Research Article

Impact of Climate Change on Maize Productivity in Khyber Pakhtunkhwa, Pakistan

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Abstract | This research was premeditated to estimate the impact of climate change on maize productivity in Khyber Pakhtunkhwa, Pakistan. Chitral, Swat, Mansehra, Peshawar, and D.I. Khan Districts were selected from different agro-ecological zones of Khyber Pakhtunkhwa. The climatic and non-climatic variables employed for the study were area under maize, maximum temperature, minimum temperature and precipitation, respectively. For statistical analysis, panel data record for twenty years (1996-2015) across five districts of the province were scrape together from Development Statistic of Khyber Pakhtunkhwa, Pakistan Bureau of Statistic and Pakistan Meteorological Department, Khyber Pakhtunkhwa. Hausman test recommended fixed effect model (as opposed to random effect) as a fit model for given estimation. The major findings proclaim that maximum temperature has negative impact on the yield of maize. Impact of precipitation show a positive and significant contribution to maize yield. High temperature has deleterious impact on maize productivity. Therefore, policy exertions needs to be concentrated toward impact of climate change on maize productivity. Development of temperature resistant maize verities for Khyber Pakhtunkhwa is also a good option. Moreover, awareness among farmers on climate change is required regarding plantation of trees and afforestation.

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Introduction

Climate change is the foremost environmental concern facing by all community in the world through which humanoid activity are directly or indirectly affected. Climate and weather both play a strategic role in agricultural productivity. It has been deliberated that in the coming epoch's climate variation will tip to reduce crop yield in many countries in the world (Falco et al., 2011). Climatic variation is change in climate pattern over a period of time. Climatic variation results in rise in temperature, precipitation and other weather conditions like greenhouse gas (GHG) emission, variation in magnitude, frequency, distribution of rainfall and other weather extreme condition like flood, drought, and intensification in sea level and cyclone that has destructive impact on economic growth of agriculture. Due to climate variation round about 400-500 natural cataclysms occur since 1980s (Intergovernmental Panel on Climate Change (IPCC, 2007; Gumel et al., 2016).

It is avowed by intergovernmental panel on climate change that earth temperature will be amplified by 1 to 3.5°C (2 to 6°F) by 2100 (IPCC, 2007). Variation in climate highly affect environment economically, physically and socially throughout that can negatively affect food security, and livelihood of farmers community particularly in developing country across the world (Gumel et al., 2016).

Agriculture is extremely yawning to climate change. High temperature results in reduction of yield of important crop that boost weed and pest propagation, precipitation influence to increase likelihood of short run crop while decreased long run production (Nelson et al., 2009). Kurukulasuriya and Rosenthal (2008) professed that tropical region of many poorer countries of the world are vulnerable to climate change and are predictable to be predominantly destructive.

Cereal crops like wheat, rice, maize, barely etc. are mostly grown and consumed throughout the world is highly affected by the unending climate change scenario. Kumar and Singh (2014) scrutinized that with an increased in temperature by 2.3°C to 4.5°C will lead to dropped cereal crops grown in south Asia and Sub Saharan Africa by 4-10% and 12% respectively 2070-99. They additionally projected that an increased in temperature in South East Asia, Latin America, Europe and North America will encourage cereal production positively (Supplementary Table 1).

Pakistan is among the top countries of the world highly susceptible to climate variation and vulnerability. It is observed that in last decade there is 0.57°C rise in temperature and extreme episode of precipitation in Pakistan. Such life-threatening climate events has adversely affect all sectors of economy such as agriculture, energy and water Technical Need Assessment (GoP, 2016).

In Pakistan there is practicing two types of pattern of cropping named, Rabi and Kharif. Crops which are grown in the month of November to April are known Rabi while crops grown from May to October are Kharif crops. These two-cropping pattern boost agricultural economy of Pakistan. The performance of these two crops seasons depend on climate condition throughout the years because climate change can adversely affect agricultural growth through variations in temperature and precipitation (Siddique et al., 2016).

Maize (Zea Mays) is one the emerging crop which is mostly suffered by climatic condition. Maize is known as queen of cereal. Maize is the fourth important crop after wheat, cotton and rice in Pakistan. It is a Kharif crop and its season start from June and continue till November in Khyber Pakhtunkhwa.

The major objectives of the study are to measure the impact of climate change on maize productivity in Khyber Pakhtunkhwa and to suggest policy and prescription on the basis of findings of this study.

Materials and Methods

This research was directed in different districts of Khyber Pakhtunkhwa zones. The Environment Protection Agency divided Khyber Pakhtunkhwa into four zones on the basis of weather condition like temperature,precipitation,rainfall,topography,altitude etc. Environment Protection Agency (EPA, 2016).

Data

For analyzing the impact of climate change on maize production in different zones of Khyber Pakhtunkhwa secondary data was castoff. Data on maize yield and area was acquired from Development Statistics of Khyber Pakhtunkhwa whereas data on temperature and precipitation was obtained from Regional Meteorological Center (RMC) Peshawar of Pakistan Meteorological Department.

Measurement and definition of variables used in model

Dependent variable: Maize Yield was counted as dependent variable and measured as thousand kilograms per hectare.

Independent variable: Independent variable were categorized into two parts, non-climatic variables and climatic variables.

Climatic variable: Climatic variable exemplified maximum temperature, minimum temperature and precipitation record from June to November for each year. Temperature is articulated in degree Celsius (°C) whereas precipitation is said in millimeter (mm).

Non climatic variables: Area under maize crop was included as independent non climatic variable. Area was expressed in thousand hectares for selected districts.

Conceptual framework of the model

Fixed effect model: Fixed effect model was presented by Deschenes and Greenstone (2007) that avoid the misspecification problems associated to hedonic approach. This is deliberated most appropriate and ideal model due to quick reaction to sudden change in weather condition as well as it control the effect of unobserved variable (Mendelsohn and Dinar, 2009). This Fixed effect model exploits the apparently year-to-year deviation in temperature and precipitation to measure whether agricultural returns are more or less with change in climate (Barnwal and Kotani, 2010). General form of fixed effect can be simplifying as:

$$Yit = \alpha i + \beta xit + \varepsilon it \quad t = 1 \ldots \text{T and } i = 1 \ldots \text{N} \quad \ldots..(1)$$

αi is correlated with x which is unobserved time invariant individual effect for every cross section whereas εit is error term. Parameter (β) represent slope that is same for all cross sections and it does not change because every cross section has its own agriculture achieves. For estimation of fixed effect model least square dummy variable (LSDV) is used.

Table 1: *Agro ecological zones of Khyber Pakhtunkhwa with districts.*

Zone	Description	Districts
1	Northern mountain, higher northern mountains	Chitral, Swat, Bunir, Shangla , Upper Dir, Lower Dir
2	Sub humid eastern mountains and wet mountains	Batagram, Haripur, Mansehra, Torghar, Kohistan, Abbottabad
3	Central plain valley	Peshawar, Mardan, Charsada, Nowshehra, Hangu, Swabi, Kohat
4	Piedmont plain, Suleiman piedmont	Bannu, Karak, Lukhymarwat, Tank, DI Khan

Source: *Environmental Protection Agency of Khyber Pakhtunkhwa, 2016.*

Random effect model

Random effect model work on the assumption that there is no association among unobserved time invariant variables and independent variable that's why fixed effect model is ideal and better estimator in panel approach. If the mention assumption is violated than fixed effect will give unbiased calculation while random effect will not (Siddique et al., 2016).

In random effect αi is uncorrelated with x while Individual effects are randomly scattered crosswise.

$$Yit = \beta xit + \alpha i + \mu it \quad \ldots.(2)$$

Generalized least square (GLS) is used to estimate random effect.

Durbin Wu Hausman test

There are two axioms made around individual specific effect given in Table 2, which are fixed effect axiom and random effect axiom. Random effect model assume that individual specific effects is not associated with the independent variable. If this assumption holds than random effect model is the most appropriate model to use, but if not hold than the model is considered inconsistent. Fixed effect model assumes that there is association of individual specific effects with independent variables. For the proper selection of the best model a Durbin Wu Hausman test used to differentiate between random effect and fixed effect model (Gardinar et al., 2009).

Table 2: *Properties of fixed effect and random effect model estimators.*

	H_0 is true	H_1 is true
β_1 (RE estimator)	Efficient	Inconsistent
β_0 (FE estimator)	Inefficient	Consistent

Source: *Authors contribution in setting table, 2017.*

Model Specification

The model for panel data estimation is given as:

$$Ln\ Y_{it} = \beta_0 + \beta_1 lnAr + \beta_2 lnMaxTemp + \beta_3 lnMinTemp + \beta_4 lnPreci + D_{2\text{-}5}\ Temp + D_{6\text{-}9} Preci + U_{it} \quad \ldots.(3)$$

Where;

Y= Maize Yield in kg per hectare; Ar = Area under maize production; Max Temp= Maximum Temperature; Min Temp= Minimum Temperature; Preci= Precipitation; $D_{2\text{-}5}$Temp=District dummies for temperature; $D_{6\text{-}9}$ preci= District dummies for precipitation; β_0 and β_i= Coefficients to be estimated; U= Error term; i= Cross section; t= Time period.

Results and Discussion

This section comprises descriptive statistics of the selected districts of Khyber Pakhtunkhwa. This chapter further discussed about the impact of maximum temperature, minimum temperature and precipitation on maize yield in the selected regions. Furthermore, analysis and results of research as well as the explanations along with findings of the research are discoursed.

Descriptive statistics

Table 3 present the descriptive statistics of the variables being taken for estimation. The important factors reflected for the study is climatic and

Figure 1: *District wise distribution of Khyber Pakhtunkhwa on map;* **Source:** *Pakistan travel forum.* http://www.pakistantravelforum.com/threads/khyber-pakhtunkhwa-kpk.64/

non-climatic variables. The statistics table given below illustrate the number of observation, the variables that are maize yield, area, maximum temperature, minimum temperature and precipitation with their mean value, standard deviation, minimum and maximum values for the districts selected for research. The data include five cross section where data is taken for twenty years from 1996-2015. These values are attained by using Stata software.

Table 3: *Descriptive statistics of variables used for panel data (1996-2015).*

Variables	Obs	Mean	Std. Dev.	Min	Max
Yield	120	1978.10	441.07	1172.94	3158.73
Area	120	28.12	26.30	0.9	98.3
TempMax	120	23.15	3.31	16.95	30.4
TempMin	120	5.62	2.01	1.73	9.45
Precipitation	120	71.47	31.80	20	132.15

Source: *Estimated from data, 1996-2015.*

In the research area the mean yield calculated is 1978.10 kg per hectare with a standard deviation of 441.07 while the minimum and maximum value seemed is 1172.94 and 3158.73 correspondingly. Calculated mean maximum temperature noted is 28.12°C with a maximum value of 30.4°C and minimum is 16.95°C whereas standard deviation premeditated is 3.31. The mean minimum temperature is 5.62°C with a minimum and maximum of 1.73°C and 9.45°Crespectively while the standard deviation is 2.01. Precipitation resulted a mean of 71.46mm with a standard deviation of 31.80. The minimum and maximum precipitation in the research area note down 20mm and 132.15mm respectively.

Trend of annual maize yield

Figure 2 shows maize yield creeping movement which signpost a slightly increment from 1996 to 2005. Yield has been decline in 2005 and 2006 but it re-claim sidestep after 2008 and goes up furthermore. The annual mean yield was calculated as 1726.4 kg per hectare. Throughout these year except 2 to 3 years there is slightly ups and downs in the maize production and yield. 2012 and onward there is much positive and maximum improvement yield of maize. The maximum maize yield was calculated in 2002 kg per hectare in 2015, whereas lowest yield calculated was 1504 kg per hectare in 1997 (Supplementary Table 2).

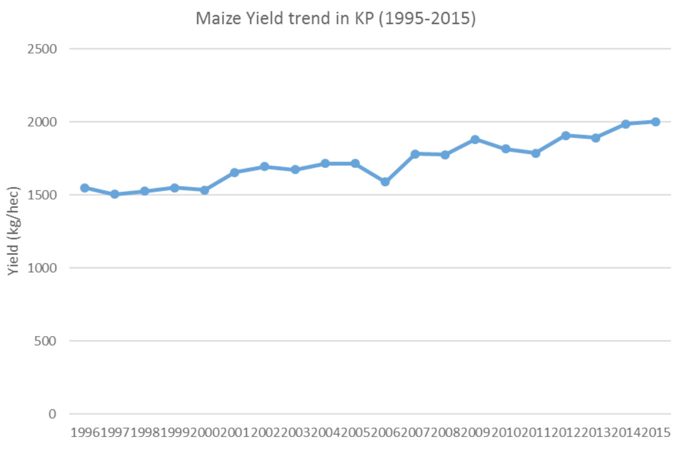

Figure 2: *Average maize yield trend of Khyber Pakhtunkhwa for twenty years (1996-2015);* **Source:** *Authors' estimates from panel data, Khyber Pakhtunkhwa.*

Trend of annual maximum temperature of Khyber Pakhtunkhwa (1996-2015)

Figure 3 indicate the temperature layout where highest temperature of 32.68°C is recorded in DI Khan in 2002. The mean maximum temperature recorded in Peshawar, Swat, D.I. Khan, Mansehra and Chitral was 29.72°C, 24.68°C, 31.67°C, 25.30°C, and 23.98°C respectively throughout twenty years. D.I. Khan is declared higher temperature district according to research calculation, whereas Chitral has average maximum temperature trend. According to Meteorological department of KPs there is a slightly average change in maximum temperature for all district. There is unexpected drop in maximum temperature in Swat in 2009. The Maximum temperature trend is shown zigzag wise in below figure.

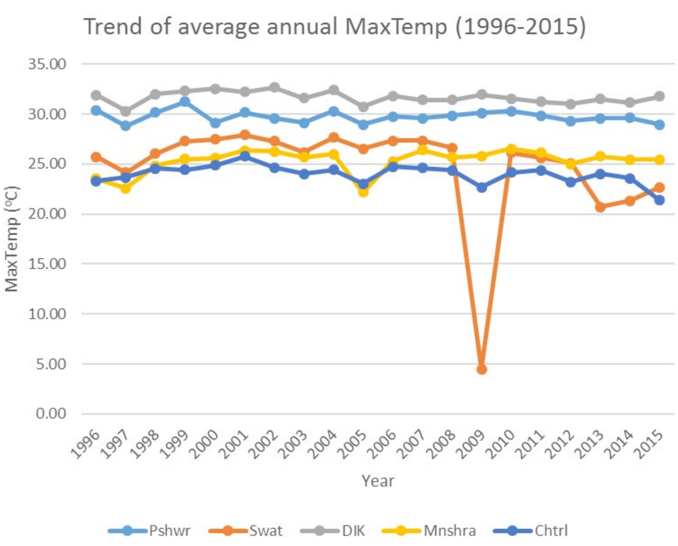

Figure 3: *Trend of annual maximum temperature in Khyber Pakhtunkhwa (1995-2015);* **Source:** *Authors' estimates from panel data, Khyber Pakhtunkhwa.*

Trend of annual minimum temperature of Khyber Pakhtunkhwa (1996-2015)

Figure 4 illustrates the impulsive trend of annual average minimum temperature in the selected districts of Khyber Pakhtunkhwa for the certain time period of 1996 to 2015. There is a sluggish zigzag movement in minimum temperature from 1996-2008 in all districts. Furthermore, there is a surprising decreased in minimum temperature in 2009 where minimum temperature reach to lowest level of 7°C at district Swat, while the average means minimum temperature calculated was 10.73°C. Moreover, the lowest minimum temperature for Peshawar, Swat, DI Khan, Mansehra and Chitral was recorded 15.53°C, -7.42°C, 15.56°C, 10.39°C and 7.60°C individually for twenty years' time period of 1996-2015. According to Pakistan Meteorological department Khyber Pakhtunkhwa the minimum temperature remains between 6°C and 9°C for Chitral since 1996 to 2015.

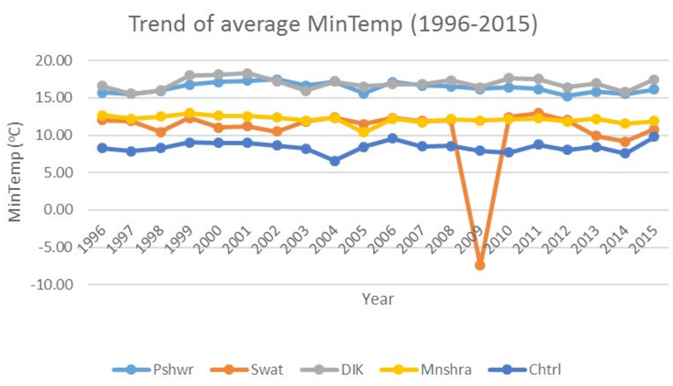

Figure 4: *Trend annual Minimum Temperature of Khyber Pakhtunkhwa (1995-2015);* **Source:** *Authors' estimates from panel data, Khyber Pakhtunkhwa.*

Trend of annual precipitation of Khyber Pakhtunkhwa (1996-2015)

The statistics for precipitation and there up down and zigzag movement is presented in Figure 5. There is a change scenario of trend for precipitation in the selected districts of Khyber Pakhtunkhwa for the time period of 1996-2015, that show a slightly different picture than temperature. According to meteorological department of Khyber Pakhtunkhwa the average highest precipitation rate was recorded in 2006 in Mansehra which was 190.35mm, whereas the lowest value of precipitation was calculated at D.I. Khan in 2002 which was 12mm. The mean precipitation for the year 1996 to 2005 was detailed as 40.37mm, 83.97mm, 27.31mm, 116.74mm and 35.53mm for Peshawar, Swat, D.I. Khan, Mansehra and Chitral separately. The precipitation figures for the research time period remain different from year to year and district to district.

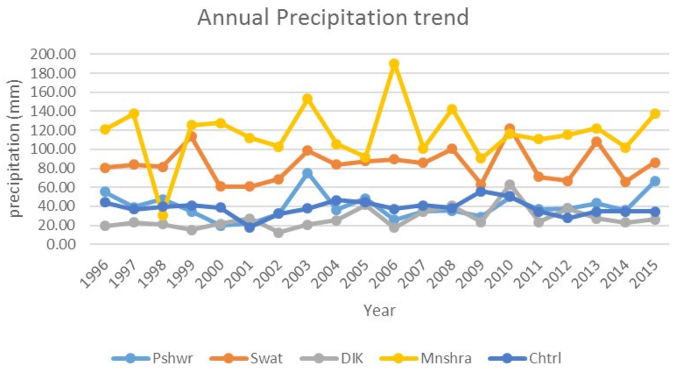

Figure 5: *Trend of annual precipitation of Khyber Pakhtunkhwa (1995-2015);* **Source:** *Authors' estimates from panel data, Khyber Pakhtunkhwa.*

Fixed effect, least square dummy variable model for panel data (1996-2015)

Results of fixed effect model from panel data are illustrated in Table 4. Area under maize revealed insignificant effect on maize yield; implies area did not affect maize yield in the research area. The fallout further declared maximum temperature statistically significant at degree 1% but with negative coefficient that means that maximum temperature has negative impact on the yield of maize. 1% increase in temperature will decrease maize yield by 5%. The outcomes further affirmed the minimum temperature contribution toward yield of maize is insignificant.

Furthermore, remarkably precipitation show a positive and significant contribution to maize yield. 1% increase in precipitation level will increase maize yield by 1.2%. Precipitation is significant at level 5%. The overall result indicated that climate has a significant impact on maize yield in the study area for the given time period 1996-2015. Estimated R-Square value was 0.591 which means that 59.1% variation the maize productivity is due to explanatory variables.

Fixed effect results further indicates the impact of maximum temperature on maize productivity in Khyber Pakhtunkhwa by introducing differential district dummy variables into fixed effect model. Peshawar was engaged as base for all other districts. Results demonstrate that D.I. Khan was significantly affected by maximum temperature and has a negative impact on maize productivity as compared to Peshawar. It was found that if there is 1% increase in temperature then the average maize productivity will be declined by 8.8% as equated to Peshawar. Additionally, maximum temperature has significant and positive impact on maize yield in district Chitral where 1% in temperature will boost maize productivity by 24.9% if compared to Peshawar. The outcome illustrated that increase in temperature has insignificant impact on maize productivity in Swat and Mansehra as likened to Peshawar due to very close environmental variation in the mention districts.

Table 4: *Fixed effect, least square dummy variable model for panel data (1996-2015).*

Ln Yield	Coefficient	S.E	T value	P-value
Ln Area	-0.05081	0.07828	-0.65	0.518
Ln Max Temperature	-0.50168	0.14124	-3.55	0.001***
Ln Min Temperature	-0.03358	0.07759	0.43	0.666
Ln Precipitation	0.11953	0.05143	2.32	0.023**
D2 MaxTemp Swat	0.05620	0.36421	0.15	0.878
D3 MaxTemp DI Khan	-0.08895	0.29871	-2.98	0.004***
D4 MaxTemp Mansehra	0.00197	0.17619	0.01	0.991
D5 MaxTemp Chitral	2.49208	0.41509	6.00	0.000***
D6 Preci Swat	0.41508	0.12263	3.38	0.001***
D7 Preci DI Khan	0.26626	0.17886	0.15	0.882
D8 Preci Mansehra	0.02392	0.11211	0.40	0.832
D9 Preci Chitral	-0.07395	0.26013	-0.28	0.77
Constant	7.3365	0.69916	10.49	0.000***
Sigma U	3.8122			
Sigma e	0.0841			
R-Square	0.5912			

Source: *researcher own estimations by using panel data (1996-2015);* **Note:** *level of significance, ***p<0.01(1%), **p<0.05(5%).*

Results also demonstrated impact of precipitation on maize productivity by introducing district fixed effect dummy variable for precipitation. The upshots estimated that precipitation has positive and significant impact on maize productivity in Swat whereas it has insignificant impact in D.I. Khan, Mansehra and Chitral due to inadequate volume of rain as precipitation has positive impact on maize productivity. 1% increment in precipitation will boost average maize productivity by 4% in swat as compared to Peshawar.

Results show some significant and insignificant variation of climatic and non-climatic variables with the maize yield. It was affirmed that area did not play a key role in maize productivity and observed as insignificant which is in contrast to Bilham et al.,

2011. The outcomes further affirmed the minimum temperature contribution toward yield of maize is insignificant while maximum temperature was significant and contribute negatively to maize yield. Furthermore, the results indicated that when maximum temperature increases the output of maize decreases in D. I. Khan while it boosts yield in Chitral positively. The reason may be that Chitral is situated in temperate zone where temperature always lower as compared to other mention study areas so increase in temperature has positive impact whereas DI Khan is in tropical zone where already temperature behave intensively so the reason may be increase in maximum temperature will have negative impact on yield of maize. These results are in line with Gupta et al. (2014) and are dissimilar to Chandaran and Kashype (2016), Dait (2015) and Hanif et al. (2010). Precipitation has positive involvement to maize yield. The impact of precipitation shows more reliable and positive impact on maize yield in Swat while taking interactive dummies district-wise. The reason may be Swat is in temperate zone and the frequency of rainfall is more than in other districts of Khyber Pakhtunkhwa. The findings of precipitation are strongly substantiated by Loum and Fogarassy (2015), Chen (2014), Ahmed and Schmitz (2011) and Bilham (2011).

Conclusions and Recommendations

Fixed effect model resulted the impact of climate change on maize productivity in Khyber Pakhtunkhwa, Pakistan by taking panel data record of twenty years 1996 to 2015. The variables used for fixed effect model estimation was climatic and non-climatic variables like area under maize production, maximum temperature, minimum temperature and precipitation. For best fitted district fixed effect on maize productivity, interactive dummies were incorporated into model. The outcomes show negative but significant impact of maximum temperature on maize productivity. Maximum temperature was significant at level 1%. Area results come insignificant and same as the case for minimum temperature. Surprisingly precipitation contributed some positive and significant role toward maize productivity. Precipitation was significant at level 5%. Climate change show a significant and adverse impact on maize productivity in Khyber Pakhtunkhwa.

As results declared that increase in maximum temperature has negative impact on maize productivity, therefore there will be adverse impact on food security of the county as well. Hence policy exertions should be concentrated toward impact of climate change on maize productivity. Furthermore, high temperature has negative impact on maize productivity thus development of temperature resistant maize varieties for Khyber Pakhtunkhwa is also a good option. The main problem with the farmers is awareness among farming communities, raising awareness is required on climate change by bountiful information regarding climate change by the extension workers and by policy makers. It is needed to make policy regarding adaptation and mitigation policy by government to increase agriculture production and reduced climatic impacts on agriculture.

Author's Contribution

Asim Khan conducted this study, searched for literature and wrote first draft of the manuscript. Shahid Ali supervised and helped in model specification and statistical analysis. Syed Attaullah Shah helped in technical writing and editing of the manuscript. Aftab Khan reviewed literature and gathered data. Raza Ullah incorporated and corrected references and constructed tables and figures. All authors read and approved the final manuscript.

Supplementary Material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.sja/2019/35.2.594.601

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