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RESEARCH ARTICLE

GLOBAL CLIMATE CHANGE AND ITS IMPACT ON WORLD CEREAL PRODUCTIVITY AND AREA OF LAND UNDER CULTIVATION

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ABSTRACT

The over ambitious approach of mankind towards development has invited so many environmental problems. Rising temperature is one of them. It is expected that the rising temperature will have a dent over the cereal productivity despite the fact that a lot of improvement have been realized in farm mechanization. It was also expected that rising temperature will affect the soil fertility and may reduce/stop the process of bringing new land under the farm cultivation. To analyze these relationships simple statistical tools like correlation and regression are used. The statistical results are against the expectation. We have a positive regression coefficient between cereal productivity and temperature showing that with the rise in temperature cereal productivity has increased. The correlation value between temperature and capital states that the negative impact of temperature is eliminated by improving the process of adoptability since increase in temperature is accompanied by rise in the use of capital. At the same time the positive correlation value between temperature and land shows that temperature has not made any negative impact on soil quality and thus cereal productivity.

INTRODUCTION

Though there are some question marks over the results given by Intergovernmental Panel on Climate Change (IPCC) in its assessment however there is general agreement over the fact that the climate of the world is changing. This climate change has already affected the economic system of the world (IPCC, 1996) in which some economies got positive and some got negative impact (Magrin *et al.,* 1999) over their economic activities. Even in the same economy sectoral differences are realized in response to climate change (IPCC, 2001). Regional variation has also emerged as an important aspect of the climate change (Sala and Paruelo, 1994; De Siqueira *et al.,* 1994; Rosenzweig *et al.,* 1994). But in aggregate it is acknowledged that the climate change has brought more bad news than good one (Adams *et al.,* 1998) that forced the natural and social scientists to analyse the size of economic losses, the degree of vulnerability of various economies, its measurement, causes of the problems and their probable remedies. Among all sectors of the economy agriculture is termed as most sensitive to the climate. The productivity and the production of agricultural commodities are primarily determined by the climatic conditions in ceteris paribus condition because it not only provides an environment for the growth of the crops and their health but also decides the quality and texture of the soil which is the primary determinant. A change in climate is expected to bring changes in almost all spheres of agricultural practices.

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Since we can not discuss all the dimensions of climate change and its impact on agriculture, in the present paper we will try to explore that;

1. How global climate change has affected the world cereal productivity
2. How global climate change has affected the land area under cultivation of cereals and
3. How the capital has reacted towards world cereal productivity with reference to climate change.

REVIEW OF LETERATURE

The agricultural production and productivity are primarily determined by the climate. A change in climate is expected to influence the whole agricultural system (Waggoner, 1983). To know the effects of climate change on agriculture many studies have been conducted around the world. It is estimated that a change in climate may bring negative impact on maize production in Argentina by a fall in the yield ranges between 36 to 17 per cent (Sala & Paruelo, 1994). In the same manner a study about climate change and its impact on agriculture system of Brazil revealed that the production of wheat may go down by 50 to 15 per cent. Further the production of maize and soybean is expected to fall by 26 to 2 per cent and 61 to 6 per cent respectively (De Siqueira *et al.,* 1994). The study conducted by Rosenzweig *et al.,* (1994) estimated that in USA the production of wheat and maize may reduce by 20 to 2 per cent and 30 to 15 per cent respectively because of climate change. However there may be positive impact on the production of soybean. Murdiyarso (2000) reviewed the impact of climate change on potential rice production in Asia in the light of adaptation to climate variability and change. He found that the potential yield of rice may go down by 7.4 per cent per degree increment of temperature. The study predicts that rice production in Asia may decline by 3.8 per cent in next century. In 2007 a study was conducted to examine the impact of climate change on crop farming in Camroon (Lambi *et al.,* 2007). The analysis finds that net revenues from agriculture fall as precipitation decreases or temperature increases.

Conceptual Framework

To analyse the effects of climate change on agriculture most of the previous studies have used two methodologies namely production function approach and Ricardian Approach. Production function approach which is also known as crop modeling is a laboratory based study which is conducted under controlled agricultural experiments. Because of this nature of the study the outcomes may not reflect the rational results since agriculture is not practiced in laboratories but in open fields. Hence scientists prefer the Ricardian approach of production analysis (Mendelsohn *et al.,* 1994) which is closer to the reality and uses the data of actual field outcomes instead of outcomes of laboratories. For the present analysis we too use the Ricardian approach.

In this study the performance of agriculture is represented by world cereal productivity. Though the world cereal productivity may be affected by a number of factors, for the present study only four indicators are chosen. These are land area under cultivation, capital, temperature and precipitation (the later two as representatives of climate). In this limiting model it is assumed that every increase in area of land under cultivation comprises of low productive soil (Recardo, 1817) which put negative impact on cereal productivity. This means that an increase in land area under cultivation is negatively related with world cereal productivity. Capital which is an important factor of the model is represented by tractors, tools and machinery and it is assumed that an increase in capital stock will not only improve the cereal productivity but also give strength to fight against negative impact of climate change. Capital represents the degree of vulnerability of agriculture to the climate change (temperature variation) since it helps in shortening the period of sowing and harvesting in addition to providing the assured irrigation facilities as and when required so as to fight against the high temperature and low rainfall (Pingali and Heisey, 1999).

The third indicator of the model is temperature. Temperature may have negative as well as positive impact on world cereal productivity depending upon the temperature of a region because for the crops the ideal temperature ranges between 8^0 to 32^0 C. Different studies have shown that the variation in average temperature – an indicator of climate change has great importance in determining the level of productivity (Rosenzweig *et al.,* 1994). Precipitation is last indicator of the model. Precipitation too may have negative as well as positive impact. An increase in precipitation may provide enough water for irrigation that increases the cereal productivity and vice versa (Falco and Chavas, 2008). From the above discussion the relationship between the determinants of world cereal productivity and the volume of cereal productivity can be analysed by taking world cereal productivity as dependent variable and land area under cultivation, capital, temperature and precipitation as independent variables. The model can be expressed in form of population regression function (PRF) as;

$$Y_i = \beta_1 + \beta_2 L_i + \beta_3 K_i + \beta_4 T_i + \beta_5 P_i + u_i$$

Where, Y_i represents the average quantity of cereal productivity, L_i, K_i, T_i and P_i represent the figures of Land Area under cultivation (sq.km), size of capital in terms of number of tractors and machinery, annual average temperature in degree Celsius and annual average precipitation in millimeters respectively in i^{th} time period. u_i represents the error term of the model.

The above PRF model for log values may be rewritten as;

$$\ln Y_i = \ln\beta_1 + \beta_2 \ln L_i + \beta_3 \ln K_i + \beta_4 \ln T_i + \beta_5 \ln P_i + u_i$$

Or

$$\ln Y_i = \beta_0 + \beta_2 \ln L_i + \beta_3 \ln K_i + \beta_4 \ln T_i + \beta_5 \ln P_i + u_i$$

Where $\beta_0 = \ln\beta_1$

On the basis of above model we have formed different regression equations (double and multivariate) for the period of 1961-2007.

RESULTS AND DISCUSSION

The correlation matrix for the variables (land, capital, precipitation, temperature and cereal productivity) obtained with the help of SPSS programme based on the log values are represented as follows:

Correlation matrix

	Yield	Area under Cultivation	Capital	Temperature	Precipitation
Yield	1	.963**	.983**	.817**	-.173
Area under Cultivation		1	.982**	.831**	-.204
Capital			1	.810**	-.207
Temperature				1	-.092
Precipitation					1

Source: Given in Appendix 1.

All the values of correlation at 0.01 level of significance are significant except precipitation. The correlation matrix clearly tells that the world cereal productivity is largely determined by capital use that may be the reason behind higher cereal productivity in developed nations where use of capital is very high. The correlation value between cereal productivity and temperature is relatively lower than the capital but it is statistically significant. A highly significant correlation value between capital and land under cultivation clearly explains that the use of tractors and machines have played a crucial role in the growth of area of land under cultivation. We can also observe from the above table that the correlation value between temperature and land under cultivation is statistically significant i.e. 0.831. This value implicitly said that temperature may be a determining factor in case of area under cultivation because a particular minimum temperature is required for maintaining the soil fertility and sowing of crops. On the basis of above model the relationship between world cereal productivity and land under cultivation, capital, temperature and precipitation can be represented in form of regression equation based over the log values of all parameters as follows for the period of 1961 to 2007.

lnY_i= 22.488 -2.249 ln L_i +1.078 ln K_i +2.55 ln T_i + 0.279 lnP_i

Equation 1

Standard Error (19.461) (1.304) (0.167) (1.186) (0.370)
t values 1.156 -1.725 6.44 2.15 .0753

For the present regression equation the value of R^2 is 0.956. This indicates that on average the world cereal productivity is dependent on these four explanatory variables by nearly 96 per cent. The standard error of estimate is also low. The t values for all independent variables show that the coefficient of regression for all variables is statistically significant. However there is difference in degree of association between cereal productivity and explanatory variables. The land area under cultivation for cereal production in the world is negatively associated with world cereal productivity. The negative sign of coefficient of land under cultivation for cereal productivity may be because of the fact that the increase in land area under cultivation is mainly comprises of less fertile soil. Keeping all other independent variables constant one percent rise in land area under cultivation can reduce the world cereal productivity by 2.25 per cent. Similarly one per cent increase in capital, temperature and precipitation can increase the productivity by 1.08 per cent, 2.55 per cent and 0.28 per cent respectively. The analysis of degree of association between dependent and independent variables shows that temperature (the positive relationship between temperature and world cereal productivity may be because a large portion of agricultural land lies in humid climatic zone where a slight increase in temperature can have positive impact on cereal productivity. But at the same time we can not negate the fact that climate has negative impact as well which is clear from various studies of different regions) and precipitation have the highest determining positive effect on the cereal productivity of the world in comparison to capital and land under cultivation (non climatic indicators). To know the individuals or group importance of predicators in explaining effects on world cereal productivity following multivariate and bivariate regression equations are prepared:

lnY_i= -10.841 +0.805 ln K_i +1.841 ln T_i +0.3 ln P_i

Equation 2

Standard Error (2.369) (0.057) (1.145) (0.381)
t values -4.576 14.141 1.607 0.787
$R^2 = 0.95$
lnY_i=-30.241 + 14.619 ln T_i - 0.726 ln P_i

Equation 3

Standard Error (5.056) (1.842) (0.978)
t values -5.981 7.935 -0.743
$R^2 = 0.66$
lnY_i=0.777 -0.454 ln L_i +0.90 ln K_i

Equation 4

Standard Error (15.716) (1.007) (0.127)
t values 0.049 -0.451 7.089
$R^2 = 0.97$
lnY_i = -29.978 + 14.252 ln T_i

Equation 5

Standard Error (19.461) (1.304)
t values -6.842 8.618
$R^2 = 0.67$

lnY_i = 9.563 - 1.878 lnP_i

Equation 6

Standard Error (1.685) (1.732)
t values 5.675 -1.084
$R^2 = 0.03$

lnY_i = -6.309 + 0.843 ln K_i

Equation 7

Standard Error (19.461) (1.304)
t values -15.885 35.496
$R^2 = 0.97$

The Equation 2 shows that the importance of temperature and capital remain same even after eliminating the effect of land area under cultivation on world cereal productivity. The effect of changes in temperature became stronger on world cereal productivity after dropping land area under cultivation and capital. The value of coefficient of regression further increased to 14.252 when we take temperature as single determinant of world cereal productivity. This shows that as dependency of world cereal productivity increases on temperature the degree of association between these two becomes stronger and stronger with a fall in average prediction capacity from 96 per cent to 66 per cent. From equation 3 it can be further observed that in absence of land under cultivation and capital the model turn out to be more prone to climate change. Throughout the analysis it can be seen that temperature is positively related with world cereal productivity. Keeping in mind the trend of world temperature (which has increased over the time) it can be said that an increase in temperature has led to increase in world cereal productivity and vice versa. The positive value of regression coefficient for temperature may be against the general notions that rising temperature has negative impact over the cereal productivity (Singh, 2010). This may be because of the fact that rising temperature is not a problem in itself. General crops may bear the average temperature of 32^{o}C. The rising temperature may harm the corps if it is accompanied by the seasonal disturbances like drought, floods, falling moisture, cyclones etc.

The other indicator of climate change is precipitation. This though seems to be not much effective in predicting the world cereal productivity in the presence of land area under cultivation, capital and temperature but when we drop these other indicators one by one the value of regression coefficient of precipitation increases slowly and slowly from merely 0.279 in equation 1 to 1.878 in equation 5. For the study period the precipitation has show two different behavior. Firstly it is positively related with world cereal productivity in the presence of land area under cultivation and capital.

APPENDIX.1

Years	Land Area (sq. km)	Capital (No. of tools, machinery & tractors)	Temperature (Degree Celsius)	Cereal Yield (Kg per Hectare)	Average Annual Precipitation (mm)
1961	44506825	9957528	14.01	1430	2.67
1962	44615135	10348175	NA	1521	2.68
1963	44712252	10771839	NA	1586	2.63
1964	44807418	11186249	NA	1587	2.68
1965	44937600	11520046	13.9	1636	2.58
1966	45051951	12551045	13.96	1677	2.66
1967	45173561	12886785	14	1761	2.64
1968	45275392	13140297	13.94	1778	2.64
1969	45493555	13430582	14	1802	2.64
1970	45568735	13576372	14.02	1829	2.68
1971	45710895	13920917	13.89	1980	2.67
1972	45860846	14231394	14	1967	2.57
1973	46015797	14562981	14.13	1997	2.78
1974	46158554	14903737	13.89	1978	2.72
1975	46233666	15357889	13.94	2090	2.77
1976	46233344	15690270	13.86	2097	2.62
1977	46280202	16122244	14.11	2144	2.64
1978	46324149	16570364	14.02	2307	2.68
1979	46470726	17033688	14.09	2342	2.65
1980	46596814	17370731	14.16	2302	2.63
1981	46668609	17823575	14.22	2449	2.72
1982	46805212	18198281	14.06	2545	2.57
1983	46992437	18595620	14.25	2453	2.6
1984	47195326	18985114	14.07	2704	2.67
1985	47546301	19420636	14.03	2710	2.63
1986	47811829	19906958	14.12	2704	2.62
1987	47997059	20323967	14.27	2691	2.55
1988	48258005	20414525	14.29	2612	2.7
1989	48409678	20692877	14.19	2768	2.68
1990	48516683	20755239	14.37	2882	2.64
1991	48527119	20616582	14.32	2873	2.57
1992	48890891	23218243	14.14	2786	2.53
1993	49165338	23364933	14.14	2734	2.57
1994	49284625	23532645	14.25	2810	2.59
1995	49253747	23601562	14.37	2759	2.63
1996	49273641	23671328	14.23	2940	2.66
1997	49276202	23849429	14.4	2988	2.57
1998	49373427	24018700	14.56	3659	2.67
1999	49465381	24252472	14.32	3105	2.74
2000	49537512	24769635	14.31	3065	2.69
2001	49607891	25358526	14.36	3129	
2002	49443623	25520037	14.52	3071	
2003	49309790	25837879	NA	3114	
2004	49393713	26050571	NA	3358	
2005	49394474	26557007	NA	3281	
2006	49314750	26862012	NA	3285	
2007	49261240	27433179	NA	3382	

Source: (i) www.worldbank.org (ii) www.mospi.co.in (iii) http://data.giss.nasa.gov/

Secondly it turned to negative in absence of these above two non climatic parameters particularly capital. This reveals that falling precipitation will have positive impact only in the presence of capital that facilitates the various agricultural activities otherwise falling precipitation may put negative impact.

From the regression equation 1 to 7 it can be observed that there are two sets of indicators that determine the world cereal productivity. One belongs to climate and represented in terms of temperature and precipitation and other belongs to non climate which are represented by land area under cultivation and capital. In the presence of non climatic factors though temperature plays important role however in absence of this, it's important has not only increased but precipitation also became effective in controlling the world cereal productivity. However, predicting capacity of climate reduces in the absence of non climatic factors. It can be therefore said that the negative effect of fall in precipitation on world cereal productivity has been/can be minimized by using non climate sensitive factors which are land area under cultivation and capital. Climate change is also associated with the size of land area under cultivation. It is believed that a rise in temperature reduces the moisture content of soil and makes it unfit/low usable for cultivation. But it may be fruitful in humid climatic zone. In the same way falling precipitation increases the area of dry land and reduces the area under cultivation and vice versa. Equations 8, 9 and 10 discuss these relationships between land area under cultivation and temperature & precipitation.

$\text{Ln } L_i = 11.905 + 2.237 \ln T_i - 0.163 \ln P_i$

Equation 8

Standard Error (0.746) (0.272) (0.144)
t values 15.955 8.225 -1.132

$R^2 = 0.68$

$\text{Ln } L_i = 11.747+2.236\ln T_i$

Equation 9

Standard Error (0.653) (0.246)
t values 18.001 9.078

$R^2 = 0.69$

$\text{Ln } L_i = 17.982–0.326\ln P_i$

Equation 10

Standard Error (0.746) (0.272)
t values 15.955 8.225

$R^2 = 0.04$

Equations 8 and 9 clearly show that the rising temperature has put positive impact on area under cultivation for cereal production, this may be because of the fact that a large area of land under cultivation for cereals falls in humid climatic zone. The value of regression coefficient is also very high which shows the effectiveness of temperature in determining the land area under cultivation for cereals production. From equations 7 and 9 it can be realised that though falling precipitation is negatively related with area under cultivation for cereal production however the value of regression coefficient is so small that it is insignificant. It may be because of rise in capital consumption which provides the assured means for irrigation. The values of R^2 in equation 8 and 9 reveal that it is the temperature which is comparatively more effective in predicting the average area of land under cultivation for cereals.

Conclusion

While accepting the temperature as an indicator of climate change, the present paper has discussed the relevance and reliability of temperature in determining the level of cereal productivity of the world. The regression models have clearly revealed that temperature is an important determinant of world cereal productivity. A rise in temperature has positively affected the world cereal productivity. Independent to the other variables temperature has become more effective in determining the world cereal productivity. The degree of association between temperature and world cereal productivity increases as we drop other factors one by one. The falling precipitation has negatively affected the world cereal productivity but it is not significant along with other factors however it becomes significant in absence of other factors. It can be therefore said that climate change has great implication for agriculture because it affects the productivity of the farm. Climate change has proved to be effective in determining the area of land under cultivation for cereal production. Temperature has always been an important determinant for area under cultivation with or without precipitation and it is positively related. But precipitation has not been significant factor in determining the area of land under cultivation, however, its degree of association increases independent to temperature. As far as the role of capital in reducing vulnerability of cereal production to climate change is concerned the answer is yes. In the presence of capital the regression coefficients for temperature and precipitation are low while in absence of this their value increases. In the same manner in the presence of capital the regression coefficient for precipitation is positive while in absence it becomes negative showing that the negative effect of fall in precipitation can be neutralize by use of capital.

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