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FOODGRAINS PRODUCTIVITY IN INDIA AND SUBSTITUTION BETWEEN CLIMATIC AND NON-CLIMATIC FACTORS

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Abstract

The present research paper tries to analyze the impact of climatic and non-climatic factors on productivity of foodgrains in India. The climatic and non-climatic factors have been defined with the help of composite index. The climatic factor is represented by rainfall measured in terms of millimeter (mm), CO_2 emission in metric tonnes per capita and maximum & minimum temperature in centigrade. The non-climatic factor include area under cultivation in million hectares, area under assured means of irrigation as percentage of total cultivated area, size of labour and use of fertilizers in lakh tonnes. The Cobb-Douglas production function result shows that both climatic and non-climatic variables are positively associated with Yield of foodgrains production and results are statistically significant. As compared to climatic factors, the non-climatic factor has emerged influential in affecting the productivity of foodgrains in India. As far as the substitutions between the two factors are concerned, apparently it looks that non-climatic factor can be substituted for the climatic factor but to what extant this substitution could be cost effective, depends on the relative price of the two factors.

Keywords: Foodgrains Productivity, Climatic Factors, Non-climatic Factors, Cobb-Douglas Production Function, Factor Substitution.

1. INTRODUCTION

The technical reform in agriculture introduced in India in form of 'Green Revolution' has been one of the greatest achievements that have improved the farm productivity as well as production. This improvement in technology was highly subsidized and did not put much burden on farmers with reference to the purchase of inputs or cost of inputs. Higher prices of inputs of the new technology further subsided by the massive increase in farm income. The realization of increased output was also become possible because of increase in area under cultivation supported by mechanization of farm practices and availability of assured means of irrigation. This improved the confidence of farmers and they started believing that Indian agriculture is no more a gamble of monsoon. But in the long run, unfortunately, this modern system of farm practices not only degraded the environmental quality but also disturbed the ecological balances and became responsible for climate change in India and started affecting the farm practices negatively (Sharma and Sharma, 2000). In addition to this, when the Indian Government moved on the path of economic reforms in early 1990s and became the founder member of World Trade Organization (WTO) in 1995, started withdrawing the subsidies on agricultural inputs, provided to farmers and consequently the cost of agricultural inputs followed a rising trend. Under these circumstances, it becomes very difficult for producers (farmers) to use increased level of agricultural inputs. In addition to this, the environmental degradation leading to climate change has further worsen the situation. Though at the aggregate level we have a rising trend for food grains production, it has been observed by many studies that there has been a fall in the productivity/yield of some crops (Kumar et al., 2023). The fall in the yield has also been recorded in some regions (Nayak et al. 2022).

Since most of the farmers in India are either small or marginal, it is difficult for them to cope up with this situation at their own and eventually the responsibility to fight against these evils fall on the shoulder of the governments, central as well as respective state governments. As a member of the WTO, it is very difficult for the governments to provide any direct fiscal support to the farmers to mitigate. However, indirect support may be provided by the government on the name of maintaining ecological balance and protecting environment (Stiglitz et al. 2007). Any support under this category may improve the status of climatic factors like rainfall, temperature, moisture content in atmosphere etc., and can improve the level of productivity of crops or can restrain the falling trend of yield in certain crops in some specified regions at least. But it is quite possible that the same level of fiscal support for improving the use of non-climatic factors may have better impact on the yield of the crops. It is, therefore, important to estimate the level of efficacy of these two broader categories of factors of production; climatic and non-climatic, in affecting the productivity of crops. The present paper makes an attempt to analyze the comparative position of these two broader categories of factors of production in affecting the level of productivity of foodgrains in India.

2. REVIEW OF LITERATURE

The negative impact of climate change on agriculture is more dangerous, more-specifically for India, because 52 percent of the population depends on climate sensitive-sectors like agriculture, forestry and fishery for their livelihood (Sathaye et al., 2006). Out of them 80 percent farmers are small and marginal and as a result, their ability to survive under the impact of climate change is reduced (Ranuzzi and Srivastava, 2012). The negative impact of CO_2 and temperature on agricultural output has been found in many studies like; Bannayan et al. 2014; Chandio et al. 2020; Sarker et al. 2014; Epule et al., 2018; Chandio et al., 2022; Warsame et al., 2021; Asumadusarkodie, 2016 and Gbetibouo and Hassan, 2005.

Hundal S. S (2007) examined through simulation model in Punjab and reported that 1°C rise in temperature can cause a 3 to 10 percent reduction in the yield of wheat and rice, respectively. A study conducted by Singh and Sharma, (2018), observed that variability of foodgrains is climate-sensitive and climate changes have adversely affected the yields of crops.

Non-climatic inputs such as irrigation, fertilizer, and seeds are represented in the studies of Chand and Prappurathu, 2012; Kumar and Sharma, 2013; Tripathi and Prasad, 2009 as the main indicators of agricultural productivity. However frequent natural hazards and contemporary climate change have mostly affected India due to lack of arable lands, dependence on rain fed farming, and less adoption capacity of technology (Birthal et al., 2014). It is estimated that in the current scenario of climate change, agricultural and productivity in developing countries could decline by an average of 20% and 15%, respectively (Masters et al., 2010).

Zafar et al. (2020) studied the influence of climatic and non-climatic factors on foodgrains production using co-integration and ARDL model. The study came to the conclusion that average annual temperature, irrigation, area, fertilizer and rainfall are positively associated with foodgrains production but the contribution of mean annual temperature in affecting foodgrains production is highest.

Kumar et al. (2017) estimated that the climatic factors have negatively affected the foodgrains availabilities, crop intensity, suitable irrigation facilities, use of modern technology and use of high yielding varieties of seeds. Ninan and Bedmatta (2012) used the cross section analysis of crops, and pointed out that climate change will differ across crops and areas. The study found that increase in temperature is the principal cause for declining agricultural productivity of foodgrains in different parts of India. This study suggested that mitigating the negative impact of climate change requires a better understanding of long-term innovation pathways, land use and the dynamic behavior of agricultural ecosystems.

Kalra et al. (2008) conducted a state wise analysis of four states of India, namely Punjab, Haryana, Rajasthan and Uttar Pradesh. The study observed that wheat, mustard, barley and chickpea production has decreased due to an increase in seasonal temperature. Kumar and Parikh (2001) argued that the prediction of large-scale changes in the climate would lead to huge reduction in foodgrains yield by 2060.

In the light of the above, it can be said that a very negligible studies are available that have used climatic factors as a single factor of production and non-climatic factors as well as a single factor of production.

3. RESEARCH METHODS

Present study seeks to identify the relative contribution of climatic and non-climatic variables (independent variables) in affecting yield (dependent variable) of foodgrains production in India. For the present study four important factors are taken to represent non-climatic factors with the assumption that food grains are produced by using high yield varieties (HYV) of seeds. These are area under cultivation (AUC) in million hectares, area under assured means of irrigation (AUI) as percentage of total cultivated area, labour (LR) and use of fertilizers (FTR) in lakh tonnes. The data for all these factors are collected from the Agriculture Statistics at Glance, Reserve Bank of India, World Bank, Ministry of Consumer Affairs, Food and Public Distribution, Government of India (www. Indiastat.com). The climatic factors are represented by rainfall (RF) measured in terms of millimeter (mm), CO_2 emission in per capita metric tonnes and maximum (MXT) & minimum (MIT) temperature in centigrade. Information regarding these variables is obtained from the Indian Meteorological Department (IMD, Government of India). The statistical results are based on the information collected for all these variables for a period of 32 years from 1986-87 to 2017-18. For both the factors affecting yield of food grains; (climatic and non-climatic factors) composite indices are prepared. The composite indices are calculated with the help of simple weighted index which maintains the uniqueness of multiple units. The outcomes of these indices are based on measurement of sub-indicators which have no common meaningful unit of measurement (Saisana and Tarantola, 2002). In calculation of these indices, four important steps are involved. These are selection of variables, normalization of data, weighting of data and summarization of results (Jones and Andrey, 2007). The present study used a standardization method to summarize and weight the indicators into an index (Gbetibouo et al., 2010) with the help of following expression.

$$Y_j = \sum_{i=1}^{n} w_i \, (x_{ij} - \bar{x}_i)/s_i$$

Where, Y = index, W = weight, X = indicator value, $\bar{x}$ = mean, S = standard deviation, i the indicator, and j the specific region.

After converting the selected climatic and non-climatic indicators in two broader categories, log linear regression model is used for obtaining the productivity function of foodgrains production by using climatic and non-climatic factors as independent variables and yield of foodgrains as dependent variable. The estimated productivity function can be represented as:

$$LnY = A + \alpha(LnCL) + \beta(LnNC) + U_i \qquad \textbf{(1)}$$

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Where Y represents yield, A is the intercept, CL represents climatic indicator, NC represent non-climatic indicator, and Ln represents the Natural log. This is a linear production function. To obtain the regression coefficients for the proposed model, EVIEWS software is used to fit the equation (1).

3.1 Marginal Rate of Technical Substitution

MRTS shows that the rate at which one factor is substituted for other so that the same level of output can be maintained. The MRTS is the slope of the isoquant connecting the two inputs (climatic & non-climatic) as long as the output remains the same. Marginal rate of technical substitution can be worked out by using the following formula:

(i) MRTS of climatic (CL) for non-climatic (NC) is

$$\mathrm{MRTS}_{(\mathrm{CL,NC})} = \frac{\mathrm{MP_{CL}}}{\mathrm{MP_{NC}}} = \frac{\alpha}{\beta} \qquad \textbf{(2)}$$

(ii) MRTS of non-climatic (NC) for climatic (CL) is

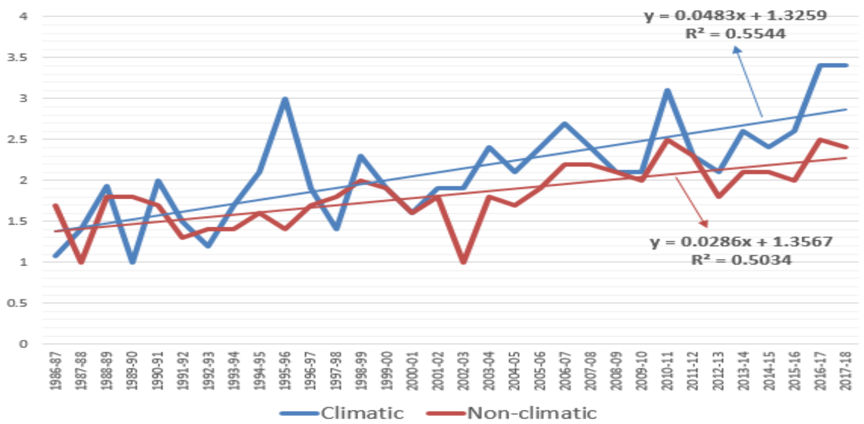
$$\mathrm{MRTS}_{(\mathrm{NC,CL})} = \frac{\mathrm{MP_{NC}}}{\mathrm{MP_{CL}}} = \frac{\beta}{\alpha} \qquad \textbf{(3)}$$

Where, MP_{CL} is marginal product of climatic factors and MP_{NC} is marginal product of non-climatic factors. In general, the sign of MRTS is negative and shows a tradeoff between two inputs.

4. TRENDS OF CLIMATIC AND NON-CLIMATIC INDICATORS

The trend line is linearly fitted for both climatic and non-climatic indicators with R-squared value of 0.55 and 0.50 respectively. Overall, both climatic and non-climatic indicators have shown a rising trend during the study period. Initially, the influence of non-climatic indicator was higher than that of climatic indicator, but over time, the influence of climatic indicator has improved and become greater than that of non-climatic indicator. The improvement in the influence of the climatic indicator may be due to various initiatives taken by both the central and state governments towards increasing forest cover and reducing the pace of environmental pollution on account of rising economic activities (Kothari et al., 2020). A comparatively lesser influence of non-climatic indicator is the result of a fall in the size of direct support provided by the government to farmers for input purchases and other logistic supports after economic reforms and the emergence of the World Trade Organization (WTO) (Meléndez et al., 2009). The relative impact of climatic and non-climatic indicators is very much clear from Fig. 1.

Figure 1: Trends of Climatic and Non-Climatic Indicators



(Source: Author's Processed Data from Table 1)

Nevertheless, it is important to note that, theoretically, climatic factors are not supposed to be influenced by non-climatic factors. Climatic factors are determined by changes in the natural environment. Contrary to this, non-climatic factors are controlled by humans and can be adjusted as per the behavior of climatic factors. For example, if, in any time period and at any place, the rainfall is less, it can be substituted by the assured means of irrigation. It means that there is a one-way substitution between climatic and non-climatic factors. Hence, the substitutions between non-climatic and climatic indicators depend on the behavior of the climatic factor. The trend line shows the increasing gap between climatic and non-climatic factors over the period of study. Figure 1 shows three distinct patterns between climatic and non-climatic indicators. Initially, before the emergence of the WTO, as the influence of climatic indicator improved, it led to a fall in the influence of non-climatic indicator (with a few exceptions). In the post-WTO regime, there is a fall in the influence of climatic indicator, and hence, to save agricultural practices, the influence of non-climatic indicator has improved or the non-climatic indicator has been substituted for the climatic indicator. This phenomenon is up to 2001–02. After 2001-02 the influence of both climatic and non-climatic indicators has increased.

5. RESULTS AND DISCUSSION

Both climatic (CL) and non-climatic (NC) factors are important determinants of productivity. To know the contribution of these two variables in deciding the level of productivity of foodgrains in India, the Cobb-Douglas production function approach is being used with the help of the log-linear regression model. To ensure the use of statistical data for empirical analysis, the classical assumptions test is being done. The statistical results of this test satisfied the various conditions allowed for the use of data for empirical study. The statistical results of the model are presented in Table 2.

Table 2: Summary Statistics for Equation 1

Variables	**Coefficient**	**Standard Error**	**t-statistics**	**Probability**
Climatic	**0.66**	0.16	4.02	**0.0004**
Non-Climatic	**0.70**	0.26	3.09	**0.0043**
Constant	**0.14**	0.12	1.15	0.2579

R-Squared	**Adjusted R-Squared**	**F-Statistic**	**Prob.(F-Statistic)**
0.67	**0.65**	**30.10**	0.000000

(Source: Author's Processed Data)

The regression result for the model explained by equation 1 is statistically significant as explained by the value of the F statistics. The explanatory power of the selected variables in the model is also good which is very much clear from the values of R-squared and adjusted R-squared. Both the variables of the model; climatic and non-climatic are statistically significant and positively related with the foodgrains productivity. It means that productivity of foodgrains can be improved by improving the climatic conditions as well as the access of non-climatic factors. The non-climatic factor has proved to be more powerful in affecting the productivity of foodgrains but the importance of climatic factor may not be undermined as its coefficient value is comfortably good (0.66). In addition to this, the summation of the two coefficients is more than one; the factors combined together provide an increasing returns to scale to the yield of foodgrains production in India.

5.1 Substitutability between Climatic and Non-climatic Factors

For the present study two major factors (climatic and non-climatic) have been selected as the explanatory variables for a change in productivity of foodgrains in India. It has been observed that in the post reform period there are some incidences of fall in the productivity of foodgrains which is more evident from the state wise data and in some cases it is constant. The main factor which has been kept responsible for this is the sharp rise in the cost of inputs. Since under clauses of WTO commitments, no direct subsidy can be provided on farm input to reduce the cost of production, the only option which we have is to support the farmers for environmental protection, conservation of resources etc. In this way, in most of the cases government support can be mainly provided to improve the climatic conditions to support the foodgrains production. However, rationality behind this can be only judged by knowing the tradeoff in efficiency of climatic and non-climatic factors in affecting the productivity of foodgrains. The tradeoff between the productivities of climatic and non-climatic factors may give us necessary information and justification for providing subsidies/support to a particular category of factor of production.

On the basis of statistical results for equation 1, the marginal rate of technical substitution between climatic and non-climatic factors may be represented as by using equations 2 and 3.

(i) MRTS of Climatic (CL) for Non-climatic (NC)

$$\mathrm{MRTS}_{(\mathrm{CL,NC})} = \frac{0.66}{0.70} = 0.94 \quad \textbf{(4)}$$

(ii) MRTS of Non-climatic (NC) for Climatic (CL)

$$\mathrm{MRTS}_{(\mathrm{NC,CL})} = \frac{0.70}{0.66} = 1.06 \quad \textbf{(5)}$$

The MRTS of climatic factors for non-climatic factors is 0.94, indicating that increasing one unit of climatic variables requires substituting 0.94 units of non-climatic variables (equation 4). Similarly, the MRTS of non-climatic variables for climatic variables is 1.06, indicating that if we increase one unit of non-climatic variables; we must replace 1.06 units of climatic variables (equation 5) to retain the same level of yield. However, as the substitution between two factors of production depends on their relative price, a decision can be made only after receiving this information.

5.2 Diagnostic Test

To validate the model and statistical results, a classical assumptions test is done that comprises of multicollinearity, heteroscedasticity, serial correlation and normality tests. For analyzing the problem of heteroscedasticity, white test is being used. The serial correlation test is done with LM (Bruesch Godfrey) test. The Variance inflation factor is used to detect the problem of multicollinearity whereas; Jarque-Bera test is used to examine the normality of the data.

Table 3: Diagnostic Test

Diagnostic Tests	Test Name	Prob.values	Value
Serial correlation	Bruesch Godfrey (LM) test	**0.09**	-
Heteroscedasticity	White test	**0.62**	-
Normality	Jarque-Bera	**0.35**	-
Multicollinearity	Variance inflation factor	-	**1.49**

(Source: Author's Processed Data)

The findings in Table 3 show that the model passes the diagnostic tests. Errors are normally distributed, and their variance is constant over time. Further, there is no evidence of serial correlation, heteroscedasticity, and non-normality of the data because the probability values of these tests are greater than 0.05. For multicollinearity, the value of VIF is 1.49 which indicates that there is no problem of multicollinearity (Shrestha, 2020). Therefore, the model is properly specified and satisfied the classical assumption tests.

6. CONCLUSION

The Cobb-Douglas production function result shows that both climatic and non-climatic variables are positively associated with yield of foodgrains production and results are statistically significant. As compared to climatic factors, the non-climatic factors are comparatively more influential in affecting the productivity of foodgrains in India. This is clear from coefficient values. The elasticity of yield with respect to climatic factor is 0.66 whereas the with respect to non-climatic factors the value is 0.70. As the summation of the two coefficients is more than one, the factors combined together provide an increasing return to scale to the yield. A fall in productivity at any point of time may just be a part of cyclical or seasonal fluctuations or a result of any other unwanted climatic/non-climatic event.

As far as the substitutions between the two factors are concerned, apparently it looks that non-climatic factor can be substituted for the climatic factor but to what extant this substitution could be cost effective, depends on the relative price of the two factors. Estimation of the prices of climatic and non-climatic factors can be one of the areas for future studies.

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APPENDIX

Table 1: Values of composite index for Climatic and Non-climatic factors

Years	Yield	Climatic	Non-Climatic	Years	Yield	Climatic	Non-Climatic
1986-87	1128	1.08	1.65	2002-03	1535	1.93	1.00
1987-88	1173	1.41	1.04	2003-04	1727	2.38	1.81
1988-89	1331	1.93	1.82	2004-05	1652	2.07	1.69
1989-90	1349	1.00	1.75	2005-06	1715	2.42	1.95
1990-91	1380	2.00	1.71	2006-07	1756	2.66	2.17
1991-92	1382	1.49	1.31	2007-08	1860	2.38	2.17
1992-93	1457	1.18	1.40	2008-09	1909	2.13	2.14
1993-94	1501	1.73	1.42	2009-10	1798	2.14	1.99
1994-95	1546	2.08	1.61	2010-11	1930	3.08	2.45
1995-96	1491	3.00	1.40	2011-12	2078	2.32	2.26
1996-97	1614	1.91	1.68	2012-13	2129	2.13	1.83
1997-98	1552	1.41	1.79	2013-14	2120	2.56	2.13
1998-99	1627	2.31	1.96	2014-15	2028	2.40	2.12
1999-00	1704	1.89	1.88	2015-16	2042	2.59	2.04
2000-01	1626	1.62	1.62	2016-17	2153	3.43	2.50
2001-02	1734	1.91	1.79	2017-18	2233	3.35	2.38

(Source: Author's Processed Data)