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EFFECTS OF CLIMATE CHANGE ON AGRICULTURE IN INDIA

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Abstract

Climate change is extended an alteration in temperature of normal climate patterns at a particular region. Climate change has been a regular kind of disaster for the agriculture in India. Uttar Pradesh climate is hot monsoon which may consider as warm weather around the year. Climate change has influenced by the major gases of Green House i.e. Co2, Ch4 and N2O and other gasses from fossil fuel burning, motor vehicle pollution. This study is basically focused on at national level, how climate change is affecting to the agriculture production in India that how climate is affecting the agriculture production at national level. In this research secondary data have been used to find out the result. Due to increase in greenhouse gases climate is changing and it is impacting in several ways to the agriculture along with temperature and rainfall. There is a decline in production of Kharif crops and the use of land area due to decrease in rainfall in India. As an extraneous factor fertilizer (N+P+K) play a significant role in sustaining the production of rice and wheat. In concluding remark, it is necessary to take effective measures to stop the climate change as it is impacting on agriculture production negatively in short term but in long term adaptation of climate change will mitigate more than half agriculture production.

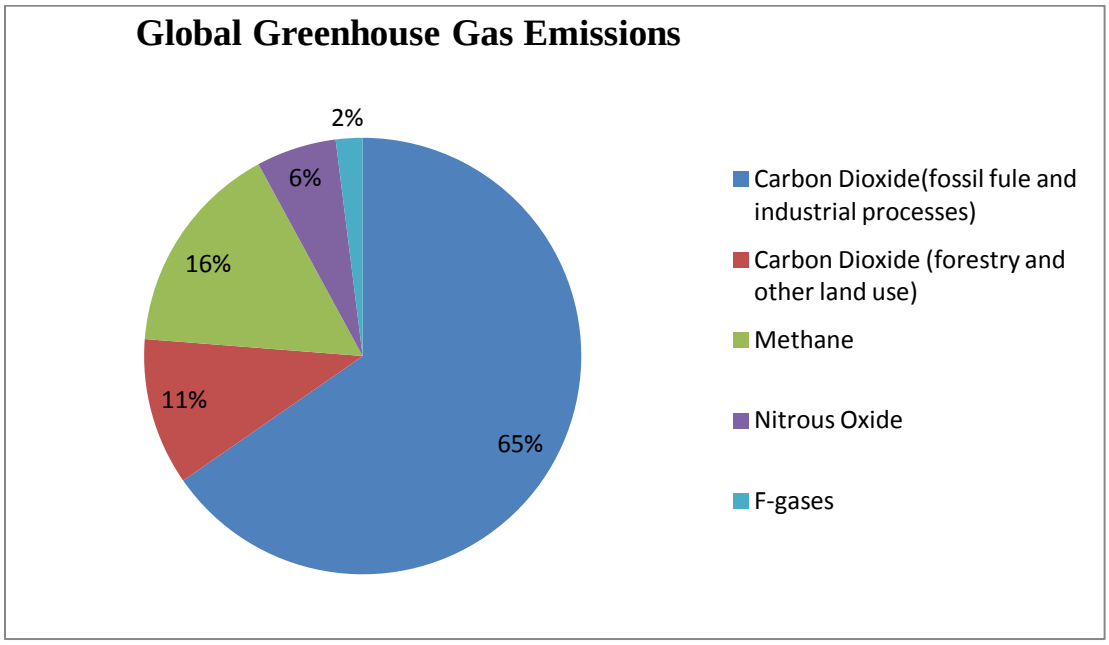
Keywords: Climate change, Agriculture production, Temperature, Rainfall, Disaster

Introduction

Climate change is the extended an alteration in temperature of normal climate patterns at a particular region. Climate change has been a regular kind of disaster for the agriculture in India. Some time it is favourable to the formers and some time it is non – favourable. Climate includes temperature, clouds, humidity, rainfall, drought, speedy wind, atmosphere pressure etc. Climate change is an environmental effect which is uncontrollable by human being and it is a natural process which normally occurs at any place. Climate changes refer that deviation in the global climate. It explains changes in the inconsistency of the environment during the time from long period.

Climate change harmfully affects wheat and rice yield. Globally observed that wheat yield shown that there is a decrease of 0.60 ton/ha/dec up to 0.40 ton/ha/dec in 2000.In other side rice production has a small raise of 0.50 ton/ha/dec up to 0.60 ton/ha/decade in 2000. Birthal et al. (2014) has anticipated that, there will be a considerable variation in rainfall and temperature till 2100 in India, so that there will be decrease near 15% in yield of rice and near 22% in yield of wheat shall be happened.

Intergovernmental Panel said on Climate change that 90 to 95 per cent climate changes are occurred due to human action. United Nation Framework convention on Climate Change (UNFCCC) said that it is presumption of human causation that climate variability for non-human caused variation. Normally climate change has long term considerable change in the normal weather that particular region faced. Normal weather means, normal temperature, precipitation and wind pattern. Most important climatic mechanism which control the growth, yield and quality of wheat and rice are the availability of sunlight, moisture and temperature, sunlight and moisture. In recent year the possibility of global climates changes in increasing day by day. Carbon dioxide and other kind of harmful gases are increased from normal percentage and negatively affecting to the environment, which is also changing the climates. Climate change has influenced by the major gases of Green House i.e. Co2, Ch4 and N2O and other gasses from fossil fuel burning, motor vehicle pollution. The major factors for increasing greenhouse gases are contributing as below;



Source- IPCC 2014 **Graph: 1**

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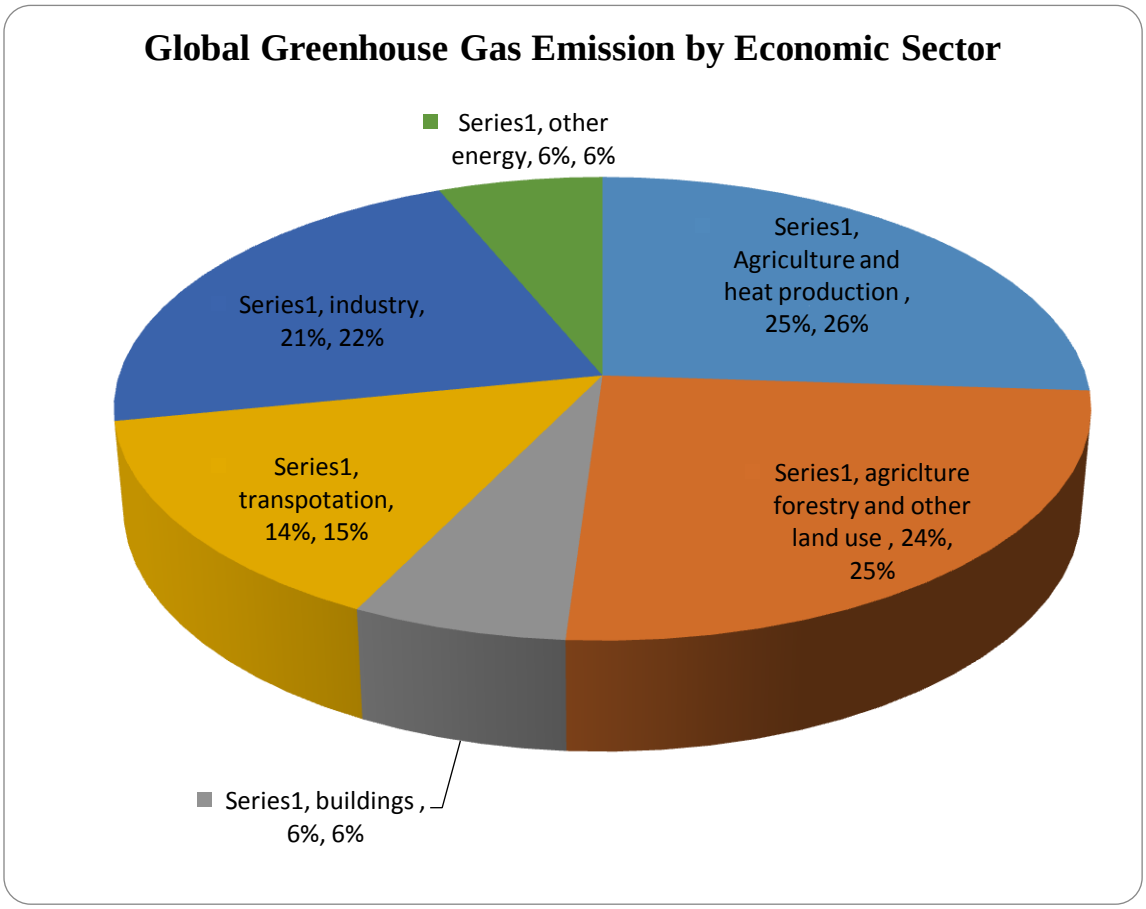


Source- IPCC 2014 **Graph: 2**

Greenhouse gas emission and physical manifestation of increasing anthropogenic& development activities around the globe are the major source for global worming threats. Climate change can be mega catastrophe if people and government will not serious actions. Climate change is the greatest threat to the environment in the world and it is duty of every government and scientist to do forcefully needful as required. Industrialization without taking measures pollution control steps, contribution of Co2 emission at high level also increase the atmospheric change and affecting to the climate. Following is the distribution of Green Gases as revealed by Industry

Climate Change and Agriculture in India:

Agriculture is the nerve centre of Indian due to its high share in employment and livelihood creation. However, its involvement to the gross domestic product (GDP) of India is diminished day by day.

Role of Agriculture sector is important in Indian economy in the perspective of employment and poverty allegation in India. The contribution of agriculture in national income has been reduced from 56%in 1950-51 to 39.6%in 1980-81 and 26.3% in 2001-2002. As per the 2013-14 advance estimates released by CSO, the agriculture and allied sector accounted at base price 2004-05, the GDP was 16.8% in 2007-08 and 13.9% in 2013-14.

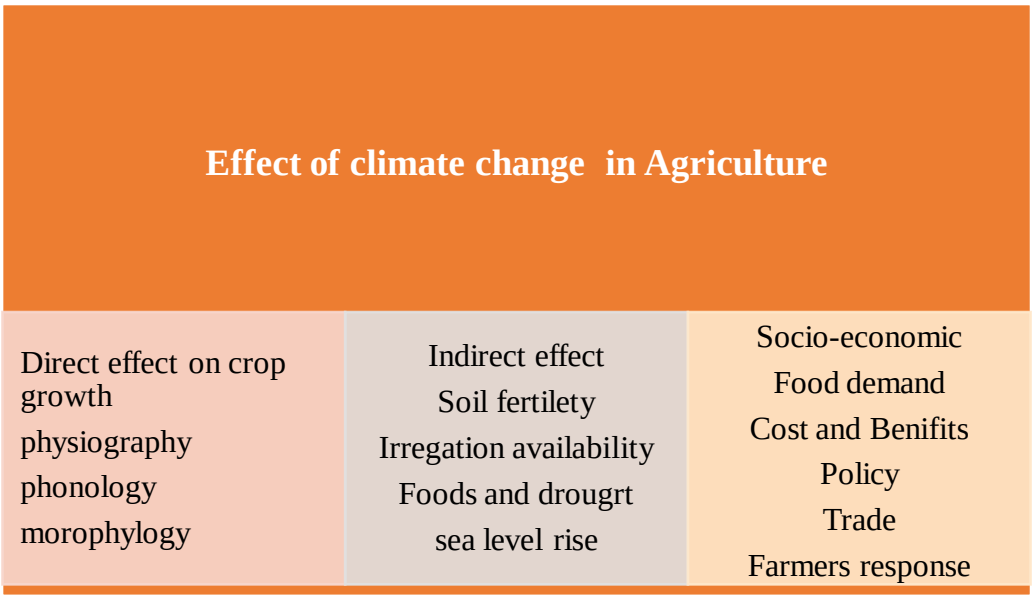
Presently, CSO has released new series of national income at base price 2011-12 , the contribution of agriculture is 18% in total GDP during 2013- 14. According to the CSO the growth rate in GDP during 2018-19 is estimated at 7.1% in comparison to the growth rate of 6.7% in 2017-18.

Agriculture's share in GDP has declined rapidly in the recent past year. 50%of the total labour force in India is engaged in Agriculture. Agriculture and allied sectors are critical in terms of employment and livelihoods for the marginal and small farmers. With decline in the size of landholding in agriculture, India has to focus on resource efficiency in smallholder farming to meet the SDG target and also to attain sustainability in agriculture.

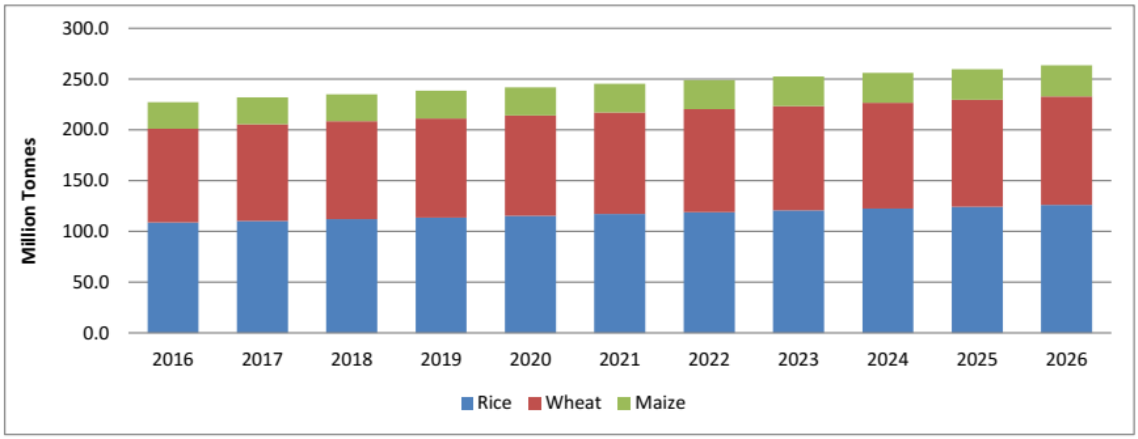
A combination of resource efficient methods, dynamic cropping pattern, farming which is approachable to climate change and intensive use of ITCs should be the backbone of smallholder farming in India (economic survey) thus it leads to unnecessary stress on the land and area under food green cultivation then it will turn into reduction of it. It is very much challenging to the government to maintain sustainable growth to ensuring food, dietary security along with income security of the farmers as well as increasing agriculture production with limited natural resource. According to Manmohan Singh "the need to shift large surplus farmers to non –agriculture sector, saving per capita income of farmers would rise only when fewer people engage in farming".

Presently agriculture growth is based on some extraneous factors but growth should not be at the cost of sustainability of our natural resources. Right now, it is compounded of soil and mismanagement of ground water. Deforestation is also affecting to soils and water. There is an urgent need to take action on those fronts where deforestation, miss use of ground water fertility of soil should be stop.

Figure: 1 Effect of climate change in agriculture



Projected production of Wheat, Rice and Coarse grains in India



Source: OECD- FAO Agriculture Outlook (2017-2026)

Graph: 3

Table: 1

Projected Demand and Supply of Food Commodities for the 12th Plan period

(Million tonnes)

Crop/Group of Crops	Projected Demand		Projected Supply	Actual Production	
	2016-17	2020-21	2016-17	2006-07	2011-12
(1)	(2)	(3)	(4)	(5)	(6)
Rice	110	117	98-106	93	104*
Wheat	89	98	93-104	76	94*
Maize	19	22		15	22*
Nutri Cereals	36	38	42-48	34	42*
Cereals	235	253	240-251	203	240*
Pulses	22	25	18-21	14	17*
Foodgrains	257	277	258-272	217	257*
Oilseeds/Edible oils	59	71	33-41	24	30*
Sugarcane/Sugar	279	312	365-411	355	358*
Vegetables	161	189		116	147**
Fruits	97	124		59	75**
Milk	141	173		103	122**
Fish	11			6.9	8.3**
Meat, other than poultry	3.7	5.0		2.3	2.7**
Poultry Meat	3.3	4.3			2.2 @

*4th advance estimate for 2011-12; **Production for the year 2010-11; @ Production 2010-11 for only commercial poultry meat.

Source: 12th Plan Document, Planning Commission

Table: 2 Food Production data

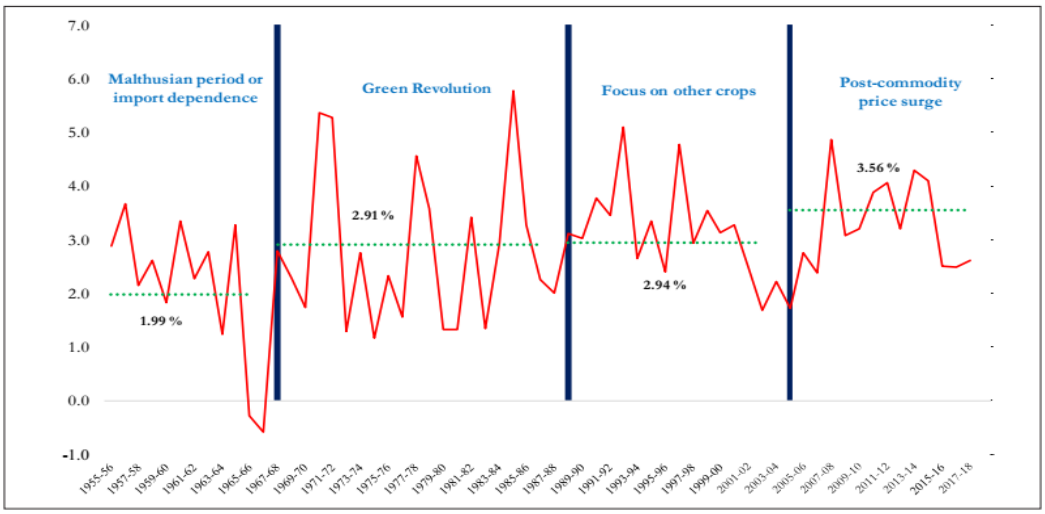
Year	Production of Rice	Production of Wheat	Annual mean temperature	Fertilizers (N+P+K)	Annual rainfall (mm)
2003-04	88.53	72.16	25.61	160.94	1243.6
2004-05	83.13	68.64	25.66	167.99	1080.5
2005-06	91.79	69.35	25.59	183.98	1208.3
2006-07	93.36	75.81	25.73	203.4	1161.6
2007-08	96.69	78.57	25.68	216.51	1179.3
2008-09	99.18	80.68	25.56	225.7	1118
2009-10	89.09	80.8	26.05	249.09	953.7

2010-11	95.98	86.87	26.04	264.86	1215.5
2011-12	105.3	94.88	25.63	281.22	1116.3
2012-13	105.24	93.51	25.61	277.9	1054.7
2013-14	106.65	95.85	25.69	255.36	1092.5
2014-15	105.48	86.53	25.74	244.82	1044.7
2015-16	104.41	92.29	25.93	255.76	1085
2016-17	93.88	98.38	26.21	267.53	1083.2
2017-18	94.48	97.5	26.04	259.49	1127

Source: Data on Production of Rice, Wheat and Fertilizers has been taken from Annual Report 2017, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmer Welfare, Government of India.

Valid Agricultural gross value added Growth in India, 1960-2016

(5 year moving average in percentage)



Source: Survey calculations.

Note: Numbers represent average agricultural growth rates for each period in percent.

Graph: 4

According to 2001 census, there were 1.03 billion populations in India. Now there is 1.21 billion in 2011(census 2001). Presently population was growing at the rate of 2.12 % per year during 1991 to 2001 which declined to 1.76 % per year in the decade of 2001 to 2011. There is a declined in below poverty line as earlier there were 35.97% during 1993-94 and 27.5 percent in 2004-05. It was 23.52 percent during 2010-11. India made a significant development in

agriculture production by way of new agricultural strategies. As outcome the agriculture production has greater than before during 115.6 Mt in 1960-61 to 241.4 Mt in 2010-11.

Data Source:

In this study secondary data has been compiled from the various sources to fulfil the above objectives of the study. We have analysed the empirical relationship between seasonal crops wheat, rice and environmental variables, time series data approach used, suggested by(Krishna deo et.al) was followed. The analysis have performed on a detailed 2001-2018 time series data on Agriculture output (wheat, rice), fertilizer ,area under cultivation and weather realization cover over India. We have collected data from different sources such as agriculture statistics at glance, Annual report (2017-2018) of Government of India, www.Indiastat.com. The crops that have been collected for study are production of rice, wheat. Data on the all India annual mean temperature and annual average rainfall are obtained from the website of the Indian Meteorological Department.

Hypothesis of the Study:

H_{01}: There is no effect of annual rainfall on production of rice in India**.**

H_{02}: There is no effect of annual mean temperature on production of rice in India.

H_{03}: There is no effect of Fertilizers (N+P+K) on production of rice in India.

H_{04}: There is no effect of annual rainfall on production of wheat in India.

H_{05}: There is no effect of annual mean temperature on production of wheat in India.

H_{06}: There is no effect of Fertilizers (N+P+K) on production of wheat in India.

Data Analysis and Result

Hierarchical Multiple Regression Analysis

Results: Production of Rice in India:

Figure – 2, shows that data are normally distributed with the help of P-P Plot of Regression Standardized Residual:

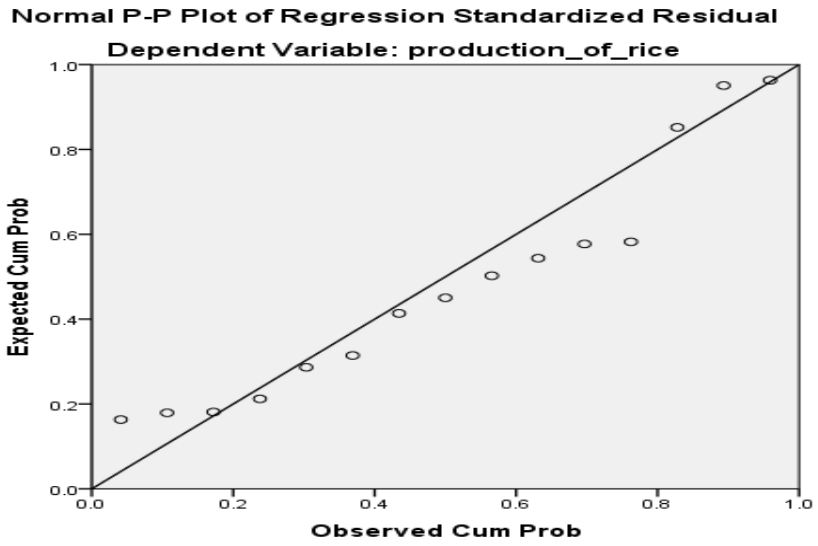


Figure 2 Normal P-P Plot of Regression

It can be seen from the above Normal P-P Plot that dots are reasonably near to the best fit line. There is less deviation of residuals and appears a good fit on P-P plots which means there is no measure deviation from normality.

Descriptive Statistics Table –3			
	Mean	Std. Deviation	N
Production_of_Rice	96.88	7.298	15
Fertilizer (N+P+K)	234.30	39.338	15
Annual mean temperature	25.78	.210	15
Annual Rainfall	1117.5933	75.54874	15

Correlations Table - 4					
		production_of_rice	fertilizer	temperature	rainfall
Pearson Correlation	Production_of_Rice	1.000	.694	-.154	-.201
	Fertilizer(N+P+L)	.694	1.000	.471	-.455
	Annual mean temperature	-.154	.471	1.000	-.282
	Annual Rainfall	-.201	-.455	-.282	1.000
Sig. (1-tailed)	Production_of_Rice	.	.002	.292	.236

	Fertilizer(N+P+K)	.002	.	.038	.044
	Annual mean temperature	.292	.038	.	.154
	Annual Rainfall	.236	.044	.154	.
N	Production_of_Rice	15	15	15	15
	Fertilizer(N+P+K)	15	15	15	15
	Annual mean temperature	15	15	15	15
	rainfall	15	15	15	15

In this study, we have used the Hierarchical Multiple Regression Model for the analysis of the result where Table – 3 describes the summary statistics of the Production of Rice, Fertilizers, Annual mean temperature and annual rainfall. Table – 4 shows the correlation between the dependent and independent variables where only fertilizer is significantly correlated with the Production of Rice.

Model Summary Table – 5

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.694[a]	.481	.441	5.456	
2	.886[b]	.785	.726	3.820	.918
a.. Predictors: (Constant), fertilizer					
b. Predictors: (Constant), fertilizer, rainfall, temperature					
c. Dependent Variable: production_of_rice					

Table – 5 explain the model summary where R-Square is equal to 0.481 which means 48.1 percent variations in the dependent variable are explained by the independent variable (Fertilizers) in the first model. While in the second model, the value of R-Square 0.785 has increased after including new independent variables (Annual mean temperature and annual rainfall) which means 78.5 percent variations in the dependent variable has been explained by the independent variables by the second model which represent the highly fitness of the model.

ANOVA Table – 6						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	358.614	1	358.614	12.048	.004[b]
	Residual	386.950	13	29.765		
	Total	745.563	14			
2	Regression	585.024	3	195.008	13.362	.001[c]
	Residual	160.539	11	14.594		
	Total	745.563	14			
a. Dependent Variable: production_of_rice						
b. Predictors: (Constant), fertilizer						
c. Predictors: (Constant), fertilizer, rainfall, temperature						

Table – 6 shows that both of the models are significant but the model second is more significant than model first where dependent variable is significantly related with the independent variables.

Coefficients Table - 7						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	66.734	8.798		7.585	.000
	fertilizer	.129	.037	.694	3.471	.004
2	(Constant)	589.185	142.771		4.127	.002
	fertilizer	.190	.032	1.023	5.962	.000
	temperature	-21.203	5.536	-.610	-3.830	.003
	rainfall	.009	.015	.092	.585	.571

Table – 7 contains the information about the coefficients and p values of the test. P-value for climate variable annual rainfall is not significant because p-value is more than 0.05 which means null hypothesis **(H_{01})** is accepted that is rainfall has no significant impact on production of rice in India. But P-value for annual mean temperature &fertilizers (N+P+K) are less than 0.05and

shows the significant effect on production of rice which means null hypothesis**(H_{02}& H_{03})** are rejected.

H_{01}: There is no effect of annual rainfall on production of rice in India**.**

H_{02}: There is no effect of annual mean temperature on production of rice in India.

H_{03}: There is no effect of Fertilizers (N+P+K) on production of rice in India.

Production of Wheat in India:

Figure – 3 shows that data are normally distributed with the help of P-P Plot of Regression Standardized Residual.

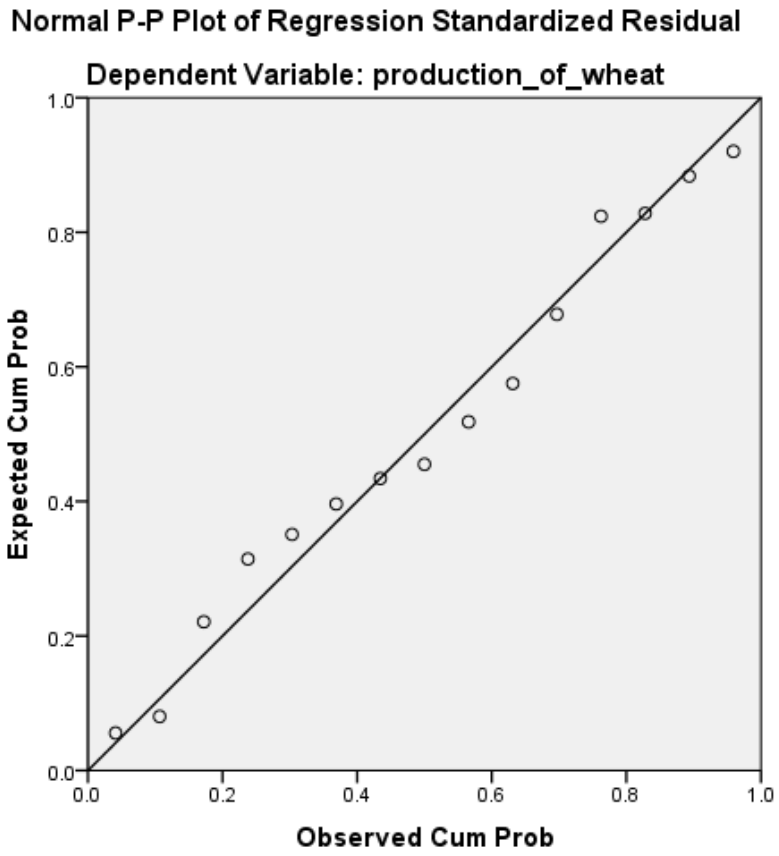


Figure 3 Normal P-P of Regression

It can be seen that dots are the above Normal P-P Plot that dots are reasonably near to the best fit line. There is less deviation of residuals and appears a good fit on P-P plots which means there is no measure deviation from normality.

Descriptive Statistics Table – 8			
	Mean	Std. Deviation	N
Production_of_wheat	84.79	10.423	15
Fertilizer(N+P+K)	234.30	39.338	15
Annual mean temperature	25.78	.210	15
Annual Rainfall	1117.5933	75.54874	15

Correlations Table – 9					
		production_of_wheat	fertilizer	temperature	rainfall
Pearson Correlation	production_of_wheat	1.000	.913	.479	-.351
	2``fertilizer	.913	1.000	.471	-.455
	temperature	.479	.471	1.000	-.282
	rainfall	-.351	-.455	-.282	1.000
Sig. (1-tailed)	production_of_wheat	.	.000	.035	.099
	fertilizer	.000	.	.038	.044
	Annual mean temperature	.035	.038	.	.154
	Annual Rainfall	.099	.044	.154	.
N	Production_of_wheat	15	15	15	15
	Fertilizer(N+P+K)	15	15	15	15
	Annual mean temperature	15	15	15	15
	Annual Rainfall	15	15	15	15

Table – 8 describes the summary statistics of the Production of wheat, Fertilizers, Annual mean temperature and annual rainfall. Table – 9 shows the correlation between the dependent and independent variables where fertilizer and annual mean temperature are significantly correlated with the Production of wheat and annual rainfall shows the insignificant correlation with production of wheat.

Model Summary Table – 10					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.913[a]	.833	.820	4.416	
2	.918[b]	.842	.799	4.668	.880
a. Predictors: (Constant), fertilizer					
b. Predictors: (Constant), fertilizer, rainfall, temperature					
c. Dependent Variable: production_of_wheat					

Table – 10 presents the model summary where R-Square is equal to 0.833 which means 83.3 percent variations in the dependent variable are explained by the independent variable (Fertilizers) in the first model. While in the second model, the value of R-Square 0.842 has increased after including new independent variables (Annual mean temperature and annual rainfall) which means 84.2 percent variations in the dependent variable has been explained by the independent variables by the second model which represent the fitness and accuracy of model second is high than model first.

ANOVA Table – 11						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1267.378	1	1267.378	64.993	.000[b]
	Residual	253.502	13	19.500		
	Total	1520.880	14			
2	Regression	1281.163	3	427.054	19.596	.000[c]
	Residual	239.718	11	21.793		
	Total	1520.880	14			
a. Dependent Variable: production_of_wheat						
b. Predictors: (Constant), fertilizer(N+P+K)						
c. Predictors: (Constant), fertilizer, rainfall, temperature						

Table – 11 shows that both of the model are significant but the model second is more significant

Coefficients Table – 12

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	28.118	7.121		3.948	.002
	Fertilizer(N+P+K)	.242	.030	.913	8.062	.000
2	(Constant)	-76.224	174.462		-.437	.671
	Fertilizer(N+P+K)	.244	.039	.919	6.263	.000
	Annual mean Temperature	3.511	6.765	.071	.519	.614
	Annual rainfall	.012	.019	.087	.645	.532

a. Dependent Variable: production_of_wheat

than model first where dependent variable is significantly related with the independent variables. Table – 12 contains the information about the coefficients and p-values of the test. P-value for climate variable annual rainfall and annual mean temperature are not significant because p-value is more than 0.05 which means null hypothesis **(H_{04} &H_{05})** is accepted that is annual rainfall and annual mean temperature has no significant impact on production of wheat in India. But P-value for fertilizers (N+P+K) is less than 0.05 and shows that fertilizers has the significant effect on production of wheat which means null hypothesis **(H_{06})** is rejected.

Conclusion

Based on different data and its analysis, it is found that during 2001- 2015, there is a variation in temperature, rainfall the use of fertilizer. Since 2001 temperature is increasing from 27.91 to 28.56 in 2014-2015 and summer rainfall is decreasing from 2001 to 2015. There is a decline in production of Kharif crops and the use of land area due to decrease in rainfall. As an extraneous factor fertilizer (N+P+K) play a significant role in sustaining the production of rice and wheat. Due to increase in greenhouse gases climate is changing and it is impacting in several ways to the agriculture along with temperature and rainfall. Use of vehicles is increasing day by day, and

formers also burn their agriculture waste which indirectly supports to increase greenhouses gases. The government should take some strict action and adopt the new strategies to control such type of activities by which carbon and other allied gases could be reduced. Ground Water level is also decreasing, and there is no systematic management of rainwater harvesting and watershed management. There are many examples of different countries including India (Mumbai) where rainwater is being restored, and it make reusable by proper water treatment. Climate change is also not good for the health of human being, animals and forestry of the country.

Such type of initiatives should be taken in missionary mode; otherwise, in future, there will be lots of problem due to adverse effect of climate change. Recently in USA there was a meeting concerning control the climate change where it was decided that every country should maintain the zero carbon level. Proper use of fertilizer is good but farmers increasing the use of fertilizer continuously in the agriculture, which is harmful to human beings, insects and the productivity of land. It is also indirectly affected by underground water, which generally everyone uses for drinking and other necessities. Some scientists have said that if farmers use excess fertilizer over a long period, it will destroy the sustainability of land and there will be a massive decrease in agriculture productivity. India is second biggest populated country, and in upcoming years it will be in first position and it will be a big challenge to meet the accessibility of food requirement for every Indian. In general, there will be 1.5 times more food requirement from present by 2040. It is suggested to everyone especially to farmers and government that they should take some initiatives to stop the misuse of fertilizers to sustain the productivity of land in India.

In concluding remark, it can be said that problem of climate change, maintaining the sustainability of land, excess use of fertilizers is the unavoidable challenges which should be taken seriously by everyone who is living on this earth, otherwise everyone will face lots of problems and this earth will not be able to survive in future. The government should also adopt some strategies to minimize the effect of climate change as a policy level and promote the farmers for organic farming and reduce the use of fertilizers in agricultural food production.

References

1. Ahmad, J., Alam, D., & Haseen, M. S. (2011). Impact of climate change on agriculture and food security in India. *International Journal of Agriculture, Environment and Biotechnology*, *4*(2), 129-137.
2. Ansari, M. A., Joshi, S., & Raghuvanshi, R. (2018). Understanding farmers perceptions about climate change: a study in a North Indian State. *Advances in Agriculture and Environmental Science*, *1*(2), 85-89.
3. Aryal, J. P., Sapkota, T. B., Khurana, R., Khatri-Chhetri, A., Rahut, D. B., & Jat, M. L. (2020). Climate change and agriculture in South Asia: Adaptation options in smallholder production systems. *Environment, Development and Sustainability*, *22*(6), 5045-5075.
4. Gadgil, S. (1995). Climate change and agriculture–an Indian perspective. *Current Science*, *69*(8), 649-659.
5. Guiteras, R. (2009). The impact of climate change on Indian agriculture. *Manuscript, Department of Economics, University of Maryland, College Park, Maryland*, 1-54.
6. Gupta, A., Yadav, D., Gupta, P., Ranjan, S., Gupta, V., & Badhai, S. (2020). Effects of climate change on agriculture. *Food and Agriculture Spectrum Journal*, *1*(02), 103-107.
7. Jayaraman, T. (2011). Climate change and agriculture: a review article with special reference to India. *Review of Agrarian Studies*, *1*(2369-2021-128).
8. Jayaraman, T., & Murari, K. (2014). Climate change and agriculture: Current and future trends, and implications for India. *Review of Agrarian Studies*, *4*(2369-2021-077).
9. Kalra, N., & Kumar, M. (2019). Simulating the impact of climate change and its variability on agriculture. *Climate change and agriculture in India: Impact and adaptation*, 21-28.
10. Lal, R. (2019). Adaptation and mitigation of climate change by improving agriculture in India. *Climate change and agriculture in India: Impact and adaptation*, 217-227.
11. Mahapatra, B., Walia, M., Rao, C. A. R., Raju, B. M. K., & Saggurti, N. (2021). Vulnerability of agriculture to climate change increases the risk of child malnutrition: Evidence from a large-scale observational study in India. *PloS one*, *16*(6), e0253637.
12. Palanisami, K., Ranganathan, C. R., Nagothu, U. S., & Kakumanu, K. R. (2014). *Climate change and agriculture in India: studies from selected river basins*. Routledge.

13. Praveen, B., & Sharma, P. (2020). Climate change and its impacts on Indian agriculture: An econometric analysis. *Journal of Public Affairs*, *20*(1), e1972.
14. Rakesh, S., Sarkar, D., Kumar, S. A., Abhilash, P. C., & Rakshit, A. (2019). Climate change and agricultural policy options: Indian story. *Climate Change and Environmental Sustainability*, *7*(2), 208-211.
15. Sapkota, T. B., Vetter, S. H., Jat, M. L., Sirohi, S., Shirsath, P. B., Singh, R., ... & Stirling, C. M. (2019). Cost-effective opportunities for climate change mitigation in Indian agriculture. *Science of the Total Environment*, *655*, 1342-1354.
16. Tripathi, A., & Mishra, A. K. (2017). Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, *16*, 195-207.
17. Varadan, R. J., Kumar, P., Jha, G. K., Pal, S., & Singh, R. (2017). An exploratory study on occurrence and impact of climate change on agriculture in Tamil Nadu, India. *Theoretical and Applied Climatology*, *127*, 993-1010.
18. Venkateswarlu, B., & Shanker, A. K. (2009). Climate change and agriculture: adaptation and mitigation stategies. *Indian Journal of Agronomy*, *54*(2), 226-230.