Climate change and food production in North West India

Savita Ahlawat* and Dhian Kaur

Department of Geography, Panjab University, Chandigarh-160 014, India.

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ABSTRACT
At present, climate change is one of the most challenging environmental issues as it poses potential threat to different sectors of economy at global level. Agriculture being an open activity is primarily dependent on climatic factors and change in climatic conditions affects the production, quality and quantity of crop production in an area. This paper attempts to study effects of only two parameters of climate i.e. temperature and rainfall on agricultural production in northwest region of India. Northwest region comprising of Punjab, Haryana, Himachal Pradesh and Jammu Kashmir states is the greatest food bowl of India contributing to its food security. The analysis of mean monthly rainfall and maximum and minimum temperatures (1901-2006) shows no significant change in temperature and rainfall conditions from 1901 to 1960; but afterward the change is more pronounced. On the whole any significant change in climatic conditions will not only challenge the food production of the region but also challenge the country’s food security situation.

Key words: Adaptation, Agriculture, Climate change, Livelihoods, Sustainable development.

INTRODUCTION
Climate change is generally a significant change in long-term weather conditions of an area i.e. increasing carbon dioxide, temperature or uncertainty in rainfall; which can be caused by natural factors or by anthropogenic activities. At present climate change is one of the greatest concerns of everyone as it poses potential threat to environment and agricultural activities throughout the world. As agriculture is a climate-sensitive sector, besides ecological, technological and socioeconomic drivers, crop growth and yields are largely determined by weather conditions of the growing season. Climate change and agriculture are intensely interrelated global processes and therefore a change in climate affects agriculture production (IPCC, 2007). The change in temperature and rainfall conditions affects the growth and development of plants in multiple ways such as rise in temperature increases the pests vulnerability to different crops and change in rainfall pattern reduce water availability and also affects both the irrigated and rainfed farming activities. Thus, despite the innovations and technological advances; weather still plays a vital role in agricultural productivity at the global level. Cline (2007) also stated that due to change in climatic conditions agricultural productivity in general could decline between 10-25% by 2080 and the decline in yield in rainfed agriculture could be as much as 50%.

In India agriculture is still one of the major sectors of Indian economy. It plays an important role in overall economic and social well being of people as it contributes about a quarter of the GDP and provides livelihood to two-thirds of India’s population. Agricultural production in the country has increased after the implementation of green revolution mainly due to heavy use of high-yielding crop varieties, intensive use of inorganic fertilizers and pesticides, expansion of irrigation facilities etc. During post green revolution period most fertile areas of the country (Punjab, Haryana, coastal areas) got transferred into ‘granaries’ and country became self-sufficient in foodgrains production. Its production of foodgrains increased from only 50.82 million tonnes in 1950-51 to 257.44 million tonnes in 2011-12. Fig. 1 shows the trend of foodgrains production in India since 1950-51.

However, after a few decades of introduction of modern technology, growth of agricultural production got slowed down and environmental problems such as soil erosion, decline in ground water level, and decline in soil fertility have arisen mainly due to intensive use of chemicals and fertilizers, use of intensive irrigation system and so on. During 1990s climate change emerged as a greater threat to agriculture and is considered to have put a negative effect on foodgrains production in different parts of the country.

In the past decade, numerous studies have been conducted by agriculturalists, scientists and economists to assess the impact of climate variability and change in agricultural production in India (Sinha and Swaminathan 1991; Aggarwal and Sinha 1993; Hundal and Kaur 1996; Saseendran et al. 2000; Mall et al. 2006; Dash S.K. et al. 2007; Aggarwal 2008, 2009) . The present paper tries to understand how the change in climatic conditions and food...
production of the Northwest region is correlated, whether the climate change have negatively affected the agricultural production or not. The Northwest region is selected for the study as it is producing bulk of India’s foodgrains and hence has been chosen for the present work.

The present paper is divided into IV sections. Section I sets the problem in a perspective and provides a brief review of relevant studies. Section II presents the details of the study area followed by the objectives of study and sources of data and methodology. Section III is devoted to results and discussion and the last Section IV includes the conclusion and suggestions.

STUDY AREA
The present study has been conducted in context of Northwest India comprising of Punjab, Haryana, Himachal Pradesh and Jammu & Kashmir states, covering an area of 372597 sq. kilometers which is 11.33% of the total area of the country. The region extends from 27°39’ N to 37°6’ N latitudes and 73°26’ E to 80°30’ E longitudes. From climatic point of view, there are two major cropping seasons in this region i.e. summer or kharif season and winter or rabi season. Rice and wheat are the two major crops of kharif and rabi season respectively. In this region, production of rice and wheat increased tremendously after the introduction of green revolution in 1966. Rice production increased from just 225 thousand tonnes (1966-67) to 3736 thousand tones (2010-11) and wheat production from 967 thousand tonnes (1966-67) to 3095 thousand tonnes (2010-11). The per hectare yields of rice (2642 kg/ha) and wheat (3251 kg/ha) are also high as compared to the national average (rice- 2372 kg/ha; wheat 2885 kg/ha). The region is also a major contributor of wheat (63%) and rice (35.2%) to central pool for Public Distribution System. Therefore, this region is one of the greatest food bowls of the country contributing to its food security.

OBJECTIVES
The main objectives of conducting this study are:
(a) To show the overall climatic trends in terms of temperature and rainfall in North West India from 1901 to 2006
(b) To study their effects on wheat and rice production in this region.

As already pointed out, in the present study two parameters of climate i.e. temperature and rainfall and rice and wheat which are the two major crops of kharif and rabi season respectively are considered. These two crops are very climate sensitive. Wheat crop is vulnerable to an increase in maximum temperature and the rice crop is sensitive to an increase in minimum temperature and also rice is a water consuming crop. Therefore, change in the temperature and rainfall pattern directly affects the growth and production of these crops in this area.

MATERIALS AND METHODS
The changes in climate parameters are generally analyzed in the form of changes in temperature and rainfall patterns due to which frequency of drought increased and sometimes heavy precipitation events also occurred. In earlier studies several methods such as historical data analysis and crop simulation models were used in order to assess the impact of climate change on the yield and growth of crops. In the present study in order to achieve the set objectives, secondary data have been collected for the mean monthly rainfall and maximum and minimum temperatures for past 106 years starting from 1901 to 2006. The wheat and rice area and production data for Northwest India have been compiled from published reports and papers and average yield is calculated.

Data are plotted on graphs to show the trend of temperature and rainfall over the years. Firstly the trend of annual mean maximum and minimum temperature has been shown with the help of line graphs. Then annual and seasonal rainfall pattern has been analyzed. Relationship between change in rainfall and rice yield has also been shown graphically.

RESULTS AND DISCUSSION
Temperature: Temperature is very important climatic factor for agriculture as it affects the crop growth, soil temperature and also controls the water content available in the soil. Rise in temperature affects the physiological processes necessary for crop growth and results in decline in crop yield. An increase in temperature during grain development phase of crop especially wheat and rice will affect crops grain quality. In Northwest region, the maximum temperature shows a slightly rising trend at annual, kharif and rabi time scales with different rates during 1901-2006. Fig. 2 and Fig. 3 depict the annual maximum and minimum temperature trends from 1901-2006 periods in the region. The annual mean maximum temperature shows a slightly increasing trend after 1960s; this slight increase in maximum temperature after 1960s is mainly due to negative impact of industrialization, heavy use of mechanization in agriculture and other anthropogenic activities in this region. A study conducted at the Indian Institute of Technology, Delhi showed that in India rapid...
temperature change occurred in northern part as compared to southern part of the country. However there has been no significant change in annual minimum temperature over the time-period in this region (Fig.3).

FIG 2: Annual maximum temperature trend in Northwest India

FIG 3: Annual maximum temperature trend in Northwest India

**Rainfall:** Of all weather elements rainfall is the most important for a country like India whose economy is largely based on agriculture. It is generally said that India’s prosperity is a gamble of monsoon rains. It affects the production of crops especially rice. A regular rain pattern is usually essential for agriculture, too much or too little rainfall i.e. floods or draught condition is very harmful even destructive to crops. The annual average rainfall data (1901-2006) on Northwest India plotted on graph, shows a slight increase in rainfall trend (Fig 4). As rainfall does not show any notable change at annual scales but during *Kharif* season rainfall declined at the rate of 2.527mm per year (Fig.5).

FIG 4: Slight increase in annual rainfall trend in Northwest India

FIG 5: Decreasing rainfall trend in *Kharif* season in Northwest India

**Yield response of Rice:** Rice is the major *kharif* crop of Northwest India which is vulnerable to minimum temperature and also highly dependent on rainfall. The relationship between rice production and seasonal rainfall in the region is shown in Fig. 6. As mentioned earlier the production and yield of rice crop have tremendously increased in Northwest India after green revolution. But the impact of seasonal rainfall is largely offset by availability of assured irrigation in large parts of the region. The trends of production of rice crop since 1950s are presented in Fig. 7. Before the green revolution, this crop was grown on a limited area and the varieties used were largely local. There has been rapid growth of production of rice crop after the 1970s. But after 1990s this growth was slowed down and at present production (and also yield) of rice crop are almost stagnant in this region mainly due to change in favorable agricultural conditions.

In order to analyze the effects of decline in rainfall amount on the rice production; a correlation was run between rainfall (independent variable) and rice production (dependent variable) of Northwest India since 1970s. The
result shows that both variables are positively correlated i.e. with decreased rainfall the production of rice has also decreased. This is also supported by Fig. 6 which shows the scatter plot of two variables. In the equation of line of best fit, the slope and y-intercept value indicate characteristics of the relationship between the two variables. The value of slope of best fit line indicates the rate of change in yield of rice per unit change in rainfall. Therefore, the equation of line of best fit indicates that rainfall does not have much effect on yield of rice in this area. The need for rainfall is offset by fairly developed artificial irrigation for producing rice.

Although, in years when rainfall amount was higher (1961, 66, 74, 78, 82, 91) in this area, rice production was also recorded as high and when rainfall was less (1980, 87, 95) rice production was affected adversely to be less. Similar results have also been indicated in a study by Gadgil (1995) in which he analyzed that in India the increasing trend of rice production after green revolution declined due to deficit rainfall in summer season (e.g. in years 1965, 66, 72, 74, 79, 82). On the other hand, when all-India rainfall was in excess of the normal (e.g. in years 1964, 70, 75, 78, 83), the rice yield was also higher.

Therefore, both rainfall and rice production are directly related but value of coefficient of determination denoted by R² indicates that in this region rainfall determines nearly 2 percent of variation in rice yield. This is because rice crop is highly dependent on irrigation facilities rather than rainfall in Northwest India. After green revolution due to intensive use of irrigation facilities problems such as decline in level of ground water occurred in many parts of this region which are also responsible for decline in rice productivity.

**Yield response of Wheat:** Wheat is the major winter (rabi) crop which is vulnerable to increase in maximum temperature. The crop requires an ideal temperature of 20-25 °C for giving good yield. Fig. 2 shows that in this region there has not been any significant increase in annual maximum temperature after 1901. The production and yield of this crop has however increased due to advancements in technology. This is more true of the post green revolution period.

Fig. 8 clearly shows that the production has stagnated during the past decade. This is partly ascribed to the indirect effects of change in conditions such as decline in soil fertility, dominance of monoculture in the area and so on. Scholars such as Aggarwal and Sinha (1993), Attri et al. (2003) and Samra and Singh (2004) have analyzed the effect of change in temperature on wheat productivity in India. Aggarwal and Sinha (1993) indicated that in Northern India, a 1°C rise in mean temperature had no significant effect on potential yield of wheat and an increase of 2°C in temperature will reduce potential yields of wheat at some places. Samra and Singh (2004) also remarked that due to increase in temperature between 3-6°C in the Indo-Gangetic plains, which is equivalent to almost 1°C per day over the whole crop season, wheat crop matured earlier by 10-20 days and wheat production dropped by more than 4 million tonnes in the country.

The foregoing discussion reveals that there is no crucial change in climatic conditions till 1960s; after 1960 onwards there is slight increase in mean maximum temperature and rainfall amount declines in kharif season. Through the review of earlier studies it is clearly accepted that the crop production is highly dependent on climatic factors. But the result of present study shows that in the Northwest India rather than climatic factors, other techno-socio-economic factors, along with prevailing agricultural practices are more responsible for decline in crop yields. These factors have mainly arisen due to the negative impact of excessive use of green revolution technology in this region.

**CONCLUSION AND SUGGESTIONS**

The study clearly indicates that the yield of wheat and rice show signs of stagnation and decrease respectively in the selected area due to change in required climatic conditions. These environmental changes are likely to increase the pressure on agricultural sector, in addition to the on-going stresses of yield stagnation, land-use,
competition for land, water and other resources and globalization. Studies have shown that by 2020, food grain requirements in the country as a whole would be almost 30-50% more than the current demand (Paroda and Kumar, 2000). In view of that, the Northwest region will have to face severe challenges.

Change in climatic conditions will endanger the physical as well as economic access to food. As the region is food bowl of the country and any decline in food production will challenge the food security of the whole country, because this area contributes a large share of production in central pool. Livelihood security of farmers will also be affected by adverse changes in temperature and precipitation as food costs and the capacity to procure food are directly affected by changes in commodity supply and resultant price change.

So following adaptive measures are needed to be taken in order to have sustainable food security in the country in general and Northwest region in particular.

- Those crop varieties should be developed which are more resilient to these climatic changes.
- Farmers should be encouraged to practice mixed cropping pattern instead of monoculture and should also shift the crop planting time according to change in weather conditions.
- Along with agriculture, farmers should also diversify their source of income; so that in adverse conditions they can earn their livelihood from other sources.
- The government should also emphasize on climate change adaptation issues in development strategies and programmes.

The future food demand of increasing population can be met after adopting such strategies.

REFERENCES