

Impact of Climate Change on Sustainability of Rice Export from India

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Abstract

India is the largest producer and leading exporter of rice all over the world. Rice contributes significantly to its GDP in terms of export revenue, and largest consumer of fresh water in water stressed country like India. It has been observed that climate change has direct, indirect and differential impact on agriculture and food security, water resource and agricultural trade. Therefore, this is an emerging concern to understand and conduct in-depth analysis about the sustainability of rice production and export from India within the constraints of climate change and acute water crisis. This study analyses the trend of climate factors namely, annual rainfall, mean temperature, no of extreme events and export of rice over past thirty years and examines the causal relationship between export of water intensive rice and climate factors within constraint of water crisis. Our analytical findings indicate that average temperature has negative impact and annual rainfall and has positive impact on mean export of rice. High association between temperature (.60) and rainfall (.45) with extreme events gives a deeper understanding on dynamics of climate parameters and supports their insignificant joint impact on export quantity of rice. However, a further research integrating climate –water agriculture and trade is an agenda for future analysis. While an expected revenue loss may occur as a result of decision to reduce trade in water intensive revenue earning crops, an integrated climate-trade policy is the need of the hour to secure sustainable production and export of rice without putting much pressure on water resource in India.

Keywords: Rice Export, Production, Climate Change, Water Availability, Sustainability, India

production. However, productivity of rice in India (2.5tonne/ha) is even below the world average (3.1tonne/ha) with largest area (45320 thousand ha) under rice cultivation in present year. Moreover, India is largest consumer of water in terms of rice when it is already being placed as the top most water stressed nations of the planet due to inevitable consequences of climate change(Sharma.et.al 2018). Therefore, India has gained lots of attention from agriculturist and economist as largest exporter of water intensive agro-crops and became the highest virtual exporter of water within era of climate change and resulting water scarcity.

Climate is a key factor for agriculture in terms of quantity and quality of crops production. Therefore, success in rice production and associated economic activities such as meeting domestic demand, export and imports depend more on weather and water situation. Studies showed the negative impact of climate change on productivity of rice and wheat in many parts of globe (Ortiz 2008). A report on impact of climate change on agriculture (Nelson. et.al 2009a) revealed that, South Asian countries will be hard hit in terms of lower yield of all crops, availability of calories and additional price increases for cereal products namely, rice wheat, maize etc. In addition to this impact of extreme events on trade infrastructure, all sorts of transport systems, export prices are identified but less expertise has been provided to measure impact of climate change on a country's comparative advantage in terms of availability of factors of production (Delink 2017).

To understand and identify the linkage between climate change and sustainable export of rice, given threat of climate change, three aspects needs to be discussed:

Climate Change in India

Rice Export Trend of India

Rice production, Export and Climate Change

Climate Change in India

Climate change due to global warming is the most expensive challenge and threat to our globe. There is a growing consensus in the scientific literature that the earth is warming due to anthropogenic increases in greenhouse gas emissions into the atmosphere (IPCC 2014). India is expected to have more

Introduction

Rice is a main staple food for more than half of India's population. Rice is considered as crucial crop in terms of food security in India. India's climatic pattern, soil quality and food habit altogether support intensively production of different types of rice. Due to lower cost of cultivation and positive comparative advantage in terms of export price, India has secured second rank in exporting rice after China and together these two countries contributed about 53% of world rice

extreme events and regional difference in term of heat waves and erratic and untimely declining rainfall pattern (Fig.1a &b).

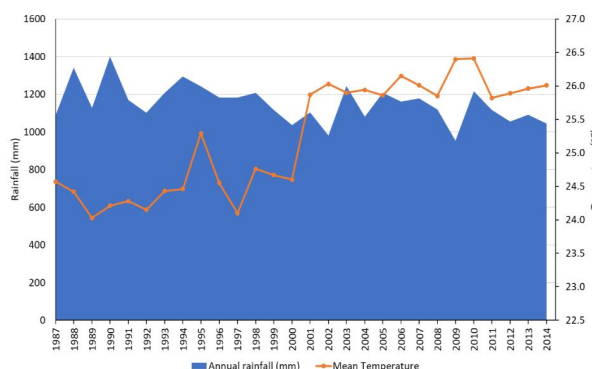


Figure1 (a): Pattern of annual rainfall and average temperature in India.

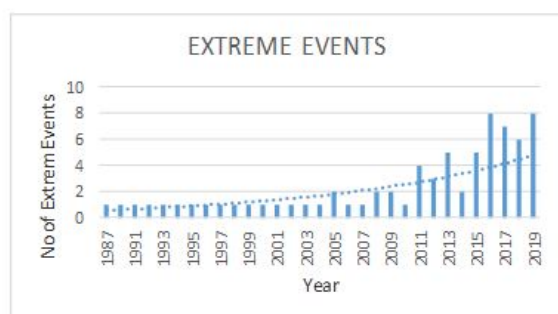


Figure 1(b): No of occurrences of extreme events

Considering past thirty years, annual rainfall recorded decreasing trend with uneven distribution of downpour. In terms of quantity it may be similar as the previous years but untimely monsoon with heavy pouring or unexpected dryness are causing major issues for farmers. A Special Report by (IPCC 2018) showed global warming reached at 1 °C above pre-industrial levels in 2017 with a rate of 2°C by each decade will expect to reach of 1.5 °C around 2040. The raise in temperature is expected to lead several changes to local as well as global climatic factors in varying degree of intensity. Huge rainfall for certain period causes flood in several states in India while at the same time many states experience meagre in rainfall.

Rice Export Trend of India

Introducing high yielding variety of seeds, improved technology, advanced agricultural know how, modified agricultural practices in terms of improved seeds, fertilizers, pesticides, manure made India strongest competitor in agricultural trade market specifically for rice. Trend in export of rice in India showed (Fig. 2) huge increase from 5 million tonnes in 1995 to 11 million tonnes in 2010. After 2010 export amount recorded slightly lower due to population growth and increase in per capita income although the figure was much higher than other countries (Chandrasekhar & Ghosh 2019). Lower cost of production and low relative price encourages India practicing more export of rice to rest of the world.

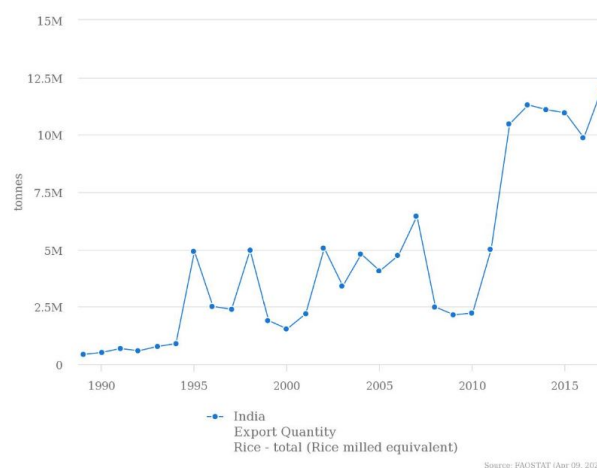


Figure 2: Trend in Exports in India (1990-2016)

Rice production, Export and Climate Change

Climate change causes lower crops yield for crops like rice, maize, wheats for tropical countries like India and higher temperature above a threshold point is more likely to affect negatively on yield. A study on Peru and Uganda, tropical countries revealed an expected adverse impacted of climate change on lower yield (ITC 2015). Nelson et al. (2009) used a DSSAT model to capture the differential impact of climate change on yield of crops in 2000 with 2050. Their study showed that climate change has a negative impact on yield for almost all crops where carbon dioxide (CO₂) induced fertilization had not been applied especially rain-fed and irrigated wheat and irrigated rice. Goswami (2017) revealed that by 2030 rice and wheat will experience lower yield by 6-10% and overall contribution of agriculture to GDP will record loss by 1.5%. Ghazouani (2017) came up with the same findings about low yield and lower production of rice in India due to global warming. Along with lower yield of rice, rice diseases namely rice blast, sheath and cum blithe are expected to be widespread due to change in climatic factors. Studies revealed that increase in temperature might impact on different stages of rice production, starting from seed quality, fertility to shorten growing cycle and productivity (Herman et.al, 2015, Pallikonda 2017). A world bank report (2013) estimated imports on food grains by India and South East Asian region will be doubled in year 2050 due to elevated earth temperature. India is going to face huge amount of loss in terms of GDP due to fallout of extreme events (Mohan 2017). Saseendran et. al. (2000) showed in their study on Kerala that due to elevated temperature yield of rice will be decreased by 6% and crop maturity period would be decreased by 8%. Due to climate change high CO₂ concentration may increase yield for rice but at the same time high temperature cause yield losses. Another study in West Bengal showed that high temperature will reduce yield of rice crops and this would be fatal if temperature rise would be in 4o C (Bhattacharya 2013). On the other hand, state level analysis in India showed that untimely, uneven monsoon rainfall result in drought or flood also has adverse impact on yield of khariff rice crops (Auffhammer et al. 2012). Another study (Maya et.al 2019) supported with their findings that more than 97% of farmers

believed that the rainfall is reduced and lower the rice production in Bangladesh. Therefore, studies at global level and region level are aligned in terms of their findings on impacts of climate change on rice productivity and maturity period. Adverse monsoon season, especially because of global climate change, cause a serious threat to availability of water in India which is primary factor for water intensive agricultural production. Despite of this fact, India uses almost twice the amount of water to grow crops as compared to China and United States (Qazi 2017). Climate impact is expected to dampen Global GDP annually by 0.3 % by 2050 by rising agricultural prices with differential impacts on both consumers and producer and reducing overall agricultural welfare unless more agricultural trade liberalization take place with adequate compensating mechanism for environments and sustainable development (Stevanovic et.al 2016). The dynamics and scope of Indian rice market domestic as well international depend on international demand for Indian rice, lower tariff barriers, buffer stock of rice held by the government and on domestic consumption (Adhikari et al. 2016). A study by Zhu,et.al (2014) showed declining trade position in terms of increase in import of cereals in Pakistan due to rising water scarcity and lower yield and moderate domestic production. Impact of increasing temperature on agricultural imports were observed in MENA countries (Tekce& Deniz 2016), although study emphasized more on negative impact of climate on yield and production (Upadhyay 2012). Food security may be affected by detrimental impact of climate change and lower down food availability which in turn will rise food price and potentially restricting trade policies (Schiavone 2010). Climate change may alter volume and direction of agro-trade by changing comparative advantage and especially for those countries whose comparative advantage stems from climatic sources or geographical sources (Tamiotti et.al 2009).

In light of above literature this study has been narrowed down to relation between climate and agricultural export of rice in Indian context. Two research questions are analyzed in this paper:

Do climatic factors have any impact on export of rice in India?

Does climate change be a threat to “sustainability” of rice export from India in long run given climate change?

Data Source

The study is based on secondary data obtained from various published sources. Compilation of time series data for a period of thirty one years (1987-2018) was done on climate parameters namely temperature, rainfall, special events and economic variables, export quantity of rice, domestic production, consumption, yield and irrigated area for rice. Data on export quantity, and value were collected from The Agricultural Food Processed Products Export Development Authority (APEDA) and TRADE MAP from Trade Statistics for International Business Development, ITC. Information on Domestic consumption of rice, population are obtained from Hand Book of Statistics, Reserve Bank of India (RBI) and World Bank. Statistics on domestic water availability, water requirement in agricultural

have been collected from Centre Water Commission (CWC) and indiastat.com website. Gross Domestic Product at constant price and India's exchange rate with US \$ are taken from world bank data source. Time series data on annual rainfall (mean rainfall) and mean temperature have been obtained from Indian Meteorological Department. No of occurrence of extreme events (floods, droughts, heat waves, cold waves, wind blows etc.) were estimated from EM-DAT database and National Disaster Management Authority, India (NADM).

Methods

To examine the impact of climate change on rice export and its sustainability in long run, we conduct the following statistical methods. Based on available data, interpolation and extrapolation have been done to get missing years for domestic consumption of rice. Annual consumption data was calculated by multiplying per person per day consumption with total population. Statistical analysis was done using SPSS 14 and PROCESS macro v.4.

Trend Analysis: General Methodology

To capture the pattern of climate parameters (Average temp, annual rainfall, number of extreme events) and economic variable (export of rice, domestic production and domestic consumption) over the study periods (1987-2018) linear time series regression analysis have been done taking time period as independent variable and rest as dependent variables. This is the most common and useful technique used by various studies to capture the movement of variables over the years.

Economic variables

$$\text{Log rice ex} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (1)$$

$$\text{Log rice production} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (2)$$

$$\text{Log rice consumption} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (3)$$

Climate Variables

$$\text{Average Temperature} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (1)$$

$$\text{Annual Rainfall} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (2)$$

$$\text{Mean number of occurrence of extreme events} = \beta_0 + \beta_1 \text{ Time} + \text{Error} \dots \dots \dots (3)$$

Where β_i represents coefficient value for independent variable, time period for each of the model. This indicates how average value of dependent variable will change as one more year would be added given rest constant.

Growth Rate Analysis

Compound annual growth rate analysis is worked out to study the growth performance of all economic parameters namely, domestic production, consumption, export and area under rice, over past thirty years. Compound annual growth rate (CAGR) which is most common and widely used technique to measure variation helps us to do the preliminary comparative study of variables over the years and build a base for further analysis (Kanan and Sundaram 2011, Rai &Thakur 2017). The total time period is subdivided into three periods, viz. Period 1: (1987-1997), Period 2: (1997-2007) and Period 3: (2007-17). For

each period CAGR has been computed for selected all variables., Based on compiled information, charts have been prepared to show the trend of variables over the years.

Correlations Matrix and Multiple Regression Analysis.

Pearson correlation analysis was done among climate variables. The objective was to identify significant association between mean temperature, annual rainfall and no of extreme events. Correlation matrix is a useful tool to select necessary variables for further regression analysis.

Empirical Models

Our study estimates the following equation models:

Model 1: $\ln \text{ export} = \beta_0 + \beta_1 \text{ rainfall} + \beta_2 \text{ temp} + \beta_3 \text{ extreme events} + \beta_4 \text{ Temp} * \text{rainfall} + \beta_5 \text{ temp} * \text{rainfall} * \text{ extreme events} + \beta_6 \text{ extreme event} * \text{rainfall} + \beta_7 \text{ extreme events} * \text{temp} + \beta_4 \text{ GDP} + \epsilon$

Model 2: $\ln \text{ export} = \beta_0 + \beta_1 \text{ rainfall} + \beta_2 \text{ temp} + \beta_3 \text{ extreme events} + \beta_4 \text{ Temp} * \text{rainfall} + \beta_5 \text{ temp} * \text{rainfall} * \text{ extreme events} + \beta_6 \text{ extreme event} * \text{rainfall} + \beta_7 \text{ extreme events} * \text{temp} + \beta_4 \text{ GDP} + \epsilon$

To identify and quantify the significant impact of climate change on export quantity of rice in India, we have conducted two linear multiple regression analysis.

Model 1 includes annual rainfall, average temperature and no of extreme events as independent variables and export quantity of rice as dependent variables.

Model 2: To understand and compare the share of contribution of economic factors along with climate variables on export, we used Gross Domestic Product at constant price (GDP) and countries exchange rate with US \$ as explanatory variables.

Interactions terms are used for climate variables to capture their combined effect on export of rice. However final model selection was done after performing stepwise regression based on model's goodness of fit, improved value of adjusted R square, significance level of coefficients. To make model more accurate and free from multi-collinearity, standardized climate variables are used and "Variance Inflation Factor" test was performed to confirm multi-collinearity among them. Also this is need to specify here, export of a nation has several economic determinants. Here in our study, our main emphasis is on to identify impact of climate variables on export, therefore, we used major two economic determinants for the regression models.

Model with Mediator (Indirect Effect)

Mediational analysis tests a hypothetical (presumed) causal chain where one variable X affects a second variable M and, in turn, that variable affects a third variable Y (MacKinnon 2012). In present context, Mediational Analysis is employed to have better understanding of the nature of relationship between the impact of climate variables on export is direct or indirect impact mediated through domestic production. Bootstrap method (Preacher and Hayes, 2004) has been used to capture the presumed mediation impact of domestic production on export

of rice controlling climate parameters. PROCESS version 3 for SPSS was used ((Hayes., A 2013) to conduct Mediation analysis.

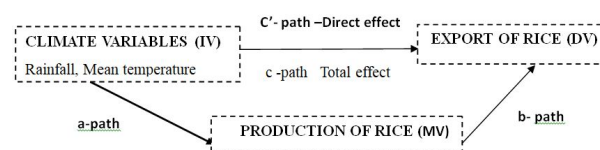


Figure 3: Impact of Climate Variables (IV) on Quantity of Export of rice(DV) in India mediated by production(MV)

Source: Aron, A., Coups, J. E., Aron, N. E. (2013). The General Linear Model and Making Sense of

Advanced Statistical Procedures in. Statistics for Psychology, chapter 15, 636.6th Ed.

a path: Mean of Production of rice = $\beta_0 + \beta_1 \text{ rainfall} + \beta_2 \text{ temp} + \epsilon$.

b path: Mean of Export of rice= $\beta_0 + \beta_1 \text{ Production of rice} + \epsilon$

c path: Mean Of Export of rice= $\beta_0 + \beta_1 \text{ rainfall} + \beta_2 \text{ temp} + \epsilon$ Direct Effect

Mediation Effect (b and c' path): Multiple regression predicting DV from MED & IV

Export of rice= $\beta_0 + \beta_1 \text{ rainfall} + \beta_2 \text{ temp} + \beta_3 \text{ production} + \epsilon$ (error term)

Significance level of Indirect Effect will determine if Domestic production behaves as mediator in explaining climate impacts on Export of rice. Significance determines if "0" lies outside the range between lower bootstrap CI and upper bootstrap.

Findings

The findings are presented in four (I, II, III, IV) sections:

Trend Analysis on Climate and Economic variables

Growth Rate Analysis on Economic Variables

Multiple Regression Analysis with Models Estimation

Mediator Effect Analysis

Trend Analysis on Climate and Economic variables

This is evident from (Table 1) export of rice (0.87), domestic production (0.92) and domestic consumption (0.98) showed an significant increasing trend over the years. Estimated coefficient registered higher for domestic consumption followed by domestic production and export of rice. Average temperature and extreme events follow a positive trend (0.85, and 0.76) whereas annual rainfall shows decreasing trend (0.56) in last thirty years. However annual rainfall does not reflect the actual variation as India is divided in different agro climatic zone with difference soil quality rainfall pattern and different weather. Further on this, different region experience different amount of precipitation and months wise variations are also there. July to September is time heavy rainfall is experienced by most of the

region. Instead of annual, monthly rainfall will give more clear picture about the pattern and amount of rainfall in India.

Variables		Adjusted R Square	Coefficients	t-Value	Sig
CLIMATE	Average Temperature	0.73	0.85	9.07	.000**
	Annual Rainfall	0.30	-0.56	-3.74	.001**
	Extreme Events	0.56	0.76	6.46	.000**
ECONOMIC	Export of Rice	0.76	0.87	9.91	.000**
	Domestic Production	0.85	0.92	13.49	.000**
	Domestic Consumption	0.95	0.98	32.89	.000**

** *P<001

Table 1: Trend Analysis for Rainfall, temperature, Extreme events, Export of rice, Domestic Production and domestic consumption

Results confirmed that average earth temperature is increasing over the years and India witnessed more extreme events with uneven and declining rainfall.

Growth Rate Analysis of export, production, domestic consumption and area under rice

Estimated compound annual growth rate for export, consumption and production indicate an increasing trend over last three decades. However, area under rice recorded a negative growth for last ten years (Table 2). Export of rice experienced a tremendous increase (20%) in all past years, whereas, consumption increased by only 1.2% similar to population growth rate and production grew by 1.7%.

RICE					Growth rate(%)		
	1988	1998	2008	2017	1988-98	1998-08	2008-17
Production (million ton)	70.49	86.08	99.18	115.26	2.0%	1.4%	1.7%
Consumption (million ton)	62.11	72.15	78.37	86.95	1.5%	0.8%	1.2%
Area under crop (ha)	41736	44802	45537	42881	0.7%	0.2%	-0.7%

Export (million ton)	0.35	4.96	2.49	12.71	30.4%	-6.7%	19.9%
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Source: APEDA, 2018, (FAO, 2018). Growth rates are estimated by authors.

Table 2: CAGR analysis on economic variables for three periods of time: Period 1(1988-1998), Period 2(1998-2008) and Period 3 (2008-2017)

Fig. 3 supports the result obtained from (table 2). A steady increase in export amount over last three decades from .35 million tons to 13 million tons with a stable and consistent growth rate of domestic consumption and slightly higher increase in production trigger an excess production of rice in India. Higher production triggers meeting increasing demand from rest of the world. Therefore, the export growth rate is more than 15 time higher than production growth rate and consumption.

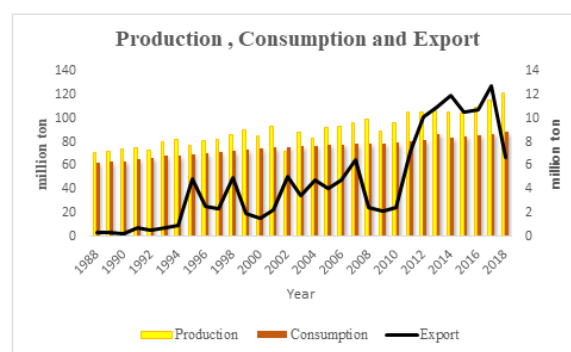


Figure 4: Rice Production, consumption, Export and population growth

Multiple Regression Analysis and Model Estimations

Before presenting the econometric model estimation results, we present how climate variable related each other and how they move together. As we are talking about weather where effects are connected, we may need special care to deal with climate parameters. Correlation results (Table 3) showed higher association between average temperature and extreme events (.60) and annual rainfall and extreme events (-.45) which are statistically significant at 1% level. In addition to this temperature and number of extreme events showed a significant positive association whereas, later showed a negative association between them. Mean temperature and annual rainfall showed negative significant association between them (-.38). Results do not reveal the exact direction of the association as relationships are complex and have differential impact on different region in India.

Pearsons-Correlation	Rainfall	Temperature	Extreme Events
Rainfall	1	-.380*	-.455**
Temperature	-.380*	1	.602**
Extreme	-.455**	.602**	1

N	32	32	32
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****P<01**

Table 3: Correlation between Climate Parameters

Model 1 Contribution of Climatic factors on export' of rice in India

(Table 4 & 5) represent two semi log linear regression models where first one includes climate variables as explanatory variables and in second one we include climate as well as economic variables to explain export of rice. Analysis started with generalized model with independent impact and their joint effects on dependent variable. Due to high correlation among temperature and rainfall with extreme events, (Model 1) faced tremendous multi-collinearity problems which was confirmed by the Variance inflated (VIF) test. To fix that problems all climate parameters were converted in standardized variables which were obtained by deducting mean value from each of the variable and divided by standard deviation. Model estimations reported in (Table 4) implies that, weather in India has significant impact on export of rice. One millimeter increase in annual rainfall given other things constant, may increase mean export by 0.73 million tons which is statistically significant at 5% Reasonable negative impact is there on export of rice due to 1degree c increase in temperature, lower down export by 0.22 million tons. Joint impact showed an insignificant impact on export. Goodness of fit indicates that 70% variation of export of rice may be explained collectively by climate variables.

(Model 2) lights on importance of climate variables in explaining export where major two economic variables are there in the model, GDP at constant price and exchange rate. As GDP does not come out significant in explaining export along with other variables and cause lower value of goodness of fit, final model includes climate parameters and exchange rate. Results revealed that (Table 5) average temperature (.28) and exchange rate (.76) have significant impact on mean export of rice given other things constant.

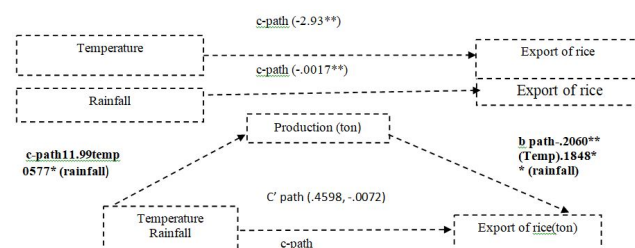
Climate Model	Standardized Coefficients	t	Sig.	Collinearity Statistics		Adjusted R Square	F
				Tolerance	VIF		
(Constant)		.23	.829			0.67	13.57**
Temperature	-.324	-.20	.84	.004	249.73		
Extreme Events	2.99	.99	.37	.001	998.61		
Annual	-2.71	-.66	.52	.001	1590.5		

	Rainfall						
	Temp*Rainfall	2.42	.63	.53	.001	1392.67	
	Temp*rainfall*extreme	-2.80	-.87	.39	.001	969.72	
(Standardized)	(Constant)		8.4	.000			0.69
	Temperature	-.21	-1.99	.056	0.86	1.17	
	Annual Rainfall	0.73	6.73	.000	0.86	1.17	

Table 4: Climate Variables regressed on Export of Rice

Climate and Economic Model	Standardized Coefficients	t	Sig.	Collinearity Statistics	
				Tolerance	VIF
(Constant)		-2.65	0.013		
Zscore (rainfall)	0.022	0.22	0.828	0.6	1.7
Zscore(temperature)	0.283	2.1	0.045	0.34	2.9
Zscore(extreme)	-0.115	-0.99	0.332	0.46	2.2
exchange rate	0.764	4.37	0	0.2	4.9

Table 5: Climate and Economic Variables regressed on Export of Rice



Path Analysis: Preacher & Hayes (2013)

Indirect effect(s) of X on Y:				
	Effect	BootSE	BootLLCI	BootULCI
a) production (Temperature)	2.4702	0.8652	1.1613	4.5456

b) production (Rainfall)	-0.0107	0.0052	-0.0224	-0.0021
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Table 6: Mediation Effect (Indirect effect)

The results from Boots tarp analysis (Table 6) and path diagram) demonstrate a significant indirect influence of climate change on export of rice mediated by domestic production. For both the variables, temperature and rainfall "0" lies between the lower CI and upper CI. However, effect is larger and positive for temperature (2.47) but for rainfall this is much less and negative.

Discussion and Conclusion

The primary objective of this study was to capture impact of climate change on export of rice in India based on past thirty years' times series data. Existing studies confirmed a strong relation between climate and agricultural production. Past studies identified indirect relation of climate change on trade in terms of impact of extreme events on export prices, exchange rates and transport cost. This study is an attempt to explore direct impact of climate on export quantity of rice.

Our analytical findings indicate that average temperature and annual rainfall have significant impact on export of rice. High temperature associates with lower export and increase in rainfall cause larger amount of export support the causal relation between climate factors and Export. Inclusion of exchange rate and GDP at constant price along with climate parameters showed a significant impact of temperature and exchange rate on export and triggered the importance of taking climate parameters in explaining rice export. High association between temperature, rainfall and extreme events gave a deeper understanding of climate parameters and supports their insignificant joint impact on export quantity of rice. Significant indirect (mediation) effect of climate parameters on export mediated by production confirms that sustainability of agricultural trade of any crops depends on its domestic production as well.

However, relations are inconclusive unless state level analysis are considered and monthly rainfall data are considered for analysis. To understand the sustainability of rice export in long run, different climate scenarios developed by IPCC need to be used to observe the change in relationship between climate and export, quantify the impacts and assessing and adopting adaptation within various range of temperature and rainfall amount. Another important sector is water, which is vulnerable to climate change and key factor for agricultural performance, needs to be incorporated in study to get better understanding of this complex relation. Therefore, detailed research and studies are required to get a comprehensive picture on impact of climate on agricultural crops in India.

While an expected revenue loss may occur as a result of decision to reduce trade in water intensive revenue earning crops, an integrated climate- trade policy is the need of the hour. Government may need to reconsider the long term impact of a certain trade policy or international law on various sectors and evaluate benefit and cost not in monetary terms but on

ecological conservation, securing biodiversity, and sustainability of resources like water and clean environment. This will help secure sustainable production and export of rice without putting much pressure on water resources in India.

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