population. It includes simple random sampling, cluster random sampling and systematic random sampling. On the other hand, non-probability sample collect data in a way that all the population are not equally facilitated in it. Types of non-probability techniques include convenience sampling, consecutive sampling, quota sampling, snowball sampling, etc.

In this research, data was collected from both primary (farmer and field experts) and secondary (meteorological department and crop reporting services Khyber Pakhtunkhwa) sources for rainfall, humidity, wind speed, temperature and Citrus production for Swat Valley of Khyber Pakhtunkhwa. For data collection, random sampling technique of Non-Probability Sampling Techniques was used. Each individual was selected randomly and completely by chance. One more reason for choosing this technique as the area selected for study i.e., Swat Valley is an expended

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area of the province but only with few villages known for Citrus production like Nawagay, Kota, Abuha, Paarai, Shamozai, and Barikot. Specific orchards were then selected for random sampling technique of data collection. The timeframe for collection of data was limited. Data was collected from farmers and agriculture experts, which included experts of the field from agriculture extension department and agriculture research institute, Swat. Farmers data were collected from the farmer of the abovementioned villages well known for citrus production.

2.3 Regression

In addition, secondary data for rainfall, temperature, humidity and wind speed for the years 1985 to 2017 (spanning 33 years) was collected from Pakistan Metrological Department Peshawar (PMD) to ensure that the findings are more robust and effective. Citrus data for the period 1985-2017 of Swat valley was collected from Crop Reporting Services, Agriculture and Livestock Department of Khyber Pakhtunkhwa. We used various statistical analysis tools such as correlation & regression, ANOVA and graphical representation for understanding the impacts of climatic variables on Citrus production. SPSS version 21.0 and excel environments were used for data entry and data analysis. To make the analysis simple, assumption of linearity was made between variables.

The following statistical model is used to examine the decline in Citrus production due to climate change, as mentioned before:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where

$Y =$ dependent variable of citrus production

$\beta_o =$ constant intercept

$\beta_1, \beta_2, \beta_3, \beta_4 =$ slope/beta coefficient of independent variables

$X_1 =$ independent variable of rainfall

$X_2 =$ independent variable of temperature

$X_3 =$ independent variable of humidity

$X_4 =$ independent variable of windspeed

$\varepsilon =$ error term representing un-explained variance

3. Results and Analysis

The primary aim of this research was to study the impact of independent variables i.e., climatic factor on Citrus production and to identify the relationship between variables. To serve this purpose, firstly, correlation analysis was performed between all variables. From the findings in Table 1, it can be observed that there is a significant correlation between Citrus production and change in temperature (p=0.039), rainfall (p=0.048) and wind speed (p=0.001). The correlation coefficient between rainfall and Citrus production is positive with a value of 0.341.

Table 1: Correlation results of respondent data (farmers/field experts)

Correlations

		MeanCP	MeanRF	MeanTemp	MeanHumi	MeanWS
Pearson Correlation	MeanCP	1.000	.341	-.360	-.176	-.603
	MeanRF	.341	1.000	-.059	.092	.019
	MeanTemp	-.360	-.059	1.000	.436	.277
	MeanHumi	-.176	.092	.436	1.000	.155
	MeanWS	-.603	.019	.277	.155	1.000
Sig. (1-tailed)	MeanCP	.	.048	.039	.200	.001
	MeanRF	.048	.	.390	.331	.464
	MeanTemp	.039	.390	.	.015	.090
	MeanHumi	.200	.331	.015	.	.229
	MeanWS	.001	.464	.090	.229	.
N	MeanCP	25	25	25	25	25
	MeanRF	25	25	25	25	25
	MeanTemp	25	25	25	25	25
	MeanHumi	25	25	25	25	25
	MeanWS	25	25	25	25	25

Table 2 provides the results of regression analysis. It can be observed that R^2 value is 0.525 but since independent variables are measured in different units, we consider adjusted R^2 value which is 0.430 (or 43%). It can be concluded that the independent variables explain 43% variation is the dependent variables behavior. Also, the overall model is significant with F (4, 20) = 5.525; p<0.05.

Table 2: Main model summary of respondent data (farmer/field experts)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.725[a]	.525	.430	.34844	.525	5.525	4	20	.004

a. Predictors: (Constant), Mean WS, Mean RF, Mean Humi, Mean Temp

Similarly, Table 3 provides ANOVA based sum of square of regression variance analysis and entries in the tables can be used to validate the R^2 value (which is the ratio of regression to residual sum of square)

Table 3: ANOVA results of Respondent data (farmers/field experts)

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2.683	4	.671	5.525	.004[b]
	Residual	2.428	20	.121		
	Total	5.111	24			

a. Dependent Variable: Mean CP

b. Predictors: (Constant), Mean WS, Mean RF, Mean Humi, Mean Temp

Table 4 outlines the regression results containing regression co-efficient values against significance level for independent variables. It can be observed that all variables except rainfall hold significant and direct (positive) relationship with citrus production with a beta value equal 0.351 ($p<0.05$). Also, the baseline intercept value of citrus is 7.510, indicating that Citrus can still be produced in defined quantities in the absence of all four independent variables.

Data was collected from the Meteorological and Crop Reporting Services in Khyber Pakhtunkhwa to generalize and expand the findings from survey. It contained field observation of dependent and independent variables. Table 5 outlines the model summary statistics with an adjusted R^2 value of 0.708, (or 70.8%). It can be compared to the earlier obtained regression model (43%) to indicate an increase of almost 27% with standard error of the estimated value 992.157. Similar pattern can be observed from results of ANOVA values, where regression sum of square has gone up to 16.508 with significance $p<0.05$.

Table 4: Regression coefficients of respondent data (farmers/field experts)

Coefficients

Model		Un-standardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.510	.910		8.258	.000
	MeanRF	.612	.272	.351	2.251	.036
	MeanTemp	-.288	.201	-.255	-1.438	.024
	MeanHumi	-.090	.306	-.051	-.293	.000
	MeanWS	-.557	.168	-.534	-3.326	.003

a. Dependent Variable: MeanCP

Table 5: Summary of Meteorological department and crop reporting services

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.868[a]	.754	.708	992.1557

a. Predictors: (Constant), Temp_ AVG, RF_AVG, Humidity_ AVG, WS_AVG, Year

b. Dependent Variable: Citrus Production in Tones

Table 6 informs that all variables exhibit a significant relationship with the dependent variable. Beside these climatic factors, a study in Punjab province of Pakistan was done by in 2009 and their findings suggested that 20 years is an ideal economic life of Citrus orchard, and thereafter, there is a decline in the Citrus production (Sharif et al., 2009). In this context, this study further adopted a new independent variable in the form of "Year", which represented the change in Citrus quantity over time in Swat. The standardized beta-coefficient is -0.896 meaning that Citrus quantity has depleted over the years. Similar phenomenon is presented in the graphical form for easy and quick understanding for the readers. For example, Figure 2 shows the quantity of citrus produced over the years in Swat valley. It is worth noting that a non-linear and constant increase can be observed in citrus quantity in the time frame of 1985-2001 followed by a swift decrease in Citrus quantity from 8000 (tons) to 4700 (tons) in two years from 2001-2003. The Citrus quantity is on continuous decline up until the year 2017. Thus, this phenomenon calls for a thorough investigation of the swift change in its quantity.

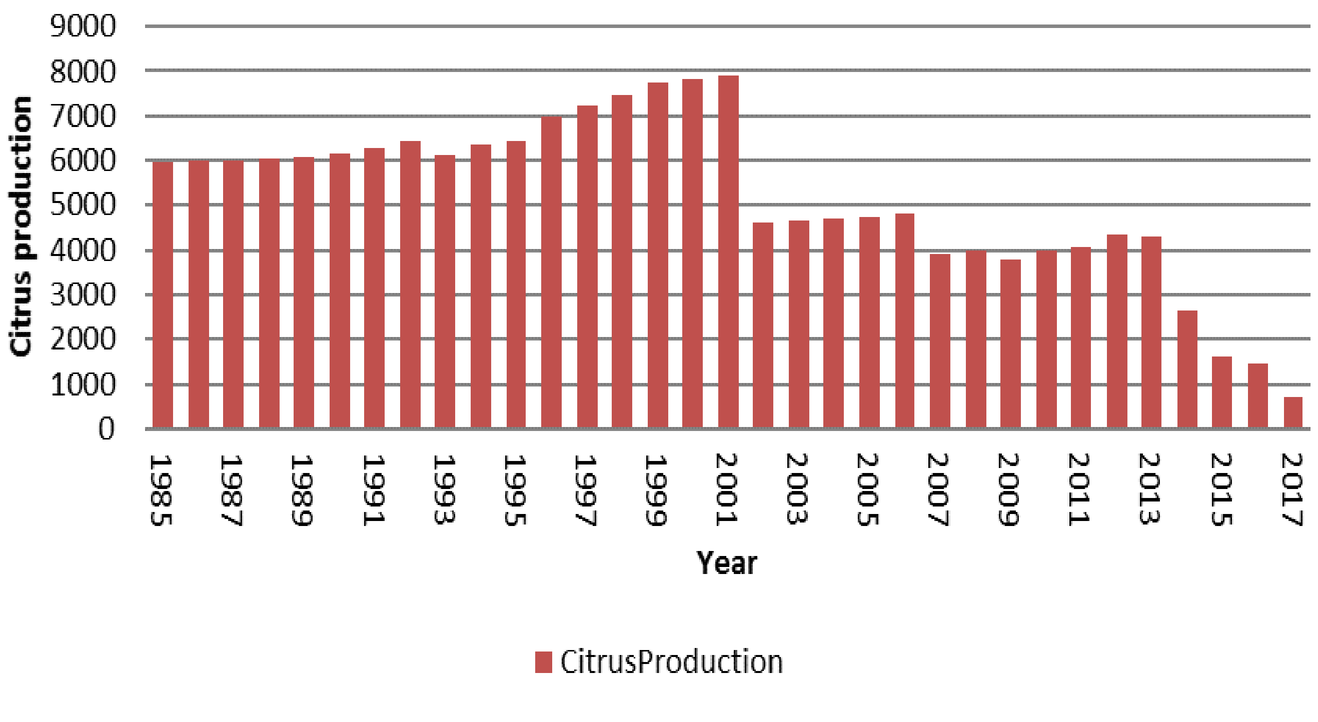

Figure 2: Trend of Citrus production over the year

Also, the rainfall coefficient is also significant and positive. Thus, it can be concluded that an increase in the rainfall can have positive impact on Citrus production. In addition, the coefficients of wind speed, humidity and temperature are negative, meaning that the Citrus quantity is negatively impacted by such variables. These findings are in agreement with the earlier attained results from personal survey.

Table 6: Regression Coefficients Meteorological department and crop reporting services

Coefficients a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	329843.6	50389.5		6.546	.000	226452.794	433234.518
	Year	-170.0	25.1	-.896	-6.751	.000	-221.691	-118.348
	RF_AVG	14.3	8.5	.169	1.677	.002	3.207	31.88
	Humidity_AVG	-211.6	58.7	-.386	-3.601	.001	-332.317	-91.067
	WS_AVG	-2708.5	986.7	-.333	-2.745	.011	-4733.136	-684.055
	Temp_AVG	-139.0	124.9	-.122	-1.112	.024	-395.411	-117.402
a. Dependent Variable: Citrus Production in Tones								

Figure 3 provides the relationship between Citrus quantities and temperature changes during the timeframe 1985-2017. It can be observed that the average temperature has been increasing in this time period while the quantity of Citrus has been decreasing. From regression analysis, it can be inferred that the temperature strength coefficient equal to -0.122 causing decrease in citrus quantity. In literature, multiple studies have reported that an increase in temperature has a strong as well as negative impact on the quantity of Citrus produced (Zouabi and Kadria, 2016; ConceišŇo et al; 2017). Any increase in temperature can have negative impact on Citrus production and can increase the rate of evaporation, decrease water level and increase the chances of diseases. Also, another study conducted in Punjab Province of Pakistan suggested that an increase in temperature can have negative effect on Citrus fruit production and can potentially decrease the yield quantity (Ahmad et al., 2017).

Another important observation from Figure 3 is that the quantity of Citrus production does not change with any change in temperature in the past decade. For example, although mixed trend in temperature can be observed, i.e., increase as well as decrease, the quantity of Citrus has been constantly decreasing. This aspect can be explained in the following two possible ways. Firstly, as evident from the beta values in Table 6, the strength co-efficient of temperature with Citrus is not strong enough compared to other independent variables. Thus, it can be inferred that the swift decline in Citrus in the past decade is attributable to other variables more than to be attributed to temperature. Secondly, global warming is a big phenomenon and we have considered mainly four variables related to it in this study. The consideration of more variables in the study design can help in the refined evaluation of the swift declining behavior of Citrus, especially in the past decade.

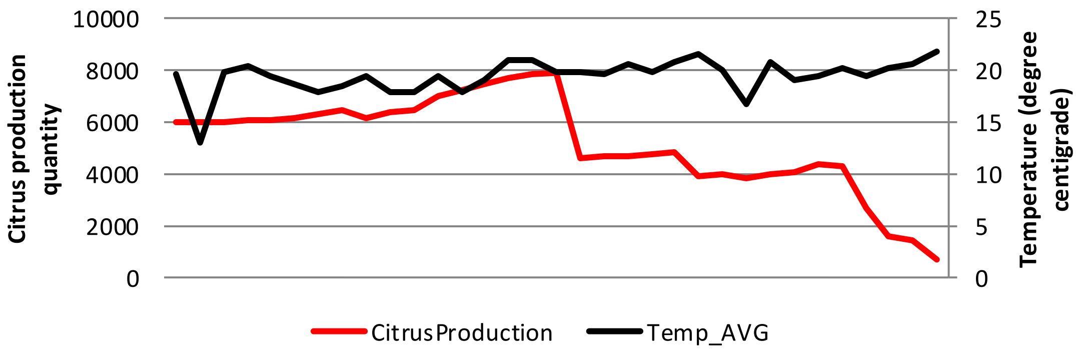

Figure 3: Trends of temperature and citrus production

The graphical relationship between wind speed and Citrus quantity is provided in Figure 4. It can be observed that more dynamics in the wind speed data points compared to those of temperature where for the first 10 years, Citrus quantity is on the rise although wind speed is stagnant (no data is available at this period of time). After this point, both wind speed and Citrus quantity are exhibiting a mixed behavior. From the regression coefficient table, the beta value is -0.333 which means that Citrus quantity decreases with an increase in the wind speed with a negative impact on Citrus production. Similarly, there is literature-based evidence that the wind speed has negative effect on the quantity of Citrus produced and large-scale changes in wind speed can potentially cause early flower, leaves, and fruit drops and it can damage the branches as well (Zhang et al., 2018). Another aspect of Citrus crop is disease propagation and wind speed play a key role in the pathogen dispersal causing Citrus canker disease in Citrus (Ference et al., 2018; Conforte et al., 2019; Bock et al., 2011) and thus causes decrease in Citrus production.

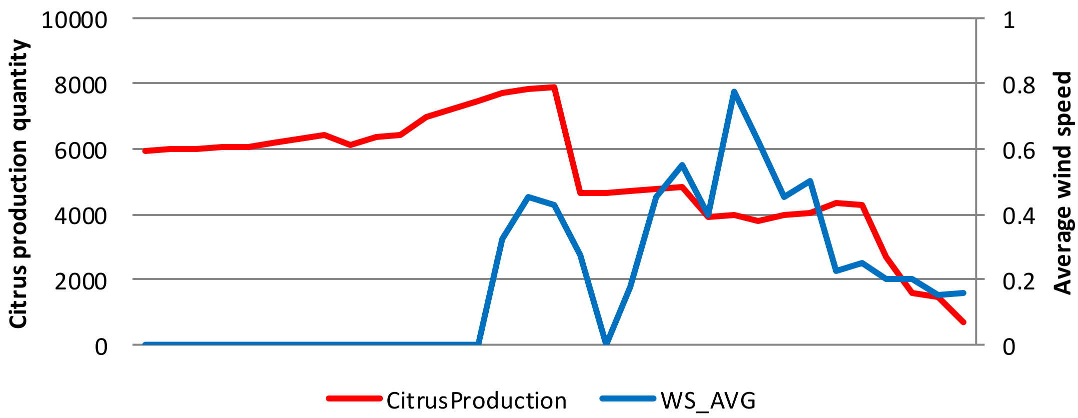

Figure 4: Trend of wind speed and citrus production

Humidity, similar to wind speed, also exhibits an indirect and negative relationship coefficient with the quantity of Citrus produced. However, a static behavior of humidity can be observed in Figure 5 where the quantity of Citrus produced changes overtime. It can be concluded that, compared to drastic changes in other variables behavior (i.e., temperature, wind speed and rainfall), the current study reports mixed trend (increase as well as decrease) in humidity in Swat region. Furthermore, it can be argued that since combined effect of all four independent variables was considered in regression, humidity is one of the confounding variables. The literature suggests that an increase in relative humidity can negatively impact the fruit and can cause blue mold disease in citrus fruit (Khadivi-Khub, 2015; Farooq et al., 2018; Mannaa and Kim, 2018). The existing research also indicates that ambient "feels like" factors such as humidity impacts the quantity (yield) and quality (fruit damages) through radiation (Mahanty et al., 2017). Also, it alters the growth of Citrus fruit through a joint effect of soil temperature and wind speed. The same has been demonstrated through correlation analysis in current study where it is shown that independent variables are correlated and they cause an impact on each other.

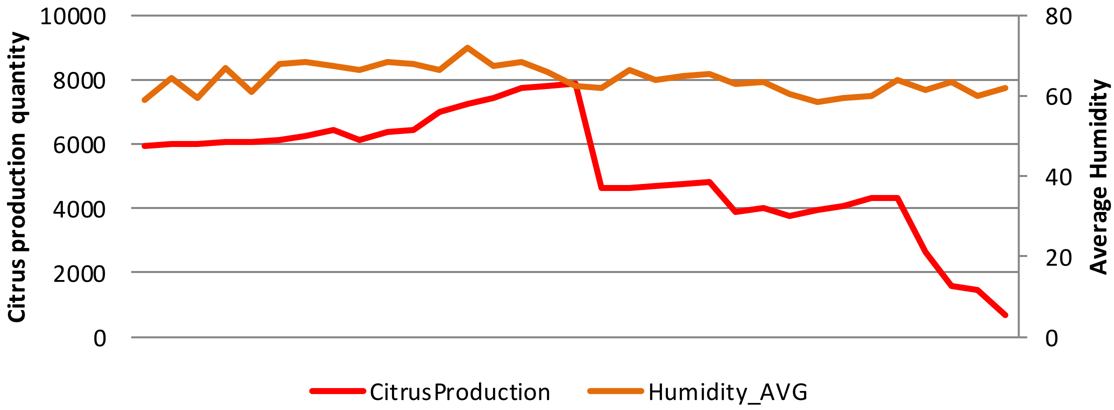

Figure 5: Trend of humidity and citrus production

Lastly, graphical representation of relationship between rainfall and Citrus production is given in Figure 6. A turbulent curve of rainfall is observed in accordance with the findings of regression analysis. As shown, rainfall has exhibited a changing pattern in the past two decades in Swat and it contributes to change in the quantity of Citrus production. This changing behavior is supported by the result indices of rainfall from data. It is evident from Table 6 that the increase in rainfall has a positive impact on the quantity of Citrus produced.

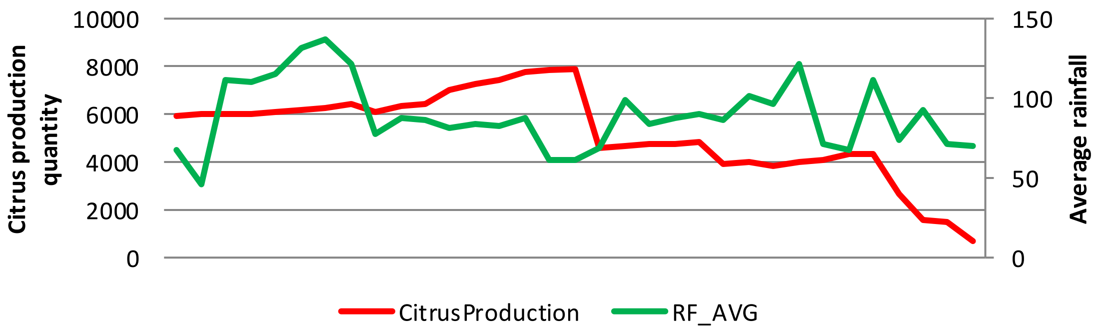

Figure 6: Trend of rainfall and citrus production

4. Discussion

The findings of this research support the literature findings stating that increase in rainfall has a positive effect on the quantity of Citrus produced (Zouabi & Kadria, 2016). In addition, a study conducted in the Punjab province of Pakistan reported that there is a direct and positive relationship between rainfall and Citrus production and increase in rainfall can reduce the effect of temperature as well (Ahmad et al., 2017). A discussion on some results is provided in the following sub-sections.

4.1 Effects of rainfall on fruits

Rainfall patterns such as frequency and timings are more important for fruits. When it rains in spring, it causes low fruit set which results in more disease propagation. Rainfall not only affects the plant production process but also changes the chilling hours. Severe rainfall in the flowering season adversely affects fruit production.

4.2 Effects of rainfall on citrus

Rainfall is a blessing for Citrus, especially in low/deficit water areas & change in rainfall pattern affects pollination process. Steady rainfall positively affects both quality and quantity of the Citrus crop. However, intensive rainfall negatively affects petal fall and yield of Citrus. Due to changing pattern of rain, adequate water supply could not be provided to orchard in an area which can ultimately result in low quality fruit production.

4.3 Effects of temperature on fruits

Increase in temperature causes increase in diseases, stress, water requirement, pre-mature fruit drop, reduce chilling hours and fruiting. Subtropical fruit need chilling hours for enhanced quality and high fruit production which is adversely affected by change in temperature. It effects ripening and maturation of fruits and change in temperature changes the dynamics of cultivators.

4.4 Effects of temperature on citrus

Temperature changes have proven effects on Citrus fruit and prolonged low temperature causes freezing injury and damaged fruit buds. On the other hand, extremely high temperature effects the irrigation requirement of Citrus crop. Due to fluctuation in temperature, flowering pattern is negatively affected which influence Citrus fruit production.

4.5 Effects of wind speed on fruits

Increase in wind increases transpiration and hence more water is required for fruit production. Increased wind velocity at maturity level causes fruit drops.

4.6 Effects of wind speed on citrus

Wind speed direction and its intensity affects fruit drop, flowers and branches. Citrus is affected by both high wind speed and storms.

4.7 Effects of humidity on fruits

Humidity is related to dew point and temperature & increase in humidity increases fungal diseases. Humid conditions can provide suitable environment to many pests and diseases (e.g., apple scab) and can affect pollination activity thus impacting fruit production.

4.8 Replacement of Citrus orchards

4.8.1 Type of fruit and reason

Because of the formation of micro climate zone in the area, chances of introducing new Citrus varieties are more. However, in district Swat, Citrus has been replaced by peach, plum and apricot primarily due to economic and environmental conditions. The environmental and climate condition of the district is favourable for producing high quality peach. Unlike the past, Swat region is no more commercially known for producing Citrus; however, it is blessed with environmental conditions which can support variety of fruits.

4.9 Problems in Citrus production

Peach is becoming an effective replacement to Citrus with more prospects of revenues. Root stock and mostly sour orange budded plants are sold so practices currently being used for Citrus production are manual and varieties available needs to be replaced by new ones. There is a lack of scientific knowledge regarding pruning, thinning, training and nutrition of the tree. Farmers need to be educated regarding good management for nutrition and diseases controls.

4.10 Role of agriculture department

Agriculture department can play an active role in conducting research on varieties development, protection measures, marketing issues, post-harvest handling and mix cropping in peach orchards. Field days, seminar on balanced use of fertilizer can also result in an increased yield of Citrus. Agriculture research focuses on evaluation and screening of new promising varieties and their availability to farmers. New methods are being developed and experience is shared with the farming community through trainings. It is suggested that research stations of the province should put more work in order to bring improvement in the production of Citrus.

5. Conclusion

Change in climate is among the most important challenges these days faced by several countries. This study offers empirical support that change in climatic conditions directly impacts the productivity of agricultural commodities as well as horticultural crops production. Citrus is one of the main fruits in Pakistan with economic importance both on regional as well as national level. Thus, the objective of this study was to examine the influence of climate change on the Citrus fruit production in Swat valley of Khyber Pakhtunkhwa, Pakistan. To meet this objective, various statistical techniques were employed to demonstrate the impact of climate change on Citrus production. The findings suggest that there is a negative relationship among various climate variables and Citrus production. Climatic variables such as temperature, rainfall, wind speed and humidity poses harmful effect on production of Citrus fruit. The results report that variation in these variables have negative impact on the production of Citrus and its quality, which alternatively affects our food safety and economy. As an agricultural-based economy, positive measures should be taken in Pakistan, else it will be difficult for the country to attain sustainable economic status especially when the world is on its way to "Green Economy".

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