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INFLUENCE OF CLIMATE CHANGE ON CROP YIELD: A CASE STUDY

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ABSTRACT

Climate is a primary determinant of agricultural productivity. Agriculture has been a major concern in the discussions on climate change. Rainfall and temperature variation are considered to be the most important and significant weather parameters in agricultural production. The present study has been taken up to find out the changes or variability in annual and monsoon seasonal rainfall , temperature and relative humidity and yield of crop over Eastern part of the state of Uttar Pradesh at Varanasi district. The results of rainfall analysis revealed that district is getting maximum amount of rainfall during southwest monsoon and its variability particularly during monsoon season is of great significance to yield of crop. To have an idea of the effect of climate change on major crop rice and wheat analysis has been done and discussed.

INDEX TERMS— Crop yield, climate parameter, rainfall, temperature

INTRODUCTION

Agriculture is the basic activity by which humans live and survive on the earth. Assessing the impacts of climate change on agriculture is a vital task. In both developed and developing countries, the influence of climate on crops and livestock persists despite irrigation, improved plant and the growing use of chemical fertilizers. The continued dependence of agricultural production on light, heat, water and other climatic factors and the significant magnitude and rapid rates of possible climate changes creates the need for a comprehensive consideration of the potential impacts of climate on global agriculture.

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It can be a change in the average weather or a change in the distribution of weather events around an average. Climates will change if the factors that influence them fluctuate. To change climate on a global scale, either the amount of heat that is let into the system changes, or the amount of heat that is let out of the system changes. For instance, warming climates are either due to increased heat let into the earth or a decrease in the amount of heat that is let out of the atmosphere.

The yield of agricultural crops is limited more by the amount of water received by and stored in the soil than by air temperature. It also depends on how much of the rainfall is retained in the soil, how much is lost through evaporation from the soil surface, and how much remains in the soil that the crop cannot extract. The amount of water transpired by the crop is also determined by air humidity, with generally less dry matter produced in a drier atmosphere. Thus, changes in both rainfall and air humidity would be likely to have significant effects on crop yields. Important effects from changes of climate need not only stem from changes in average temperature and rainfall, but also from changes in the frequency of extreme climatic events that can be damaging and costly for agriculture. The balance between profit and loss in commercial farming often depends on the relative frequencies of favorable and adverse weather.

Climate change induced by increasing greenhouse gases is likely to affect crops differently from region to region. Local people can explain how climate change becomes manifest locally and consequent affect on ecological, social and economic aspects. Food and fiber production is essential for sustaining and enhancing human welfare.

Numerous studies have examined the impacts of past climatic variations on agriculture using case studies, statistical analyses and simulation models. The possible effects of climate change on global agricultural production are investigated by many researchers. Darwin et al. [1] and Fischer et al. [2] examined changes in the global

Production of agricultural commodities. Rosenzweig et al. [6] used a crop yield model linked to a world food trade model. The Parry et al. [3] model system, like Rosenzweig et al. [7], relied on two main steps, estimating potential

Changes in crop yields and estimating world food trade responses. Darwin et al. [1] used a framework composed of a geographic information system (GIS) and a computable general equilibrium (CGE) economic model. The basic premise is that climate change would affect not only agriculture but also all manner of production possibilities associated with land and water resources throughout the world, including livestock, forestry, mining, and manufacturing, among others. The resultant shifts in regional production possibilities would alter patterns of world agricultural output and trade. Fischer et al. [2] took a somewhat different approach, developing a global spatial data base of land resources and associated crop production potentials. Current land resources were characterized according to a number of potential constraints, including climate, soils, landform, and land cover. Potential output was determined for each land class for different varieties of crop. Future output was projected by matching the characteristics and extent of future agricultural land to this inventory. The economic implications of these changes in agro-ecology and the consequences for regional and global food systems were explored using a world food trade model, the Basic Linked System. The results of the studies paint a fairly consistent picture of how agriculture might be affected by changes in temperature. Climate change is expected to result in higher temperature and rainfall over the Indian sub continent. The higher expected temperature could have adverse impacts on crop yields. At the same time, higher rainfall could enhance growing period duration Kumar et al. [17]. The livelihood of more than sixty percent of the Indian population is from rainfed areas, where rainfall during monsoon season plays a vital role by limiting the option of crop diversification. The effect of monsoon rainfall variation on the national food grain production is high, with significant reduction in food grain production during deficit monsoon rainfall years.

In the present study various climatic parameters i.e. rainfall, temperature, humidity are collected and compared with the crop yield. The dependence of crop yield to rainfall and temperature is focused for Kharif and Rabi crop in the Indo-Gangetic Plains of North India particularly eastern part of the state Uttar Pradesh at Varanasi district

DESCRIPTION OF STUDY AREA

The study area Varanasi is located in the middle Ganga valley of North India, in the Eastern part of the state of Uttar Pradesh, along the left crescent-shaped bank of the Ganga River. Varanasi district is situated in the Agro climatic zone of plain region, bordering the districts of Jaunpur in the north, Ghazipur in the northeast, Chandauli in the east, Mirzapur in the south and SantRavidasnagar in the west. The area of the district is 1526.3 km^2. Varanasi district is limited within geographical co-ordinates of 25° 14' - 25° 23.5' northern latitude and 82° 56' - 83° 03' eastern longitudes. Being located in the Indo-Gangetic Plains of North India, the land is very fertile because low level floods in the Ganges continually replenish the soil. On a local level, Varanasi is located on a higher ground between rivers Ganga and Varuna, the mean elevation being 80.71 m. As a result of absence of tributaries and canals, the main land is continuous and relatively dry. This district is divided in to eight blocks namely, Araziline, Baragaon, Chiraigaon, Cholapur, Haruha, KVP, Pindra, Sewapuri. The river system consists of the mighty Ganga highly revered by Hindus since ages and Gomti, Varuna, Asi, Banganga, Chandra Prabha and Karmanasa are tributaries of the Ganga, that drain the area.

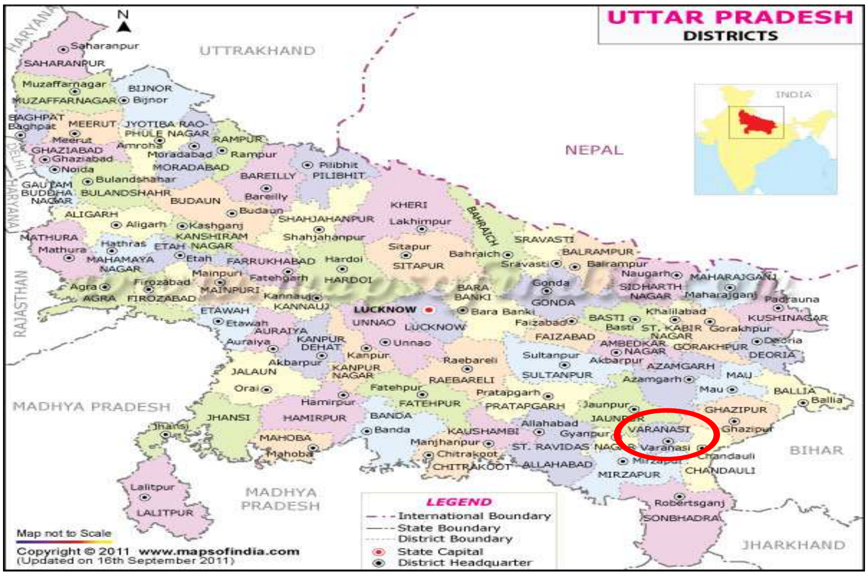

Figure 1 : Geographical Location of Study Area

Kharif, rabi and zaid are three major cropping seasons in the district, with approx 0.99-lakh hectares or 87% of the net cultivated area is being irrigated. The agricultural potential of the district can be rated as high. The major crops grown in the district are wheat, paddy & pulses. Paddy, maize, jowar and pulses like Arhar, urd are the major crops grown during Kharif season, while wheat, pea, gram and masoor are the principal crops grown during Rabi season. Paddy and maize are the crops cultivated during zaid season.

Varanasi has a humid subtropical climate with large variations between summer and winter temperatures. The temperature ranges between 32°C – 46°C (90°F – 115°F) in the summers, and 5°C – 15°C (41°F – 59°F) in the winters. The average annual rainfall in Varanasi is 1025 mm.

Existing Land use and crop pattern in the study area

Agriculture is the driving force for the economic development of the area. The percentage of share of different land use is shown in Table 1. Agriculture is dominating in land use pattern in the area. The share of the agriculture area is about 70% of the total area. The study of land utilization pattern in Varanasi reveals certain interesting trends. Varanasi district is bigger in area and land is used mainly under forest, agricultural, waste land, other current fellow, area under orchards etc.

It produces numerous crops as described in Fig. 2. The percentage of agricultural area used for different crops are shown in the pi chart. Rice and wheat are principle food grain crops. Agriculture is highly diversified in this area. Maize, bazra, lowar, pulses, soyabean, sunflower, barley, gram, peas also cultivated in this area. The yield of crop depends on the temperature and rainfall other climatic parameters.

Table 1 : Classification of land use pattern

Particulars	Area in Hectare	Percent
Forestry area	77,328	19.10
Cultivable waste land	1,480	0.40
Current fallow	2,304	0.60
Other waste land and fallow	2,008	0.50
Land not available for cultivation	1,816	0.50
Land put non agriculture cultivation	34,840	8.60
Pastures	79	0.02
Area under orchard trees and groves	2,179	0.50
Net area sown	2,82,330	69.80
Area sown more than once	1,13,689	28.10
Total cropped area	3,96,019	140.2
Net area irrigated	2,19,458	54.30

Source: District Statistical Hand - Book of Varanasi

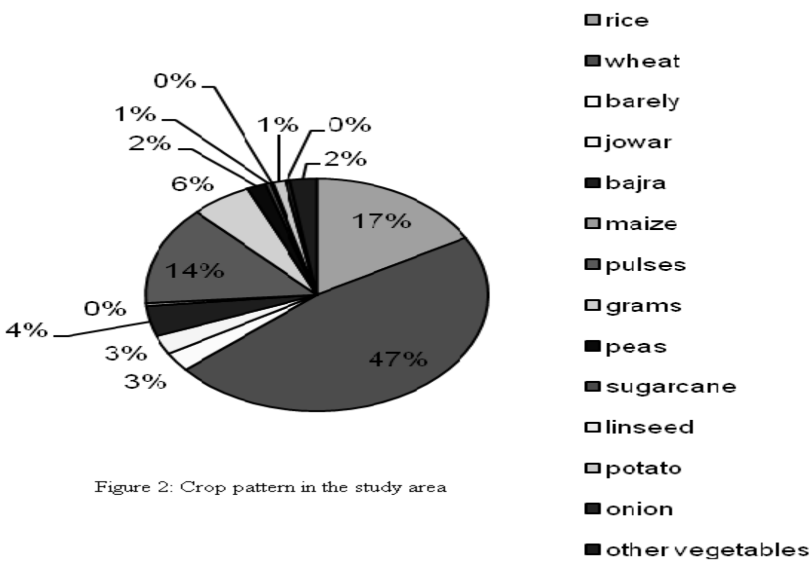

Figure 2: Crop pattern in the study area

B. Soil type - Physical properties and soil classes of the terrain are shown in Table 2 and Table 3

Table 2 : Physical properties of existing soil

Soil properties	Forest	Cropland
Sand (%)	38.6 ± 1.8	32.0 ± 1.7
Silt (%)	56.6 ± 1.3	51.8 ± 0.7
Clay (%)	4.8 ± 1.3	16.2 ± 1.1
Bulk Density(g/cm^2)	1.32 ± 0.02	1.56 ± 0.03
Water holding Capacity(%)	46.4 ± 1.03	44.3 ± 2.11

Table 3 : Soil classes of Eastern zone of UP

Sl. No.	Soil Class	Area (%)
1.	Silty clay loam to clay	31.39
2.	Clay loam to silty clay	6.5
3.	Loam	19.32
4.	Loam to clay loam	2.95
5.	Sandy loam soil with 70-80% or more land surface with bedrock exposure	39.27
6.	Gullied land	0.05

ANALYSIS AND DISCUSSION

The weekly data of rainfall, minimum and maximum temperature, minimum and maximum relative humidity, sunshine hours and wind velocity for the period 1994 to 2006 were collected from the Research Project for Dryland Agriculture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi, U.P., India. From the practical point of view each year was divided into three seasons viz., Rabi (November to March), summer (April to May) and Kharif (June to October) and seasonal climate variability was studied for different decadal periods.

Here the linear regression equation for the trend line is y = mx + b. Apply a statistical treatment known as linear regression to the data and determine constants. Given a set of years and temperature data set (xi , yi) with n is number of years.

$m_z = \frac{1}{n}\sum_{i=1}^{n} Z_i$ m_z is mean

$S_z^2 = \frac{1}{n}\sum_{i=1}^{n}(Z_i - m_x)^2 = \frac{1}{n}\sum_{i=1}^{n} Z_i^2 - m_z^2$ $(S_z)^2$ is variance

$$S_z = \sqrt{S_z^2} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_i - m_x)^2}$$ S_z is standard deviation.

$$CV_z = \frac{S_z}{m_z}$$ CV_z is Coefficient of Variation

$$CS_z = \frac{\frac{1}{n}\sum_{i=1}^{n}(Z_i - m_z)^3}{s_z^3}$$ CS_z is Skewness

$$CC_z = \frac{\frac{1}{n}\sum_{i=1}^{n}(Z_i - m_z)^4}{s_z^4} - 3$$ Where CC_z is Curtosis

Rice and wheat is the main crop in the Varanasi. The yield of these two crops due to change of rainfall, temperature and relative humidity is studied and presented in the Fig. 3-10.

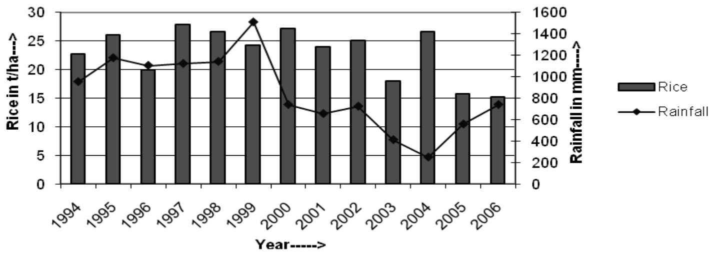

Figure 3 : Comparison of yield of rice with rainfall

It is observed from the Fig. 3 the rainfall is decreased gradually. Rice production is also varied but there is no linear relationship of variation of yield of crop with rainfall variation. It may be possible that the irrigation water is sufficient for the area for cultivation of rice.

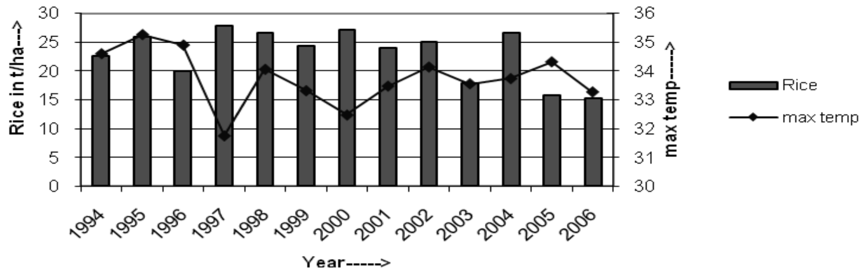

Figure 4: Comparison of yield of rice with maximum Temperature

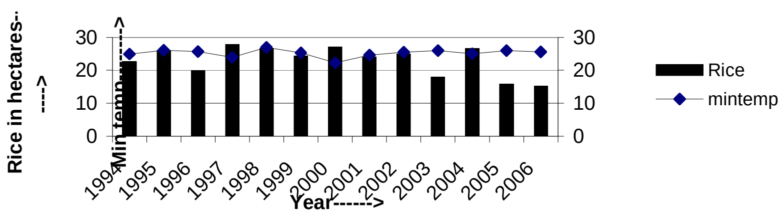

Figure 5 : Comparison of rice yield with minimum temperature

The yield of rice in different years is shown in Fig. 4 and 5 along the variation of temperature. The average maximum and minimum temperature is also plotted in same figure to show the effect of temperature variation to yield of the kharif crop.

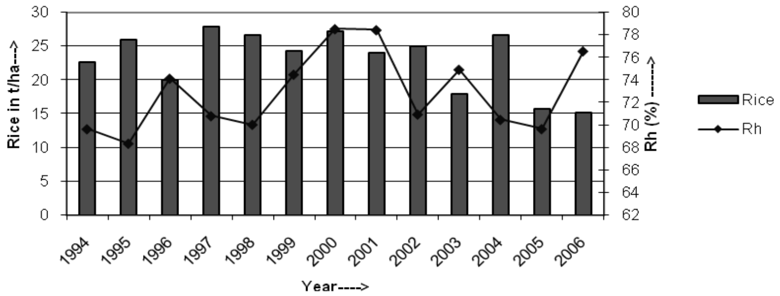

Figure 6 : Comparison of kharif yield with relative humidity

The product of rice in different years along with the average relative humidity for the kharif season is plotted in Fig. 6.

From the Fig. 6 it is observed that the yield of kharif crop depends on the variation of relative humidity. The productivity of the rice depends on natural temperature variation and relative humidity variation. The growth and yield of rice depends on these climatic parameters.

Wheat is the main food grains of the rabi season that is cultivated in the Varanasi. The yield of wheat for different climatic parameter is presented in the Fig. 7-10. The yield of wheat and the rainfall is plotted in Fig. 7. It is observed from Fig. 7 that although rainfall is less the yield is not hampered as natural irrigation is exists in this area.

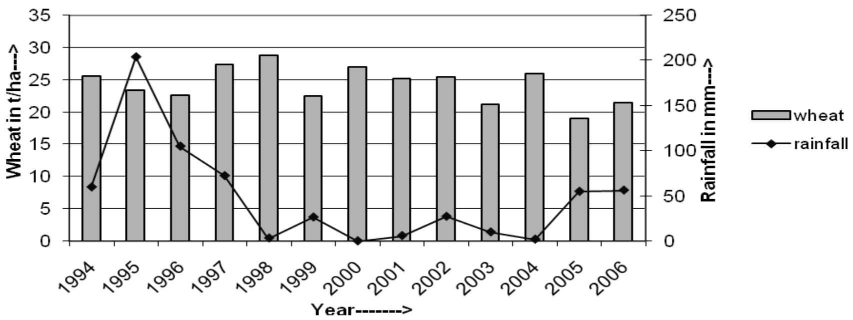

Figure 7 : Dependency of Yield of Wheat with rainfall

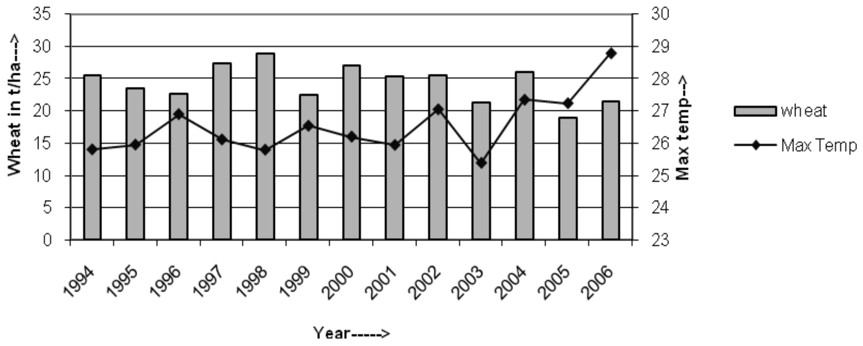

Figure 8 : Yield of wheat with maximum temparature

The yield of wheat is compared with the variation of average maximum and minimum temperature of the study are for rabi season and plotted in Fig. 8 -9.

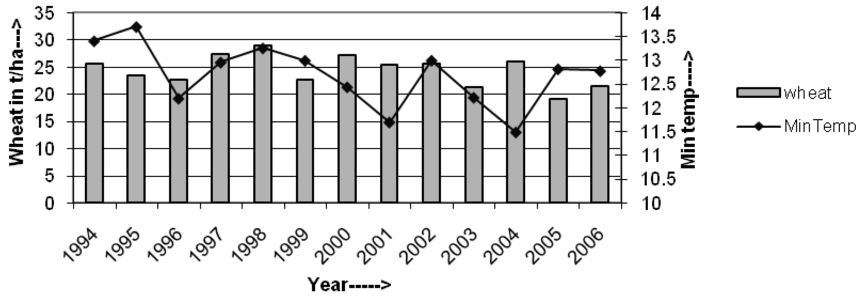

Figure 9 : Wheat production wih minimum temperature

The yield of wheat is plotted along with relative humidity in the Fig. 10 for the given duration 1994-2006. The productivity of wheat dependedent on relative humidity.

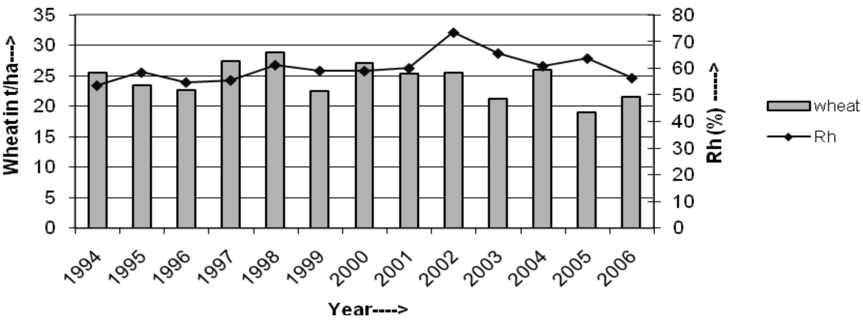

Figure 10 : Variation of wheat productivity with relative humidity

Variation of crop production depends on meteorological parameters as well as soil type. Effort has been made to comparative study of yield of two main crops rice and wheat of the area. It is observed from the study that the variation of temperature and rainfall both affected the yield of crop but the relationship is somehow complex. Crop yields affected by climate change are projected to be different in various areas, in some areas crop yields will increase, and for other areas it will decrease depending on the latitude of the area and irrigation application.

1. CONCLUSIONS

Agriculture is the main factor for the economic growth of any developing country. An effort has been made to study the impact of climate zone in eastern part of Uttar Pradesh at Varanasi district. Agriculture is mainly depended upon weather conditions including temperature, rainfall, humidity, daily sun shine etc. Climate change is likely to reduce agricultural yields significantly. Slight changes in precipitation and hydrological conditions can potentially affect crop production. An increase in precipitation will increase crop yield, crop yield is more sensitive to the precipitation than temperature. If water availability is reduced in the future, soils of high water holding capacity will be better to reduce the impact of drought while maintaining crop yield. With the temperature increasing and precipitation fluctuations, water availability and crop production are likely to decrease in the future. Direct impacts of climate change there is concern about future agricultural water requirement i.e. water availability under the combined affect of climate change, growing population and competition from other economic sections under future socio economic development.

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