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Climate change trend analysis on selected food crops at central Khyber Pakhtunkhwa of Pakistan

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Abstract

Food crop productions at the diverse parts of the world are at more serious hazard because of the adjustments in the atmosphere. This research means to study the direction of environmental change impact on sustenance crops in central Pakhtunkhwa-Pakistan by taking climatological and production variables information from Pakistan Metrological division and Federal Bauru of Statistic Pakistan for last 20 years i.e. 1994–2014 and was tested by Mann-Kendall (MK) test and Sen-Slope insights. Mean yearly temperature, normal dampness and aggregate yearly precipitation was utilized for the factual pattern examination as independent factors, while maize, rice and wheat production were chosen dependent factors. Maize production was altogether diminished, with estimation of tau (τ) 0.003 and a Sen-Slope -0.285. Wheat production was diminished (non-noteworthy), τ +0.003 and a Sen-Slope -0.282 ton for every while rice production stays steady, τ -0.913 and Sen-Slope +0 ton for each year. In The mean yearly temperature for maize, rice and wheat generation were marginally diminished however not critical with the estimation of τ +0.63 ($p>0.05$), Sen-Slope -0.022°C every year. The normal stickiness and aggregate yearly precipitation demonstrated expanding pattern in level of dampness for the entire time frame, with τ estimation of +0.31, +0.823 ($p>0.05$)mm and Sen-Slope estimation of +0.25 percent. The environmental change factors having impact of the production of maize and wheat while the rice production was not influenced significantly and this may be overcome by taking different preventive and adaptive measure to overcome the food shortage in the future for sustainable development.

Keywords: Climate Change; Mann-Kendall (MK) Test; Trends Analysis; Food Crops Production

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1. Introduction

Most of the studies on impact of changes in climate tend to concentrate on dynamic changes in climate, while impacts of climatic variation and extremes climate have been studies in less detail on production (Herrero and Thornton, 2013; Thornton et al., 2014; Wood et al., 2014). If the impact of climate risks are not evaluated, we may truly underestimate the full effects of change in climate on system of crop-livestock (Thornton et al., 2014). Climate change is rising as a noteworthy danger on food security, livelihood and agriculture of millions people in many parts of the world. Projected changes in climate and increasing climatic risks over the 21st century pose serious challenges to agricultural development in developing countries (IPCC, 2014). Climate change is one of the biggest challenges the world faces today posing a threat to many populations around the globe. Studies indicate that in many regions of the world agriculture will be affected by climate change, limiting food production and threatening food security (Tai et al., 2014; Wheeler and Braun, 2013). Climate change affects crop productivity primarily due to the effects of temperature, rainfall and CO_2 on crop physiological activities and phenological development (Lobell and Gourdji, 2012). It can also impair crop production by altering pest incidence and plant-pest interaction (Juroszek and Tiedemann, 2013). However, several factors can determine the direction and magnitude of climate change impact on farms, i. e climate change manifests itself in different ways across locations, the impact may likewise vary depending on the specific local climatic changes and, even when areas experience a similar degree of climatic changes, the detrimental consequences, for example, in regions where temperatures are already near to physiological maxima (Gornall et al., 2010). Also different crops do not respond to climate change in the same way owing to variation in their sensitivity to temperature, rainfall and CO_2 changes (Gornall et al., 2010). The impacts of climate change may also vary from place to place and farm to farm due to differences in the capacity of agricultural systems and farms to adapt to climate change (Smit and Wandel, 2006). The possible impact that climatic changes has on economic and production rely upon the amount which is likely to adjust to decrease the impact of climate change (Lobell, 2014).

A few studies shows that production of agriculture could be essentially affected because of rise in temperature (Lobell and Gourdji, 2012), changes in rain patterns (Prasanna, 2014) and level of intensity and frequency of climatic extreme events like droughts and flood (Brida and Owiyo, 2013). The average yearly temperature will increase by 2°C in the most part of South Asia by the mid of 21st century, while this increase will go beyond 3°C and 6°C in the higher elevation under the emission scenario. Change in temperature and precipitation pattern are influencing the production of crop (Malla, 2009). Essentially, the loss of local crops and domestic animals, change in crop patterns, shortage of water due to because of the scarce water resources, and expanding occurrences of pests and diseases have likewise observed (Regmi and Adhikari, 2007; Panthi et al., 2016). A few studies have demonstrated that the rate of increase in temperature at higher elevation is higher (Immerzeel, 2008; Baidya et al., 2008). This may influence the quantity and timing of precipitation, which change the water accessibility (Mishra et al., 2014). The accessed effects of historical and future change in climate on cereal crops in various areas demonstrated that the loss of yield can be 35, 20, 50 13, 60 percent for rice, wheat, sorghum, barley and maize respectively relying upon the area, and future climate situations (Porter et al., 2014).

Pakistan is one of the country most affected by climate change due to its low adaptive capacity and poor infrastructure (Stocker et al., 2014). Projections suggest a 2-3°C increase in temperature and a significant variation in the distribution of rainfall in Pakistan by 2050 (Gorst et al., 2015). The Global Climate Risk Index (GCRI) ranked Pakistan number 8 in a list of countries most affected by climate change and extreme weather events over the period 1995−2014 (Kreft et al., 2016). Due to extreme events and climate variability, rural livelihoods and major crop production such as wheat, cotton, sugarcane and rice have been greatly affected over the last two decades (Abid et al., 2015).

The resilience of the agricultural sector to climate change is one of the most important concerns for economic development in Pakistan as more than two-thirds of the country's population lives in rural areas and relies on the agricultural sector for their subsistence and livelihood (WB, 2014). Further, through adverse impacts on cereal productivity and food prices, climate change have serious implications for local food security in Pakistan, which mainly depends on cereal crops. Wheat was grown on 8.66 million hectares in 2013, supplies 37% of the total daily calories in Pakistan (Prikhodko and Zrilyi, 2013). However, the current national average wheat yield (2797 kg/ha in 2013) is much lower than the global mean (3268 kg/ha in 2013) (FAO, 2015). According to a recent study, farmers in Pakistan only realize 32% of the potential crop yield (Israr et al., 2016; Prikhodko and Zrilyi, 2013). The huge gap between actual and potential crop yields is one of the major factors contributing to the insufficient supply of cereals in the country. For instance, Zulfiqar and Hussain (2014) reported an increasing gap between per-capita wheat demand and supply in Pakistan for the period of 2013−2050. Unsteady agricultural growth coupled with a steadily increasing population may lead to serious consequences for local food security and livelihoods (Sheikh et al., 2012). Climate change may aggravate the situation if not managed adequately and in a timely manner. Developing countries are most endangered to climatic changes; therefore this research was designed with the following objectives

1.1. Objectives of the research

The general objectives of this research is to investigate the climate change impact on food crops production by using time series data for the last 20 years, with the following specific objectives.

1- To study the trends of production of different food crops in response to climatological different variables.
2- To study the movement of trend of the climatological variables in central Pakhtunkhwa of Pakistan.

2. Materials and methods

2.1. Study area

Central Khyber Pakhtunkhwa (Mardan) was the sample area for this research as show in the Figure 1. The district in east is bounded by the district of Buner and Swabi, to the north by district Buner and Malakand, to the west by district Charsadda and Malakand and to the south by district Nowshehra. The district comprises of three Tehsils i.e. Mardan, Takhtbhai and Katlang, and these consist of 74 UCs.

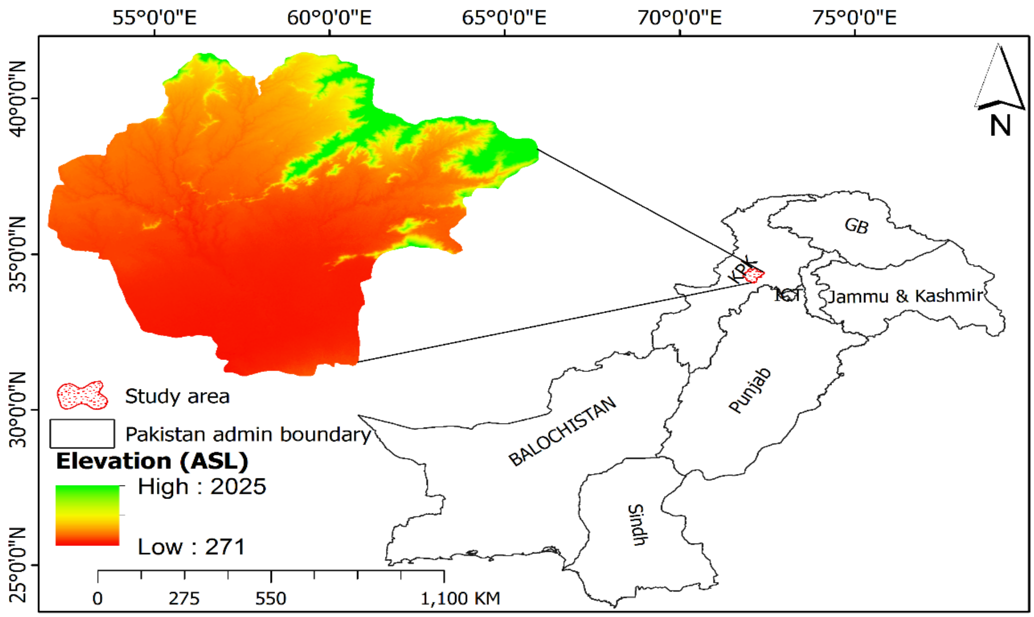

Figure 2. Location of the study area

The population of Mardan district has increased with a sky rocketing speed with average annual growth rate of 3.0 and among the population 79.8 percent living in rural areas (GOP 2015–16). It is one of the best agriculture areas due to its suitability for cultivation of food and cash crops in central Pakhtunkhwa for the growing of major and minor crops. Livestock rearing is also done in the district and it includes cows, buffaloes, goats and sheep. Fruits and vegetables are also grown and it includes orange, apple, peach, plum, apricot, rare mango and pear.

The climatological dataset i.e. temperature (°C), rainfall (mm) and humidity for the study area from 1995 to 2015 were collected from Pakistan Meteorological Department and the different crop production data was obtained from the statistics Book of Food Crop production and land from the Statistical Beaur, Government of Pakistan. For the statistical trend analysis Mann-Kendall's, Linear trend line and Sen's Slope were used with the significance level of 5 percent. These test commonly used to show the significant in the time series data. The mean annual temperature, average humidity and total annual rainfall were used for the statistical trend analysis, while maize, rice and wheat production were selected for the study area.

2.2. Mann-Kendall's trend test

The aims behind the Mann-Kendall (MK) test (Mann 1945, Kendall 1975) is to factually evaluate if there is a monotonic upward or descending pattern of the variable of interest after some time. A monotonic upward (descending) slant implies that the variable reliably expands (diminishes) through time, yet the pattern could conceivably be straight. The MK test can be utilized as a part of place of a parametric linear regression analysis, which can be utilized to test if the slop of the estimated linear regression line is not the same as zero. The regression examination requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a non-parametric (dispersion free) test. Hirsch, Slack and Smith (1982) demonstrate that the MK test is best seen as an exploratory investigation and is most suitably used to recognize stations where changes are significant and to evaluate these findings. The assumptions underlie the MK test are, when no trend is present, the measurements (observations or data) obtained over time are independent and identically distributed. The assumption of independence means that the observations are not serially correlated over time. The sample collection, handling, and measurement methods provide unbiased and representative observations of the underlying populations over time.

The Mann-Kendall test is relevant in situations when the data values x_i of a time series data can be expected to comply with the model;

$$x_i = f(t_i) + \boldsymbol{\varepsilon_i} \text{..........................} 1$$

where; f(t) is a continuous monotonic expanding or diminishing capacity of time and $\boldsymbol{\varepsilon}_i$ the residuals which can be assumed to be from a similar distribution with zero mean. It is accordingly assumed that the variance of the distribution is constant in time. The number of yearly values in the examined data arrangement is presented by n. Missing values are permitted and n would thus be able to be littler than the number of years in the considered time series.

The following formula are used to calculate the Mann-Kendall test measurement S

$$S = \sum_{k-1}^{n-1} \sum_{j-k+1}^{n} sgn(x_j - x_k) \text{..........................} 2$$

where; x_j and x_k = annual values of year j and k such that $j > k$ and

$$sgn(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \text{..........................} 3$$

Positive estimation of S shows the upward pattern in the data set; negative S value demonstrates the downward pattern and if the estimation of S is zero, at that point it shows the existence of no trends in the data set.

3. Result and discussion

3.1. Variability of climate and maize production

Maize is among one of the food crop and also act as a raw material for many other food by products and addition of value chain. Production of maize assumes an indispensable part in sustenance security for many poor family units in the developing world and particularly the rural poor. Variability of the climate is the foremost wellspring of variances in worldwide sustenance creation in nations of the developing world. Maize is produced on about 100 million hectares in developing world, with very nearly 70% of the aggregate maize generation in the developing countries, originating from low and lower center income nations (FAO, 2013). The trend analysis of maize production in ton, mean temperature, average humidity and total rainfall are presented in the Figure 3, which highlighted that the production of maize were significantly decreased during1995–2014, with value of tau (τ) 0.003 (p<0.05) and with value of Sen-Slope -0.285. This decline in the production is associated with many aspects of the variability of climate and some of these are temperature, humidity and rain fall. The temperature during the same period was almost the same with a little bit increase or decrease in their mean value from 1996–2006 and then the line are moving straight. Studies (Janjua et al., 2014 and Mahmood et al., 2012) reveal that increasing temperature and the changing pattern of rainfall have a substantial impact on maize production. The average humidity was increasing initially from 1996-1998, then decreasing from 2000–2007 and again increased from 2009 till 2013. This shows that the humidity during the 20 years' time period in the area show in a mix of relation over the period of time.

Trends Analysis	**Variables**
	Maize production
Linear equation	y = -1.57x + 53.84
MK, τ	**+0.003 (p<0.05)**
Sen's slope S	-0.285 (ton/yr)

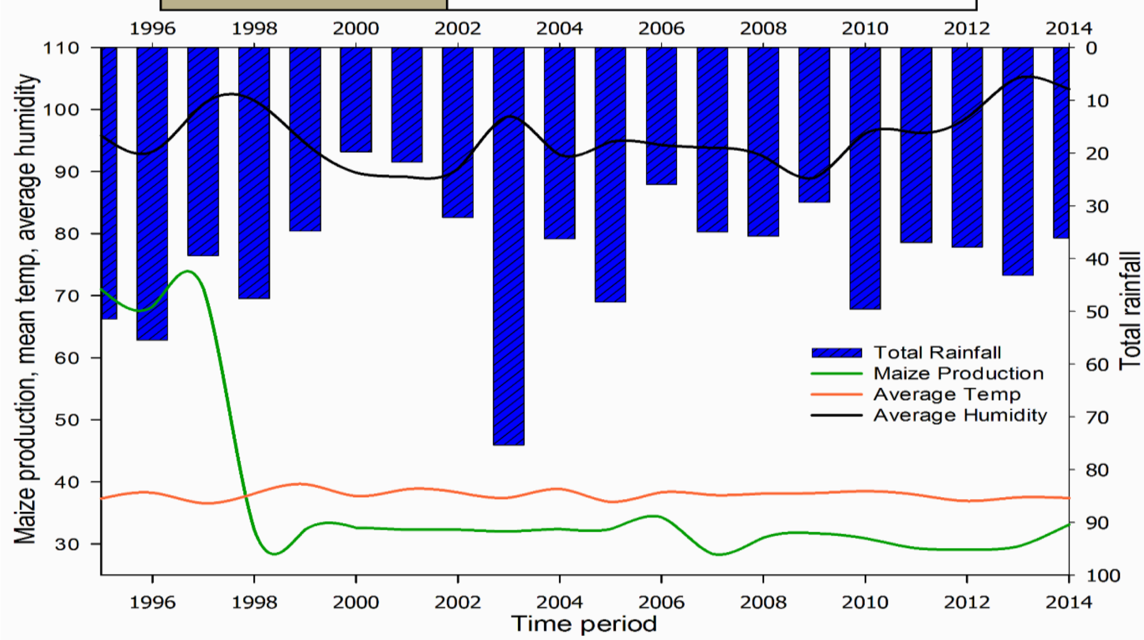

Figure 2. Mann-Kendall's statistical and trends analysis of maize production and climate variables

The rainfall also showing the mixed up relation in the Figure 2 and pointed that a maximum rainfall was noted during the years 1996, 2003, and 2010. Thus the aforementioned variability in the climate change variables leads to show decreasing trends in the production of maize in the area. These finding were contradict with the finding of (Dhakal et al., 2016) which indicated that the production of maize showed the increasing trend during the timer period of 1999–2014 in Nepal, whereas these finding were similar to the find of (Knox et al., 2016) stated that maize suffer negatively in the southern parts of Europe. Thus in this down trends continue due to the climate variability's, this will drastically affect the livelihoods of the rural poor and hence leads to overall food insecurity in the region.

3.2. Climate variability and wheat production

Trends Analysis	Variables
	Wheat production
Linear equation	y = -2.063x + 75.49
MK, τ	**+0.003 (p<0.05)**
Sen's slope S	-0.282 (ton/yr)

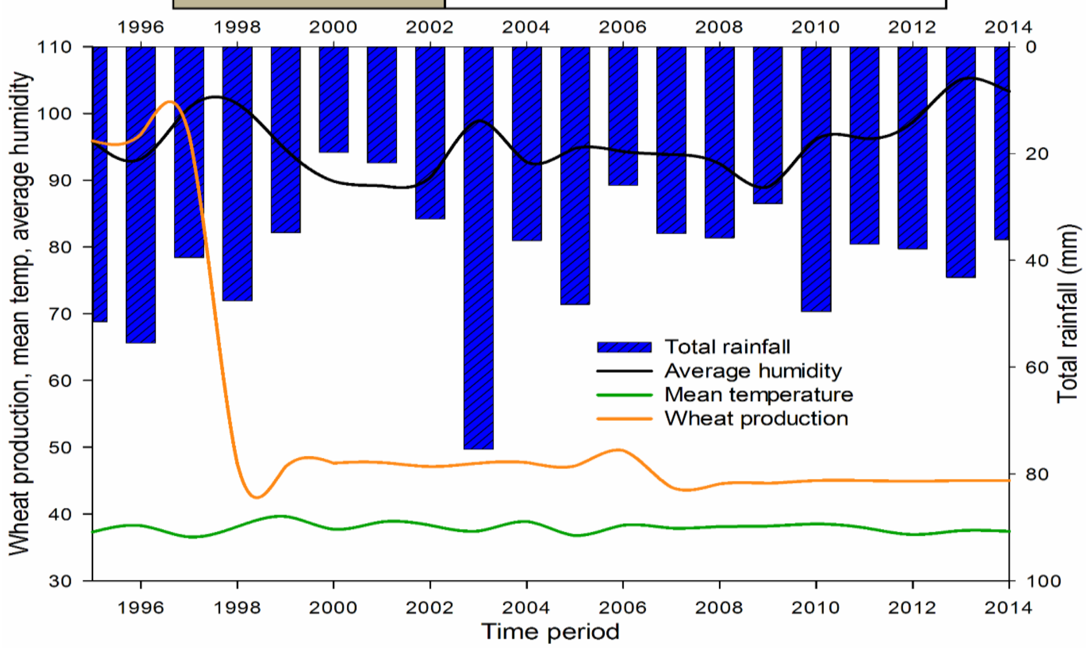

Figure 4. Mann-Kendall's statistical and trends analysis of wheat production and climate variables

Wheat has been considered as one of the essential staple sustenance sources for the population of Pakistan and contribute to the agriculture and country gross domestic product because of its broad use as a nourishment in day by day life and as a less expensive source for animal feeding. The findings of Ali et al., (2017) revealed that in South Asia approximately all models predict that climate change would negatively affect the yield of wheat. The wheat production and its trends analysis with respects to different climate variables figure out in Figure 5, which predicated that wheat production were decreased (non-significant) during the period of 1995– 2014, with the value of τ +0.003 with p less than 0.05% and value of Sen-Slope -0.282 ton per year during the available time period. These result were similar to the results of (Janjua et al., 2014) stated that change in the global climate does not affect the production of wheat in Pakistan. These finding aligned to the finding of (Knox et al., 2016) notes that in the Europe the southern parts wheat production were negatively suffer. Average humidity, total annual rainfall and mean temperature for the period of 1995–2014 are also show the different trends. The zigzag line of the average humidity shows increasing trends between 1994–1997, then a decreasing trend up to the years 2002 and this decrease and increase continue till the 2009, while after this it has increased with a considerable rate till 2013 and then decline started. Total annual rainfall showing also low and high perception during the study period and the highest precipitation was noted during the year 1996, 2003, 2005 and 2010. The increasing the decreasing trends was also noted for the temperature during the period of 1994–2006, while after this almost the trends line is constant toll 2014.

3.3. Variability of climate and rice production

Trends Analysis	Variables
	Rice production
Linear equation	y = -0.007x + 1.45
MK, τ	+0.913 (p>0.05)
Sen's slope S	+0 (ton/yr)

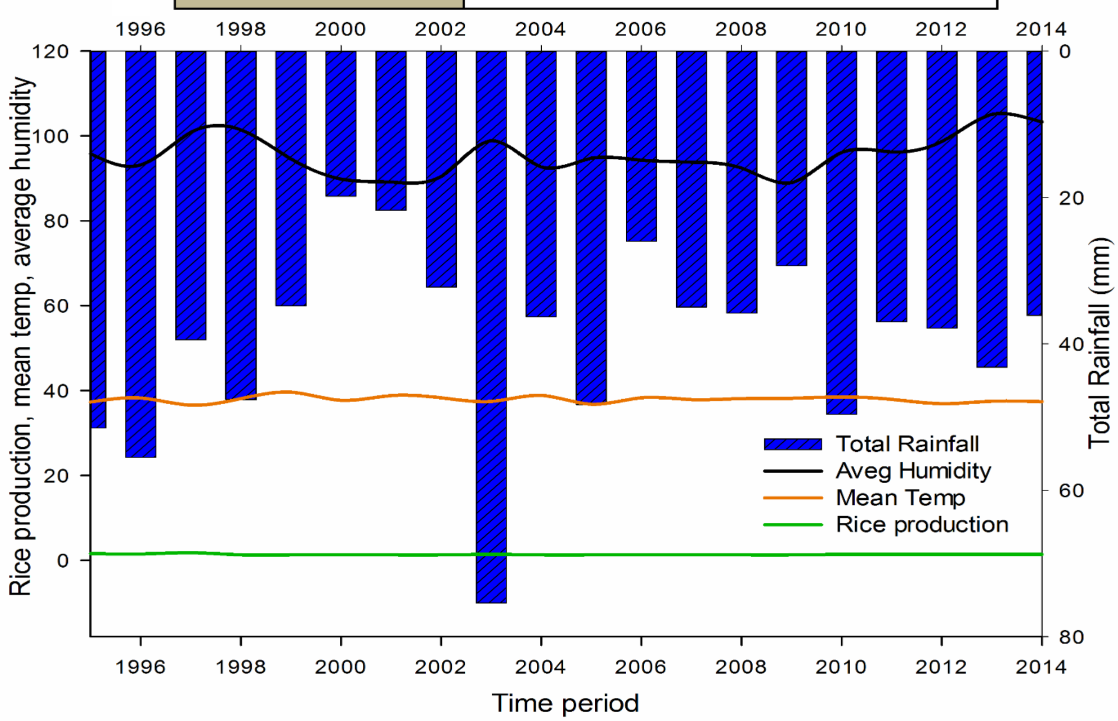

Figure 6. Mann-Kendall's statistical trends analysis of rice production and climate trends

Rice is a staple sustenance for more than 60% of the total populace and is the second just to wheat as far as yearly production rice is the second most imperative nourishment staple of Pakistan and is a noteworthy remote trade acquiring product after cotton. Rice production holds a vital position in the Pakistan's agribusiness area and contributes 3.2% of the total value added in agriculture and 0.7% of GDP (JCR, 2016). The figure 4 illustrated the trends analysis of production of rice, mean annual temperature, average humidity and the total annual rainfall over the period of 1996−2014. The production of rice remain constant during the entire study period time, with the τ value of -0.913 ($p>0.05$) and Sen-Slope value of +0 ton per year as shown in the upper corner of the Figure 7. The result of mean annual temperature, average humidity, and total annual rainfall respectively for the production of rice in the study area were similar as (Shakoor et al 2015) reveal that increased in the production of rice is due to the variation of climate.

3.4. Climate variable

In the climatic variables, the mean annual temperature for maize, rice and wheat production were slightly decreased but not significant with the value of τ +0.63 ($p>0.05$), and with value of Sen-Slope -0.022°C per year. Also the average humidity and total annual rainfall showed the increasing trend in level of humidity for the whole period time, with τ value of +0.31 ($p>0.05$) % per year, +0.823 ($p>0.05$) mm per year and Sen-Slope value of +0.25 percent per year and -0.153mm per year respectively as show the table 1. These finding were aligned with the finding of (Poudel and Shaw, 2016) stated that there impact of climatic variables were no significant impact on the all crops yields.

Table 1. Mann-Kendall's statistical trends analysis of climate variables

Trends Analysis	**Variables**		
	Mean temperature	**Average humidity**	**Total rainfall**
Linear equation	y = -0.017x + 38.1	y = +0.21x + 93.31	y = -0.331x + 43.09
MK, τ	+0.631 (p>0.05)	+0.319 (p>0.05)	+0.823 (p>0.05)
Sen's slope S	-0.022 (°C/yr)	+0.254 (%/yr)	-0.153 (mm/yr)

4. Conclusion

It was concluded from the findings of the study that the food crop production is at greater risk due to the changes in the climate which having implication for food security of livelihood of the people. The mean annual temperature, average humidity and total annual rainfall were used for the statistical trend analysis as independent variables, while maize, rice and wheat production were selected dependent variables. The trend analysis of maize production was significantly decreased with value of tau (τ) 0.003 ($p<0.05$) and with value of Sen-Slope -0.285, while wheat production was decreased non-significantly, with the value of τ +0.003 with p less than 0.05% and value of Sen-Slope -0.282. Rice production remains constant, with the τ value of -0.913

(p>0.05) and Sen-Slope value of +0 ton per year. The climatic variables, the mean annual temperature for maize, rice and wheat production were slightly decreased but not significant with the value of τ +0.63 (p>0.05), and with value of Sen-Slope -0.022^{o}C per year. Also the average humidity and total annual rainfall showed the increasing trend in level of humidity for the whole period time, with τ value of +0.31 (p>0.05) % per year, +0.823 (p>0.05) mm per year and Sen-Slope value of +0.25 percent per year and -0.153mm per year respectively. In conclusion the climate change variables having effect of the producation of maize and wheat while the rice producation was not affected significently. The study recommends that there is urgent needs for the different climate effect reduction and adaptive strategies to overcome the food insecurity in the region.

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