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Impact of Green Revolution on the Sustainability of rice-wheat Cropping Pattern and Crop Productivityin Ganga basin

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Abstract

Indian agriculture is marked by diversity resulting from both physical and socio-economic factors. Since 1967, theGreen Revolution has brought significant changes in crop diversity, cropping patterns and crop productivity across the regions.The Green Revolution has been responsible for enhanced productivity. However, recently the ill-effects of green revolution on crop productivity have also been revealed. In this backdrop, the present study attempts to evaluate the influence of Green Revolution on rice-wheat cropping pattern and productivity in Ganga Basin region. It is also attempted to analyzethe impact of rainfall variability on rice productionin the study area in order to have insight about the influence of climate change on agriculture. Subsequently, sustainability of wheat-rice cropping pattern in traditional and non-traditional wheat and rice growing areas is also addressed through Cuddy Della Valle Index. The results show influence of Green Revolution on the cropping patterns.It is also revealed that the productivity of rice and wheat is declining in non-traditional regions in comparison to traditional areas. However, the influence of rainfall variability on rice yield is insignificant.

Keywords:*Cropping pattern, Crop productivity, Green Revolution, Rainfall variability, Ganga Basin.*

Introduction

Diversity has been the major characteristic of Indian agriculture. This diversity is largely the outcome of variations in climate, topography, resource endowments as well as historical, institutional and socio-economic factors across the regions (Fischer et al., 2005; Mall et al., 2007; Bhalla and Singh, 2009).Besides, the policies adopted in the country time by time and the nature of technology that became available over time also affects the agricultural pattern and productivity. These factors most often reinforce some of the already existing variations resulting from natural factors and thus manifesting into increased regional inequality.

In earlier timeswhen agriculture was more dependent on physical parameters i.e. climate and terrain, the cropping pattern of a region used to vary from one to another region. For example, West Bengal, Bihar and parts of eastern Uttar Pradesh experiencehumid to sub- humid climate and thus are suitable for water intensive crops such as rice. In contrast, western Uttar Pradesh due to its semi- arid climate is suitable for crops that require less amount of water like wheat. However, the introduction of Green Revolution has brought dramatic changes to this conventional cropping system (Nelson et al., 2019). Due to Green Revolution, the wheat growing regions have shifted to rice and producing higher yields as compared to the traditional rice growing regions. On the other hand, the rice growing regions have become capable of growing wheat. These changes, according to some scholars are not sustainable as the natural resources are getting deteriorated due to intensive irrigation and excessive use of fertilizers. With this, there are literatures reporting reduction in the rate of yield in Punjab and Haryana (Lal et al., 1998; Sinha et al., 2015; Madhukar et al., 2019). Scholars have also argued that the growth of agricultural productivity under Green Revolution has been highly uneven (Pingali, 2012). Nevertheless, the influence of climate on agriculture cannot be worked out in spite of using any technological innovation (Krupa, 2003; Kumar, 2007; Mall et al., 2007; Arora, 2019). The phenomena of climate change that has emerged as a major threat, not particularly to Indian agriculture but at global scale (Swanson and Nyankori, 1979; Smitand Skinner, 2002). With this the sustainability of wheat-rice cropping system is also in question (Sarkaret al., 2009).

In this backdrop, the aim of the paper is to analyze the impact of Green Revolution on cropping pattern and crop productivity in Ganga basin by examining the spatio- temporal changes in cropping pattern and comparing the trend of growth of wheat and rice yields across: a) Traditional and non- traditional rice growing districts and b) Traditional and non- traditional wheat growing districts.

To assessthe sustainability ofwheat- rice cropping system in traditional and non-traditionalwheat and rice growing regions. The relationship between rainfall variability and rice productivity is also analyzed to have an insight of the impact of climate variability on agriculture.

Data and Methodology

Information about agro-climatic and agro-ecological regions of the country is derived from planning commission's website.State-wise data on gross cropped area under wheat and rice for different time periods is taken from Bhalla and Singh (2010). Along with this, data about district wise crop yield is available with Ministry of Agriculture, Government of India for 1993-2011(Dacnet.nic.in). Rainfall data have been obtained from IMD for the periodscorresponding to the crop productivity years.

For this study, wheat and rice crops have been selected that are the major crops influenced by the Green Revolution in post 1967 period.Changes in cropping pattern are analyzed on the basis ofchanges in gross cropped area under wheat and rice over time.The study area of Ganga basin has been categorized into different agro-ecological regions to get information about the natural conditions prevailing in the region that allow to grow some particular crops.Thereafter, categorization of traditional and non- traditional districts is done on the basis of deviation of crop cultivation that is not suitable under agro- ecological setting of the region and the changes in gross cropped area under wheat and rice over time.

Here, traditional wheat/rice growing regions are those whose major proportion of gross cropped area was under wheat/rice before the phase of green revolution.Amanand boro(winter and summer rice crops) are taken for traditional region.Contrary to this, non- traditional wheat/rice growing regions are those who have started growing wheat/ rice at a larger scale only after green revolution. Earlier, either they were not producing wheat/ rice at all or very little area was under wheat or rice cultivation.To represent these regions few districts have been selected from each region whose detail has been given in the table below (Table 1). These are the major wheat/rice producing units of their representative regions.

Table 1 showing details of traditional and non- traditional districts.

Sr.No.	Traditional Rice growing	Non- traditional rice growing	Traditional wheat growing	Non- traditional wheat growing
1.	Haora	Saharanpur	Saharanpur	Haora
2.	Hugli	Meerut	Meerut	Hugly
3.	24 S parganas	Ghaziabad	Ghaziabad	24 S pargana
4.	Murshidabad	Bareilly	Muzaffarnagar	Murshidabad
5.	Malda	Moradabad	Barelly	Malda

To analyze sustainability of wheat and rice in their traditional and non- traditional areas,Cuddy Della ValleIndex (Cuddy and Valle, 1978) has beencalculated in the following manner:

Cuddy Della ValleIndex(CDVI) = $CV \times \sqrt{1 - R^2}$

Where CV is the Coefficient of Variation in percent, R^2 is the coefficient of determination from time-trend regression.

Growth rates for both wheat and rice has been calculated as:

$$\frac{Base\ year - Previous\ year}{Base\ year} \times 100$$

In most parts of Uttarakhand, which is also a part of Ganga Basin wheat and rice are not the major crops except in few districts. These areas are mainly famous for horticulture and floriculture. With this there are also some issues regarding comparison of data across states because Uttarakhand has come into existence only after the year 2000. Because of these reasons the districts of Uttarakhand have not been included in this analysis.

Study Area

Ganga Basin has been taken as the unit of study as under watershed approach the whole basin is linked through process- response system. The river Ganga has a great importance not only in religious perspective but also in economy of the country including its immense environmental significance. Originating from Gangotri in the Himalayas, Ganga drains to Bay of Bengal forming in its way an extensive alluvial deposit of about 2500 km. making it one of the most fertile regions of the world. Ganga river flows through Uttarakhand, Uttar Pradesh, Bihar and West Bengal, traversing through temperate, tropical, sub- tropical and semi- Arid climatic divisions of India. Its numerous tributaries drain in other various states of North and Central India and thus make Ganga basin the largest river basin of the country. The region constitutes one of the major wheat and rice producing areas of the country and Green revolution has also been quite affective here as more than 80% area comes under irrigated condition. According to WWF- India report (2011), majority of the districts falling in the basin are showing an increase in temperature. This rise is more in Western Uttar Pradesh as compared to Eastern part. However, there has not been marked variation in precipitation pattern, although some short-term fluctuations have been marked.These climatic factors can influence the existing cropping pattern of the region and also reduce the influence of Green Revolution.Therefore, these reasons make Ganga Basin a suitable area for such kind of analyses.

Agro- climatic Regions of Ganga Basin

The Planning commission of India has worked out 20 broad agro-climatic zones of the country on the basis of physiography and climate.According to this classification Ganga Basin has been divided into following three broad categories (Fig. 1).

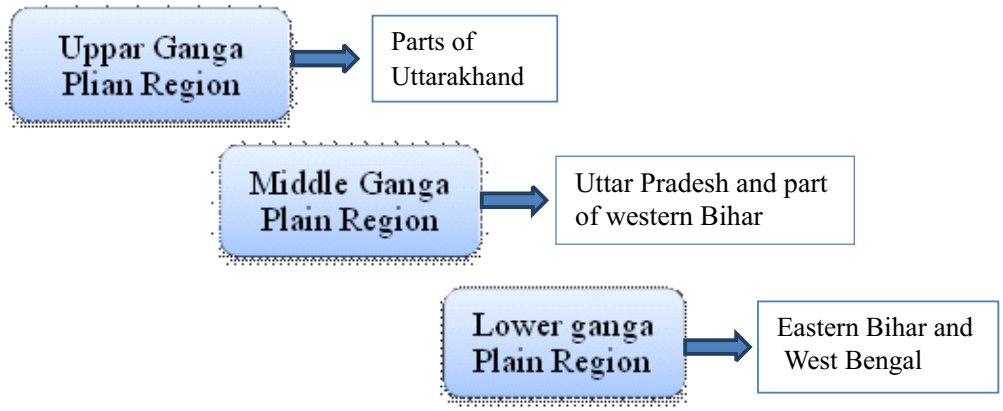

Fig. 1 Agro- climatic divisions of Ganga Basin and states falling within different divisions

However, the government of India did not satisfy with this classification and the task was given to the National Buearo of Soil Survey and Land Use Planningto prepare an Agro- Ecological region map for the country.This new classification has divided whole country into 127 divisions which was done on the basis of following parameters (Table 2, Fig. 2).

Table 2.Parameters used for the classification of Agro- ecological regions

Parameters	Constituents
Bioclimate	Precipitation, Temperature, Vegetation and Evapo-Transpiration
LGP	Rainfall, Potential Evapo- Transpiration, Soil Storage
Soil or Landscape	Soil and Physiography

i. Hot semi- arid with alluvial soil

The region experiences hot- dry summers with cool winters.Annual precipitation varies from 500- 1000 mm and increases from west to east.Length of the growing periodvaries from 90 to 150 days.Natural vegetation is tropical- dry deciduous. Major crops grown include wheat, millet, maize and pulses. However, these days rice is also being grown with the help of Green Revolution technology.It includes- western Uttar Pradesh with Allahabad and Varanasi from eastern part.

ii. Hot sub- humid (dry) with alluvial soil

The region experiences hot summers followed bycool winters. Rainfall varies from 1000 to 1200 mm.Tropical deciduous forest constitute natural vegetation of the region. Major crops grown in the region include- rice, maize and barley etc. It includes- Nainital of Uttarakhand, eastern Uttar Pradesh and parts of Bihar.

iii. Hot sub- humid with red and yellow soil

The region experiences hot summer followed by cool winters with average rainfall varying from 1200 to 1600 mm.Major natural vegetation type is Tropical moist deciduous.Most importantcrops are rice, millet, maize etc.Mirzapur of Uttar Pradesh and eastern parts of Bihar constitute this division.

iv. Hot sub- humid with Red and Lateritic soil

The region has hot summer and cool winters with average rainfall ranging between 100 to 1600mm.Tropical dry and moist deciduous forests constitute the natural vegetation of the region.Major crops in wet areas are rice while wheat is shown in dry parts. It includes Purulia, Burdhwan, Birbhum and Medinipur of West Bengal.

v. Hot sub- humid (moist) with alluvial soil

This region is characterized by hot- wet summer and cool- dry winter season.Rainfall varies from 1400 to 1600mm a year. Major crops are rice, maize pea etc.Due to the impact of Green Revolution wheat is also being cultivated.Parts of Bihar – Begusarai, Darbhanga, Munger, Champaran etc. and Uttar Pradesh- Bahraich, Basti, Deoria, Gonda and Gorakhpur come under this region.

vi. Warm sub- humid to humid with brown forest and podzolic soil

This region enjoys mild summers followed by cool winters.Rainfall varies from 1000 to 2000mm. In some parts it goes more than 2000mm.Natural vegetation varies from Himalayan moist temperate, sub – tropical and alpine pine. Major crops are wheat, millet and horticulture.Now a days rice is also being produced due to the use of new technology. Most of the parts ofUttarakhand come under this region.

vii. Hot sub- humid (moist) to humid with alluvial soil

The region experiences hot summers followed by mild to moderately cool winters. Average rainfall varies from 1400 to 1600mm.Tropical moist deciduous forest is the natural vegetation. The region has a Rice based cropping pattern due to high rainfall.Another important crop is Jute. It includes Southern Part of West Bengal – Hugli, Kolkata, Nadia,Hawra, etc.

viii. Warm per- humid with brown and red hill soils

The region has Rainfall ranging between 2000 to 4000 mm. it is a mixed crop region where

Tea is the major crop.Jalpaiguri and Darjiling come under this agro- ecological region.

Therefore, because of the physiography, climate and soil some regions are suitable for wheat and some are for rice only.

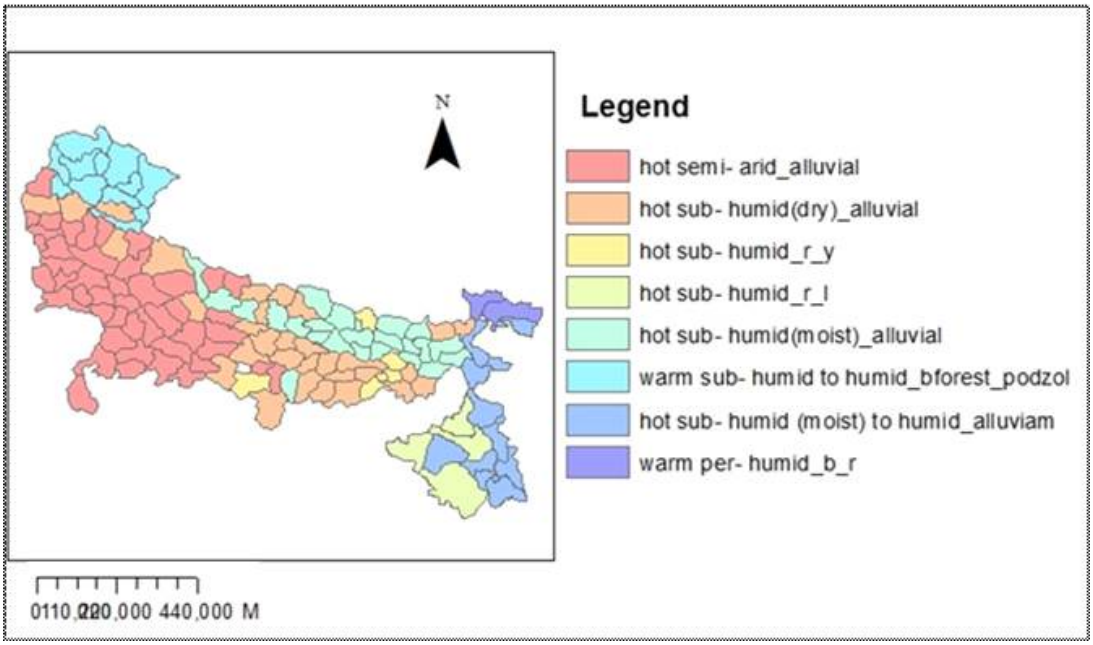

Fig 2. Agro-ecological regions of Ganga Basin

Result and Discussion

Changes in Cropping Pattern

Gross cropped area is selected to analyze the changes in cropping pattern. Due to unavailability of district wise data for pre- green revolution period, a generalization has to be made on the basis of state level information otherwise the picture would have been clearer.

By observing the figures of different period, it becomes clear that in pre- green revolution phase (1962-65), the area under drier climatic conditions used to grow less water-intensive crop such as wheat.In Western Uttar Pradesh,the major proportion of gross cropped area was under wheat cultivation (Fig.3). However, the bar of rice is also equaling to wheat because it includes eastern Uttar Pradesh also where rice has been the major crop.Bihar and West Bengal had larger area under rice cultivation in pre- Green Revolution period.During 1970-73,under the impact ofGreen Revolution, area under wheat has increased in Uttar Pradesh as compared to rice (Fig. 3).In Bihar also there appears a significant increase in gross cropped area under wheat. However, in West Bengal this rise is insignificantand less than 2% area is under wheat.

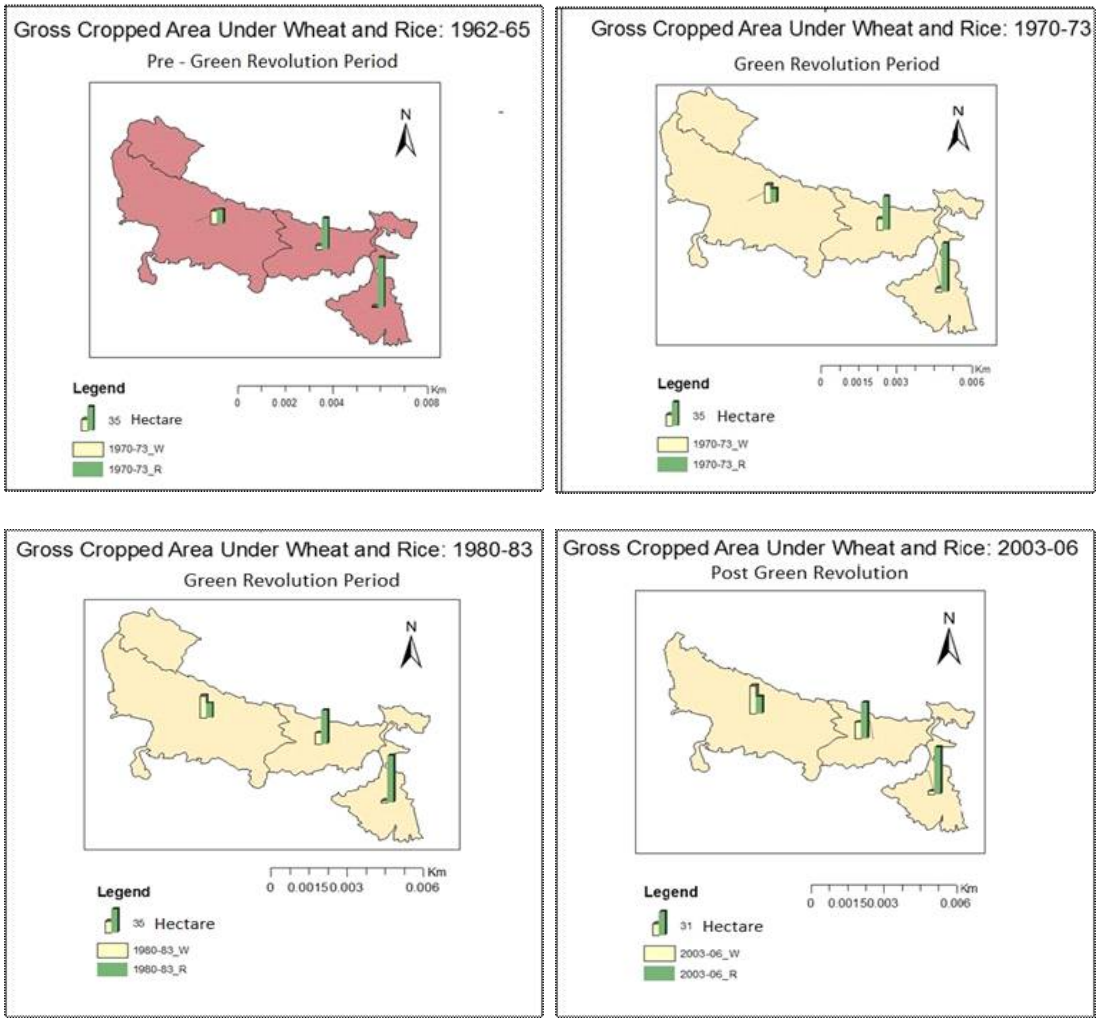

Fig. 3 Gross-cropped area under wheat and rice during pre- and post-Green Revolution period

In these states, rice has continued to occupy a larger share of gross cropped area for a longer time.The condition is almost similar during the period 1980-83 for each state with Bihar continuing to devote a slightly larger share of gross cropped area under wheat (Fig. 4).During 2003- 06 significant increases in gross cropped area under wheat is marked in Utter Pradesh and Bihar.In Bihar, the area under rice has remained almost stagnant while that under wheat has increased significantly (Fig. 5).Contrary to this, in West Bengal gross cropped area under rice has reported tremendous increase over time. However,a marginal increase in area under wheat can also be seen in West Bengal in postGreen Revolution period.

Changes in Productivity

Changes in wheat and rice productivity from the period of Green Revolution to post Green Revolution period is important to discuss because of several aspects. The Green Revolution and change in productivity of these two prime crops made it profitable. Many of the traditional crop growing regions have improved their productivity and many of the non-traditional crop growing areas

made it possible to make a profitable output from the agriculture.For the purpose of study, on the basis of agro- ecological regions and changes in gross cropped area under wheat and rice during different phases of Green Revolution whole Ganga Basin is divided into following broad categories:

a. **Traditional wheat growing region –** this category can be formed by combining i, iv and vi agro-ecological regions. This includes whole of Western Uttar Pradesh and some districts of Eastern Uttar Pradesh as Varanasi and Allahabad. In these districts a major portion of Gross Cropped Area has remained under wheat crop.

b. **Traditional rice growing region-** the agro- ecological regions ii, iii, v and vii constitute traditional rice growing region. It includes eastern Uttar Pradesh, Bihar and most of the Parts of West Bengal except Jalpaiguri and Darjiling.

c. **Non- traditional rice growing region-**mostof the traditional wheat growing areasdue to adaptation of Green Revolution technology have emerged as major rice producing areas and thus constitute non- traditional rice growing regions as Western Uttar Pradesh.

d. **Non- Traditional wheat growing regions-** similar to rice, wheat has also been affected by Green Revolution. Due to this in some of the major rice producing districts major part of gross cropped area has come under wheat. For instance, Bihar and West Bengal. However, in West Bengal still rice is the most important crop as only 3-5% area in some district is under wheat.

Changes inWheat productivity

The comparison between traditional and non-traditional region with the productivity of wheat shows that the traditional wheat growing regions have better productivity as compared to non-traditional wheat growing regions. Even there is an increasing trend in productivity of wheat from Green Revolution period to post Green Revolution period in the traditional wheat growing regions. The non-traditional wheat growing regions have more fluctuations in the productivity of wheat in the starting of the post Green Revolution. The non- traditional wheat sowing regions are showing somewhat stagnant trend. However, there have been marked fluctuations in the yield of wheat.

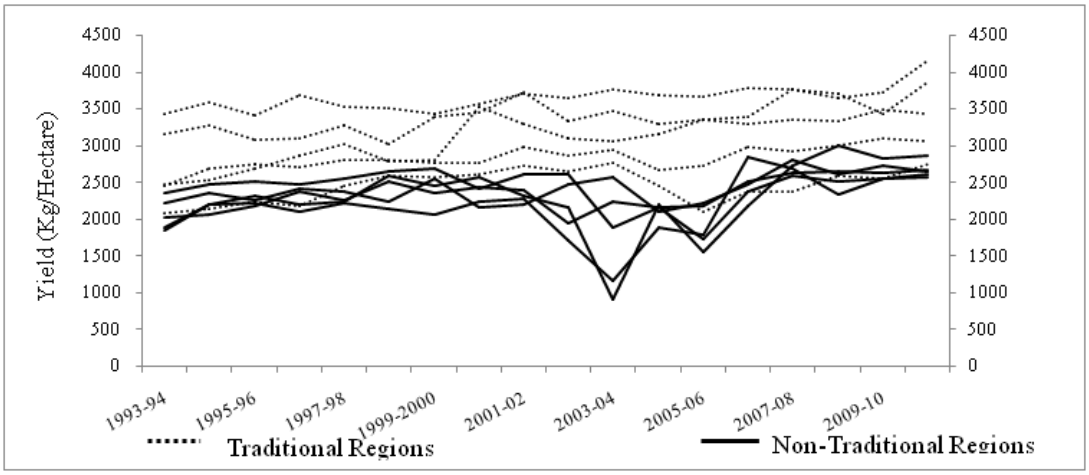

Fig 4. Comparison of wheat yield between traditional and non-traditional regions

Changes in Rice Productivity

The yield of rice has remained almost stable in non- traditional regions. While in traditional regions high fluctuation has been observed in rice yield over time.This may be because in traditional region rice productivity is more dependent on monsoon rainfall which is highly variable in our country while in non- traditional region under irrigated condition rice production has remained stable.One

significant finding has come up as in non- traditional districts the yield is stable but showing a declining trend.In opposite to this, the traditional rice growing districts are experiencing increasing trend of rice productivity.

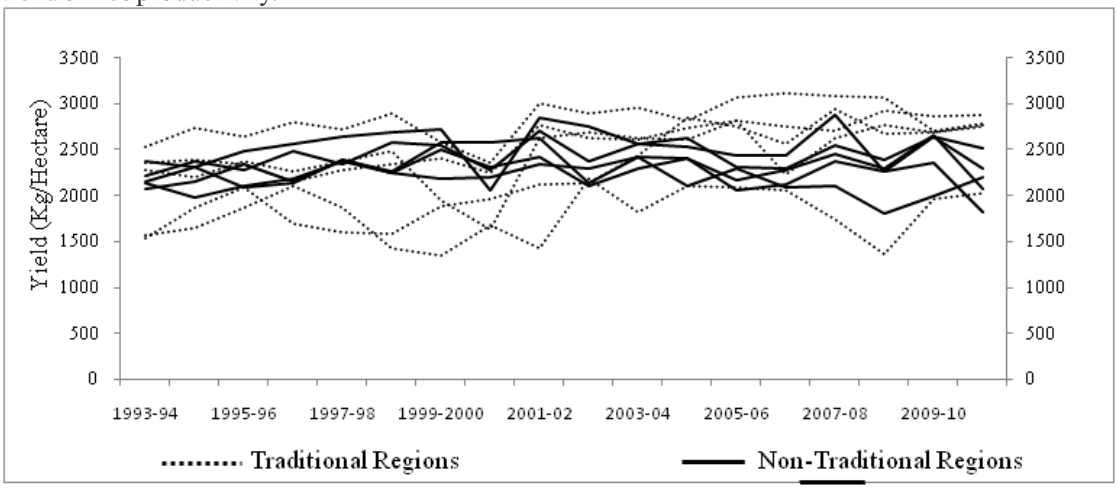

Fig. 5 Comparison of rice yield between traditional and non-traditional regions

Trend of Growth of Productivity

To analyze the impact of Green Revolution on wheat and rice productivity, it is also very important to examine the growth rate of these crops in selected regions. It is clear that the traditional wheat and rice growing areas are experiencing a higher growth rate as compared to the non-traditional region (Table 3).In case of rice the growth rate is negative for non-traditional region shows the physiographic and climatic suitability of the traditional region. Therefore, growth rate is higher for traditional region as compared to non- traditional in both the cases. The non-traditional areas are not capable of maintaining higher production for a longer duration. The production tends to fall after the technological inducement and unable to retain the previous position.

Table 3.Average growth rate of wheat and rice productivity for different regions

Regions	Growth Rate
Traditional Growing Wheat	0.43
Non- traditional GrowingWheat	0.36
Traditional Growing Rice	0.34
Non- Traditional GrowingRice	-0.01

Sustainability of Wheat and Rice

The value of CDVI in general, is comparatively higher for non- traditional wheat and rice growing areas.The traditional wheat and rice growing regions are showing a lower value of instability.However, there are some exceptions as well. For exampleHawra, a traditional rice growing district has higher instability during both summer and winter seasons.During winters, when irrigation is required for rice cultivation, Malda and Murshidabad are showing higher instability 10 and 10.6

respectively. While during summers this value is as low as 5.1 for Malda and 2.1 for Murshidabad.Similarly, the traditional wheat growing district of Bareily is also exhibiting a higher value of instability. The value being 8.1 whereas one of the non- traditional wheat growing districts Rohtas has a comparatively lower instability index 7.1.

Notes:

T_w = traditional wheat growing districts.
Nt_w = non- traditional wheat growing districts.
T_rwin = tradional rice growing districts. Yield in winter season.
T_rs = traditional rice growing district. Yield during summer season.
Nt_rs = non- traditional rice growing districts. Grow rice only during kharif season as wheat is the important rabi crop.
I = Instability Index (CDVI).

Influence of Rainfall on Rice productivity

In this study the rainfall has been compared with the productivity of rice as it is one of the most important determinant of rice cultivation. In India, the monsoon rainfall supplies water for rice cultivation in most of the regions. It has been seen that the limited availability of monsoon rainfall turns the productivity down.

Table 4.CDVI for wheat and rice in traditional and non- traditional districts

t_w	I	nt_w	I	t_rwin	I	t_r s	I	nt_rs	I
Saharanpur	3.6	Patna	8.6	Birbhum	6.3	Birbhum	8.5	Muzaffarnagar	6.3
Muzaffarnagar	4.3	Rohtas	7.1	Hawra	14.9	Hawra	15.1	Moradabad	7.2
Meerut	3.1	Samastipur	17.3	Hugli	4.67	Hugli	6.8	Pilibhit	8.1
Pilibhit	5.9	Vaishali	20.7	Malda	10.0	Malda	5.1	Shahjahanpur	6.6
Bareilly	8.1	Saran	9.5	Murshidabad	10.6	Murshidabad	2.1	Kheri	9.0

where during high rainfall years good yield has been obtained.

In Hawra and Malda the impact of rainfall on rice yield is not very significant as even during good monsoon period, the productivity has remained low (Fig. 4).

Non- traditional rice growing Districts: In non- traditional rice growing areas the rainfall does not show strong relationship with productivity.The yield of rice as in Muzaffarnagar, Pilibhit and Shahjahanpuris very concentrated that represents dominance of irrigation over rainfall (Fig. 5).Therefore, the influence of rainfall is not very effective for rice productivity in the selected area.

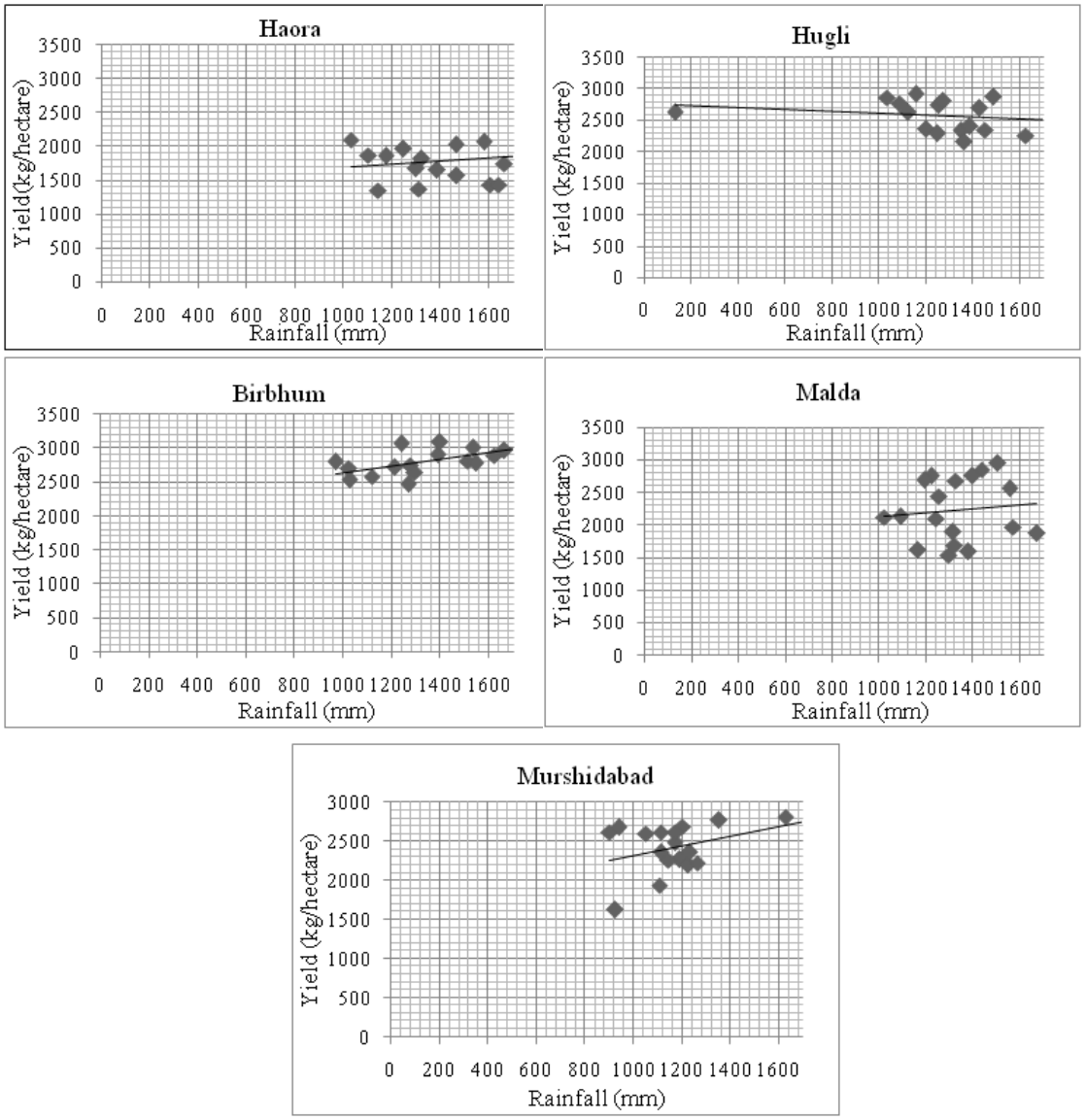

Fig. 5Impact of rainfall on rice productivity in traditional rice growing region

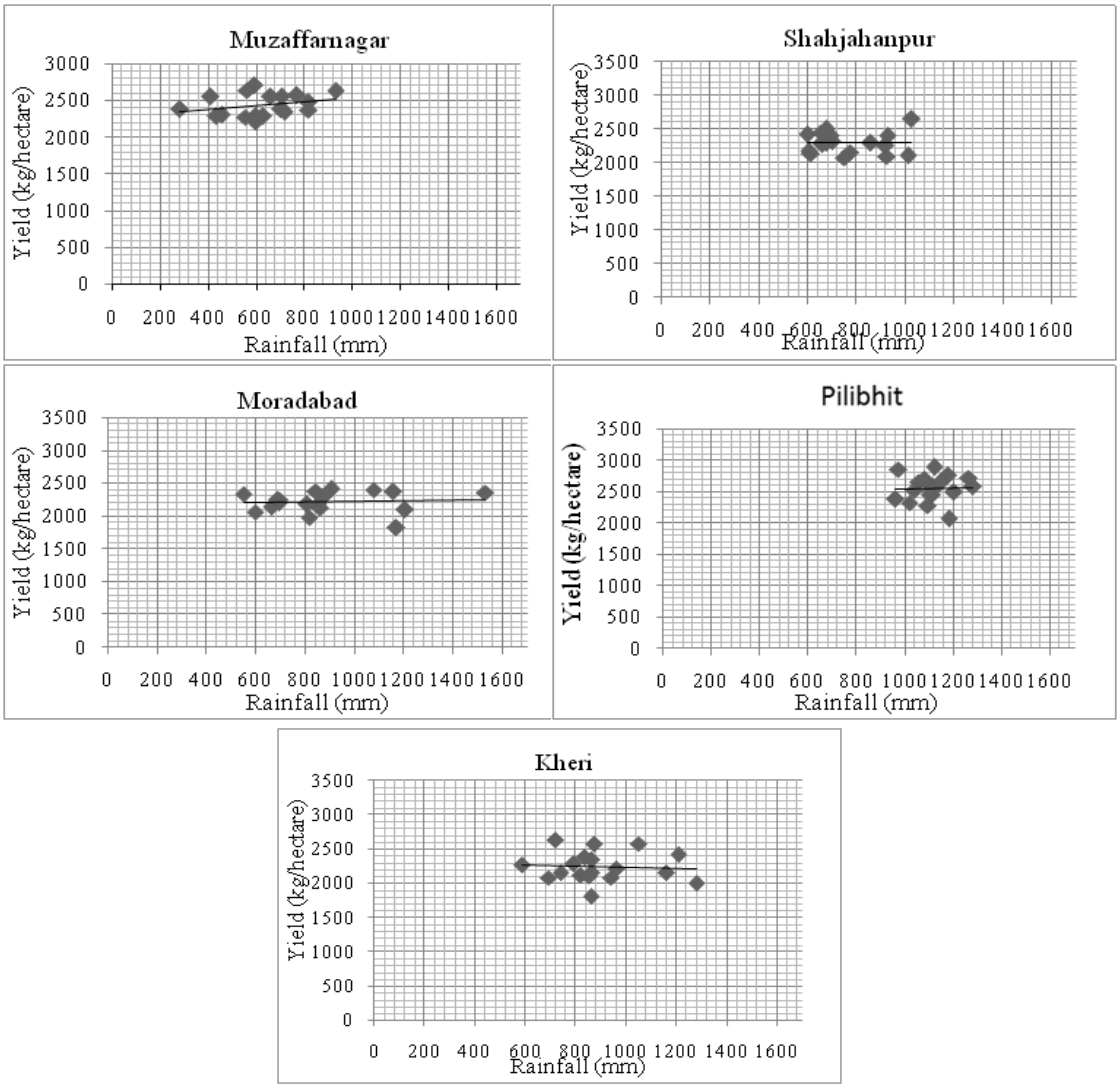

Fig. 6Impact of rainfall on rice productivity in non- traditional region

Conclusion

From the analysis it has appeared that there is a clear difference between the traditional rice and wheat growing region and non-traditional rice and wheat growing region. The Green Revolution to a large extent has transformed the cropping pattern in the Ganga Basin region. Areas which were conventionally favorable for wheat cultivation under existing geographic conditions, has a larger share of gross cropped area under rice due to Green Revolution.Similarly, regions of high rainfall, traditionally sowing rice has shifted to wheat cultivation.The productivity of wheat is higher in traditional wheat growing region and showing an increasing trend with less fluctuation.In non-traditional wheat growing region and mainly in Bihar, there appears high fluctuation in wheat yield and productivity is also appearing to be stagnant.The rice productivity is exhibiting a decreasing trend in non- traditional districts while its yield is increasing in traditional areas.With this, the growth rate is

high for both rice and wheat in their traditional regions.Some of the non- traditional rice growing regions are showing negative growth rate.The instability of wheat and rice, with some exceptionsis higher in non- traditional regions. However, Hawra being a traditional rice growing region is showing higher instability index.The productivity of rice is influenced by rainfall in traditional regions whereas in non- traditional region this impact is not significant as the production is governed by irrigation.Therefore, it is obvious that Green Revolution has brought tremendous changes to the cropping pattern in Ganga Basin and the productivity of wheat and rice, in long run, appears to be affected negatively under new "seed- fertilizer technology".

References

1. Arora, N.K. (2019). Impact of climate change on agriculture production and its sustainable solutions. Environmental Sustainability, 2: 95-96.
2. Bhalla, G.S., Singh, G. (2009). Economic liberalization and Indian agriculture: a state level analysis. Economic and Political Weekly, 44 (52): 34-44.
3. Bhalla, G.S, Singh, G. (2010).Growth of Indian agriculture: A district level study. New Delhi: Planning Commission, Government of India.
4. Cuddy, J.D.A., Della Valle, P.A. (1978). Measuring the instability of time series data. Oxford Bulletin of Economic and Statistics, 40 (10): 79-84.
5. Fischer, G., Shah, M., Tubiello, F., Van Velhuizen, H. (2005). Socio-economic and climate change impacts on agriculture: an assessment, 1990-20280. Philosophical transactions of the Royal Society of London, Biological Sciences, 360 (1463): 2067-2083.
6. Krupa, S. (2003). Atmosphere and agriculture in the new millennium. Environmental Pollution, 293–300.
7. Kumar, K. S. (2007). Climate Change Studies in Indian Agriculture. Economic & Political Weekly, 16: 13-18.
8. Lal, M., Singh, K.K., Rathore, L.S., Srinivasan, G., Saseendran, S.A. (1998). Vulnerability of rice and wheat yields in NW India to future changes in climate. Agriculture and Forest Meteorology, 89: 101-114.
9. Madhukar, A., Kumar, V., Dashora, K. (2019). Spatial and temporal trends in the yields of three major crops: wheat, rice and maize in India. International Journal of Plant Production, 14: 187-207.
10. Mall, R.K., Singh, R., Gupta, A., Srinivasan, G., Rathore, L.S. (2007). Impact of climate change on Indian agriculture: a review. Climatic Change, 82 (1-2): 225-231.
11. Mohan, D., Sinha, S. (2011). Facing the Facts: Ganga Basin's Vulnerability to Climate Change. WWF Summary Report.
12. Sarkar, A., Sen, S., Kumar, A. (2009). Rice-wheat cropping cycle in Punjab: a comparative analysis of sustainability status in different irrigation systems. Environment Sustainability, 11 (4): 751-763.
13. Sinha, B., Sangwan, K.S., Maurya, Y., Kumar, V., Sarkar, C., Chandra, B.P., Sinha, V. (2015). Assessment of crop yield losses in Punjab and Haryana using two years of continuous in-situ ozone measurements. Atmospheric Chemistry and Physics, 15 (2), 9555-9576.
14. Smit, B., Skinner, M.W. (2002). Adaptation options in agriculture to climate change: a typology. Mitigation and Adaptation Strategies for Global Change, 7: 85-114.
15. Swanson ER, Nyankori JC (1979). Influence of weather and technology on corn and soyabean yield trends. Agricultural Meteorology, 20 (4): 327-342.

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