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Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India

Ajay Kumar and Pritee Sharma

Abstract
This research paper analyzes the impact of climate change on agricultural productivity in quantity terms, value of production in monetary terms and food security in India. The study undertook state wise analysis based on secondary data for the duration of 1980 to 2009. Climate variation affects food grain and non-food grain productivity and both these factors along with other socioeconomic and government policy variables affect food security. Food security and poverty are interlinked with each other as cause and effect and vice versa, particularly, for a largely agrarian economy of India. Regression results for models proposed in this study show that for most of the food grain crops, non-food grain crops in quantity produced per unit of land and in terms of value of production climate variation cause negative impact. The adverse impact of climate change on the value of agricultural production and food grains indicates food security threat to small and marginal farming households. The state wise food security index was also generated in this study; and econometric model estimation reveals that the food security index itself also gets adversely affected due to climatic fluctuations.

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Keywords Climate change; food grain and non-food grain productivity; value of production; food security index (FSI); poverty

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Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India

Ajay Kumar* and Dr. Pritee Sharma**

1.0. Introduction

Climate change is not a new phenomenon in the world. The rise in temperature of the earth surface and in atmosphere, fluctuation in rainfall, declining ground water, flooding due to high rainfall, drought, soil erosion, heavy wind, rising sea level due to melting of glacier, cyclone, wind speed, hail storm, fog, earthquake and landslide etc., are all the clear evidence of climate change phenomenon. Though, it is a natural process but in some cases human activities are also responsible for this. There are many examples across countries where increase in the possibilities of climate change due to growing population, rapid urbanization, higher industrialization, use of modern technology, innovation, higher economic development, transport, building construction, reduction in forest area etc. are observed (Ahmad *et al.*, 2011). In mid, high latitude and higher income countries climate change has positive impact on agricultural production or crop yield, and on the other hand, lower-latitude and lower income countries experience a negative effect on agricultural production. On the other hand, developing countries are most vulnerable compared to developed countries. There are many reasons which increase the vulnerabilities for developing countries like low level of technological progress, lack of resources to mitigate the adverse effect of climate change on agriculture; and due to their greater dependence on agriculture for livelihood of large populations (Nath and Behera, 2011). This would increase the severity of disparities in cereal yields between developed and developing countries (Fischer *et al.*, 2005).

1.1. Impact of Climate Change

Climate and its variability impact all sectors of economy in several ways like abnormality in rainfall, results in severity and frequency of floods. Any increment in maximum temperature may increase mean sea levels and it would affect large populations in peninsular and coastal areas. It may increase 15 to 40% rainfall there and raise the annual mean temperature by 3 to 6 degree. Climate change adversely affects the food security in all countries through agriculture production. It affects to food security is in four dimensions, food availability, food accessibility, food utilization and food system stability. It will also have an impact on human health, livelihood assets and food production and distribution channels (FAO, 2008). Due to rising global population size, climate change will challenge agricultural production and food security (location of production, supply, volume, quality) and by 2080, agriculture output in Least Developed Countries (LDCs) may decline by 20 percent due to climate change and yields could decrease by 15 percent on average, while output in industrial countries is expected to decrease by 6 percent (Masters *et al.*, 2010). It will affect about 200 million people and their families worldwide who live by fishing and aquaculture (Greg *et al.*, 2011). In India, Gross Domestic Product (GDP) may decrease up to 6.2% and agriculture production may decrease up to 24% by 2080 due to climate change (Zhai and Zhuang, 2009; and Zhai *et al.*, 2009).

1.2. Food Security and its Components

There are more than 200 definitions about food security and its determinants which are available in literature (Hoddinott, 2009). The concept of food security emerged in the conference of United Nations Food and Agriculture Organization (FAO), World Food Conference in 1974; where availability of food was considered the sole component of food security. In 1986, World Bank has defined food security as “access by all people at all times to enough food for an active and healthy life” and this definition has included only two parameters of food security like availability and accessibility of food. In 1996, FAO defined food security as situation where “all the members of the society have access to the food according to their needs, either from their own production, or from the market or from transfer mechanism of the government.” This definition has included three parameters of availability, access and utilization of food. In 2002, FAO has given another definition for food security as the situation when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.”

Shakeel *et al.* (2012) mentioned that due to lack of proper estimation of food security, the quantity of food availability in specific time period of a particular place for consumption of the population reveals the food security; that is a function of domestic agricultural production or through imports from surplus areas. Dev and Sharma (2010) also defined the food security at the national level that mainly refers to availability in the country of sufficient stocks of food to meet domestic demand, either through domestic supply or through imports. Planning Commission (Government of India) also defined food security as a situation where “everyone has access, at all time, to food needed for an active and healthy life” (Ramasamy and Moorthy, 2012).

Currently food security includes four major components like availability, accessibility, stability and utilization of food (ADB, 2012). Availability of food indicates the physical presence of food or domestic production of food grain from agriculture or allied sector in a particular region or place in certain duration and with given technology inventory levels, local and international trade, commercial imports or food aid; and this mainly focuses on food production (ADB, 2012). Accessibility of food refers to having to acquire adequate amounts of food through production and stocks, purchase, gifts, borrowing and aid, and this interlinks with the ability of people to obtain food, either through production, purchase or transfers; this components of food security is directly linked with economic ability of the population to afford the sufficient food for their survival. Food stability is the condition where food is regularly and periodically available in the domestic market so that it also contributes to nutritional security and this includes the impact of natural shocks like floods and droughts on crop production; and this specially focuses on continuity of supply and demand of food grain product (FAO, 2009). Last component of food security i.e. utilization of food is defined as when a household's ability to absorb and metabolize the nutrients and appropriate nutritional content of the food consumed; and ability of the body to use it effectively. Utilization of food is mainly linked with nutritional value of food, interaction with physiological condition and food safety; and this provides the quality, safety and actual nutrition contents in the consumed food.

1.3. Climate Change and Food Security

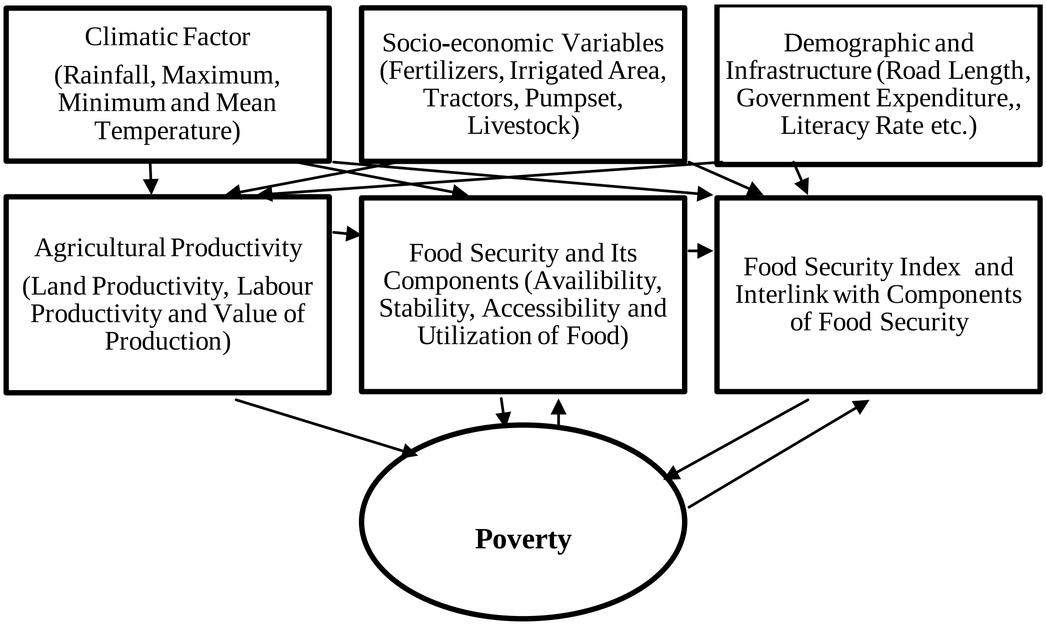
Food security is directly related to climate change because any variability in climatic factor can directly affect a country's ability to feed its people (Ahmad *et al.*, 2011). It affects all the components of food security (FAO, 2008). Availability of food is directly get affect by climate change through its impact on agricultural production. It negatively affects the crop yields, crop nests and diseases and soil fertility (Greg *et al.*, 2011). It is also get affect by climate change indirectly via its impact on economic growth, income distribution and agricultural demand (Schmidhuber and Tubiello, 2007). Stability of food, crop yields, and food supplied is negatively affected due to any variation in climatic variables (Greg *et al.*, 2011). It may also negatively affect the economic capacity of population to access the food due to any increment in food prices (Greg *et al.*, 2011). Utilization of food also may be adversely affects by climate variation, it reduces real nutrition contents of food; and it may increase the several health problems (Greg *et al.*, 2011). Overall impact of climate change may be reduction in agricultural production and employment opportunities of population resulting it would be serious threat for hunger, food insecurity, poverty and malnutrition in any region.

1.4. Agriculture Productivity, Food Security, Hunger and Poverty

Food Security directly gets affected due to any fluctuation in agricultural productivity. It is a multidimensional, multi-processing and complex phenomenon in the world. It involves interaction of multiple components of economy and it directly and indirectly gets affected by a lot of factors in economy like age, sex, occupation, income level of the population; increasing demand of food grain product due to rising population; rising price of food grains, vegetarian and non vegetarian diet; increasing cost of cultivation, low productivity of land, degradation of arable area and decreasing ground water; and low education level of farmers; and climate change and it variability (Shakeel *et al.*, 2012).

High variation in environmental factors such as temperature, rainfall and others get affect to crop growth negatively and certain crops get positively affected due to change in these environmental factors. Thus change in climatic variables may have positive and negative impact on agricultural productivity and food security situation in the economy (Greg *et al.*, 2011). Agriculture is very crucial sector that may reduce poverty in several ways (Goswami *et al.*, 2010; and Salami, 2011) like increase in crop productivity directly create more employment opportunities and improve the level of food security. Adverse implications for agricultural productivity may increase incidence of more poverty, which in turn is closely associated with hunger (Ramasamy and Moorthy, 2012). Thus agricultural productivity is an important part of food security which is an integral part of poverty eradication and hunger. Without food security, poverty may become vicious cycle; and lack of food security is thus both cause and effect on poverty (ADB, 2012). Poverty and food security are the correlated and directly related to each other (Rukhsana, 2011).

Figure 1 -Interlinkage between climatic and non-climatic variables on agriculture, food security and poverty



Climate change and poverty are interconnected in many ways like if temperature increase then warmer climate may increase the spread of diseases like malaria; and it may increase extra burden on poor people resulting increase in poverty. Higher variation in rain patterns such as drought or flooding can damage households' assets and agricultural produce leading to increment in poverty; and it may be serious threat to food security in agriculturally intensive countries (Oluoko-Odingo and Alice, 2009). In broad way agricultural productivity, food security and poverty have a joint relationship (Goswami *et al.*, 2010). Hunger and malnutrition situation due to poverty kill more people every year compared to other serious diseases like AIDS, malaria and tuberculosis; and malnutrition often leads to disease, devastating the lives of hungry poor people (Ramasamy and Moorthy, 2012). Climate variability, agriculture productivity, food security, undernourished and poverty, these all are directly linked to each other; and these are strongly correlated to each other (Hollaender, 2010).

2.0. Empirical Review

In India, numerous studies have given empirical evidence that climate change has caused decline in the agricultural productivity. Most of the studies examined economic impact of climate change on agriculture and few studies included food security with agriculture productivity. Kumar and Parikh (2001) shown for rice and wheat crop that projected largescale changes in the climate would lead to significant reductions in their crop yields, which in turn would adversely affect agricultural production by 2060 and may affect the food security of more than one billion people in India. Kumar *et al.* (2011) mentioned that decline in irrigated area for maize, wheat and mustard in northeastern and coastal regions; and for rice, sorghum and maize in Western Ghats of India may cause loss of production due to climate change. Hundal and Prabhjyot-Kaur (2007) concluded that an increase in minimum temperature up to 1.0 to 3.0 degrees Celsius above normal has led to decline in productivity of rice and wheat by 3% and 10% respectively in Punjab.

Kaul and Ram (2009) found that excessive rains and extreme variation in temperature has adversely affected the productivity of Jowar crop, thereby this has affected the incomes as well as food security of farming families in Karnataka (India). Geethalakshmi *et al.* (2011) concluded that productivity of rice crop has declined up to 41% with 4^0C increase in temperature in Tamil Nadu. Saseendran *et al.* (2000) analyzed the projected results for duration 1980-2049; found that increment in temperature up to 5^0C can lead to continuous decline in the yield of rice and every one degree increment of temperature will lead up to 6% decline in yield in Kerala (India). Srivastava *et al.* (2010) found that climate change will reduce monsoon sorghum productivity up to 14% in central zone (CZ) and up to 2% in south central zone (SCZ) by 2020; and this model also suggested that yields are likely to be affect even more in 2050 and 2080 scenarios; climate change impacts on winter crop are projected to reduce yields up to 7%, 11% and 32% by 2020, 2050 and 2080 respectively in India.

CROPGRO-Soybean model indicates that the average water non-limiting potential of the soybean crop across locations was 3020 kilogram/hectare, while water limiting potential was 2170 kilogram/hectare that is indicating a 28% reduction in yield due to adverse soil moisture conditions; and actual yield was just 1000 kilogram/hectare which was 2020 and 1170 kilogram/hectare less than the water non-limiting potential and water limiting potential of soybean in India, respectively (Bhatia *et al.*, 2008). Asha *et al.*, (2012) found that the yields of sorghum, maize, pigeon pea (arhar), groundnut, wheat, onion and cotton has decreased up to 43.03, 14.09, 28.23, 34.09, 48.68, 29.56 and 59.96 kilogram per hectare respectively in rainfed area; they also mentioned that almost 100% and 92.22% small and sample farmers respectively reported that the reduction in the rainfall was the major reason for reduction in the yield levels over the period followed by the pest and disease to the extent of 72.22%; and changes in temperature and seasonal patterns were quoted as the reason for the reduction in the yield by 42.22% of the sample respondents in Dharwad district in Karnataka (India).

Climate change has shifted and shortened crop duration in major crops rice and sugarcane, and it has significantly affected cane productivity in Uttar Pradesh and Uttarakhand (Vinesh *et al.*, 2011). The impact of rainfall is not significant for sugarcane crop in Andhra Pradesh (Ramulu, 1996). In India, projected surface warming and shift in rainfall may decrease crop yields by 30% by the mid 21st century, due to this reason there may be reduction in arable land resulting into pressures on agriculture production (Kapur *et al.*, 2009).

Above review of literature shows that climate change negatively affects the food grain productivity in India. Most studies empirically investigate the impact of climate change on agricultural productivity based on single crop or two to three crops and restrained to one state or region. But assessment of the overall effect of climate change on major food grain crops are important empirical question because food security is not a function of food grain crop only. There are many additional factors which may affect the level of food security including production of commercial crops, income of the people, geographical region, availability of drinking water, education level, level of employment, decline in cultivated land, higher population growth, rapid urbanization, lack of food grain market and number of cattle etc. Thus climate change, agriculture productivity, food security, and poverty; and these all are directly linked to each other (Hollaender, 2010).

2.1. Objectives and Organization of Paper

Based on the research gap identified in the previous section following specific objectives are aimed for the present analysis. (1) To analysis the impact of climate sensitivity on crop wise productivity of major food grain and non-food grain crops. Here we would be able to estimate which crop is more vulnerable due to any variation in climatic factors. (2) To investigate the impact of climate change on aggregate value of production of food grain and non-food grain crops (in monetary terms). This investigation will indicate the loss of income for farmers producing food and non-food grain crops with marketable surplus. (3) To generate state wise food security index by its components like availability, stability and accessibility of food. This index would be able to estimate which state is more food insecure and what is cause behind this insecurity. (4) To determines the relationship between overall food security index and its components. This estimation will point out which component of food security is most important for economy. (5) To investigates the impact of climate variables, socioeconomic and policy variables on constructed food security index and its components. (6) Analyze the impact of food security index on poverty in across states to understand the linkage between food security and poverty.

This paper is divided in five broad sections. First section, introduces about climate change, and its impact on agriculture, food security and its components, impact of climatic factor on food security and its components; interlinkages between climate change, agricultural productivity, food security, hunger and poverty; and food security and economic development. Second section presents research gap based on literature review and objectives of the study. Third section, describes detailed data description. This section also provides the descriptive method to generate of food security index (FSI); comprehensive overview of econometric models about impact of climatic and non-climatic variables on crop wise productivity, land productivity, food security index and its components; and poverty. In fourth section, descriptive and empirical findings of regression models are given. Conclusions and policy implications are drawn in fifth section.

3.0. Research Methodology

3.1. Sources and Description of Data

The data set used in present study is taken for thirteen major agriculturally intensive states with different climate zones. States includes from tropical zone are: -Bihar, Orissa, Uttar Pradesh, Punjab, Haryana, Gujarat, Madhya Pradesh, West Bengal, Maharashtra and Rajasthan; and subtropical zone: Andhra Pradesh, Tamil Nadu and Karnataka. These all states are the major food grain and non-food grain producer which contributes more than 75% total production for each crop of the country. To identify the missing values, the interpolation and graphical methods was used. The data for agricultural, socio-economic and climatic variables were taken from following sources-

Agricultural Data -Crop wise production, crop wise area sown, crop wise irrigated area and crop wise farm harvest price; state wise gross sown area, gross irrigated area, net sown area, forest area, tractor, pumpset and consumption of fertilizers were taken from Centre Monitoring Indian Economy (CMIE). Food grain production and area under food grain crops was taken from Reserve Bank of India (RBI). Number of agricultural labour and cultivators were taken from Census (Government of India).

Demographic Data -Population density, rural and urban population was taken from Census (Government of India). Literate population, literacy rate, gender ratio, credit deposit ratio

(CDR), infant mortality rate (IMR), urbanization, poverty is taken from Planning Commission (Government of India).

Livestock and Food Availability -Livestock related information is taken from Department of Animal Husbandry Dairying and Fisheries (Government of India). Storage capacity of public Goodwin is taken from different publication of Department of Food and Public Distribution, Ministry of Consumer Affairs (Government of India) and Rural Development Statistics, National Institute of Rural Development Rajendra Nagar (Hyderabad). Per capita calorie intake per day and per capita consumption expenditure (at constant level) is taken from National Sample Survey Organization (NSSO), Department of Statistics (Government of India).

Rural Development- Government expenditure (revenue + capital) on agricultural and allied sector, rural development, and irrigation and flood control; per capita net domestic product were taken from Reserve Bank of India (RBI).

Infrastructure -Railway road length is taken from Centre Monitoring Indian Economy (CMIE) and Railway Board (Government of India). Road length is taken from Centre Monitoring Indian Economy (CMIE).

Climatic Variables -Minimum and maximum were taken from the Indian Meteorological Department (IMD) (Government of India) database. This data was available on daily intervals with latitude and longitude information of monitoring stations. Due to unavailability of city wise data of temperature, the stations pertaining to specific latitude and longitude information were identified. Based on this information so generated, geographical regions were identified. Then from the groups of such stations different geographical region were linked to arrive at the state level data points. Monthly district wise rainfall information also was taken from Hydromet Division, Indian Meteorological Department *(*IMD) (Government of India). Geographical related factor is taken from Central Research Institute for Dry Land Agriculture (CRIDA), Hyderabad (India).

These data were converted in monthly averages city wise, after that data transformed in state wise monthly maximum and minimum for selected specific city, it was collected from the 354 meteorological stations in thirteen states of India. To process basic information on climatic factors like rainfall, minimum, maximum and mean temperature data, the C^{++} software was used. The SPSS software was used to extract and bring data to excel format. For each crops annual average actual minimum and maximum; and rainfall in entire crop duration was taken for the regression analyses.

3.2. Empirical Analysis

3.2.1. Econometric Model for Crop Wise Productivity

To evaluate the impact of climate change on agriculture crops in India sixteen major food-grain and non-food grain crops were taken. Food-grain crops such as rice, wheat, jowar, bajra, maize, ragi, potatoes, arhar, barely and gram and non food-grain crops such as sugarcane, cotton, soyabeans, groundnut, till and linseed were included. All these crops cover more than 75% of the total agricultural cropped area. To evaluate the impact of climate change on crop wise production for per unit land was taken as dependent variable utilizing panel for time period, 1980 to 2009. For regression analysis Cobb-Douglas production is incorporated. This model assumes that agricultural production is a function of many endogenous and exogenous variables like cultivated area, irrigated area, fertilizers, labours, tractors and pumpset; this is also function of many exogenous factors like forest area, literacy rate, etc. In functional form this may be-

$$(TP)_{it} = f\{(AS)_{it}, (IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (PS)_{it}, (FA)_{it}, (LR)_{it}\ (FHP)_{it}\} \quad (1)$$

Where, *TP* is total production for each food grain crop. *i* is cross sectional groups of states for separate crop and *t* is the time period. *AS*, *IA*, *TF*, *AL*, *TT* and *PS* are the crop wise area sown, irrigated area, agricultural labour, tractors and pumpset respectively. *FA* is the share of forest area for each crop. *LR* is the share of literacy rate for respective crops. *FA* is crop wise share of forest area {*FA*= (Gross Forest Area/Gross Sown Area)*Respective Crop Area)}; *LR* is literacy rate {*LR*= (Overall Literacy Rate/Gross Sown Area)* Respective Crop Sown Area}. *FHP* is farm harvest price for respective crops (at constant level 1993-94). Now, divide by *TP* to *AS* (for production per unit land or land productivity) than equation (1) will become-

$$(TP/AS)_{it} = f\{(IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (PS)_{it}, (FA)_{it}, (LR)_{it}, (FHP)_{it}\} \quad (2)$$

$(TP/AS)_{it}$ is production of per unit land for each crop in the equation (2). Cobb-Douglas production model assume that climatic factors are input factor for growth of crop (Nastis *et al.*, 2012). After incorporate the climatic factor equation (2) will be following form-

$(TP/AS)_{it} = f\{(IA)_{it}, (TF)_{it}, (AL)_{it}, (TT)_{it}, (PS)_{it}, (FA)_{it}, (LR)_{it}, (FHP)_{it}, (AARF)_{it}, (AAMAXT)_{it}, (AAMINT)_{it}\}$ (3)

Where, *AARF, AAMAXT and AAMINT* are the annual average rainfall, annual average maximum and annual average minimum temperature in entire crop duration respectively. In the original form of Cobb-Douglas production function model, equation (3) will be in following form-

$$ln\ (TP/AS)_{it} = \beta_0 + \beta_1\ ln\ (IA)_{it} + \beta_2\ ln\ (TF)_{it} + \beta_3\ ln\ (AL)_{it} + \beta_4\ ln\ (TT)_{it} + \beta_5\ ln\ (PS)_{it} + \beta_6\ ln\ (FA)_{it} + \beta_7\ ln\ (LR)_{it} + \beta_8\ ln\ (FHP)_{it} + \beta_9\ ln\ (AARF)_{it} + \beta_{10}\ ln\ (AAMAXT)_{it} + \mu_i \quad (4)$$

Where, β_0 is constant coefficient; β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, and β_{10} are the regression coefficient for respective variables and μ_i is intercept term in the model. Equation (4) represents the real functional form of Cobb-Douglas production function model. Similar model was used by Nastis *et al.* (2012) to analysis the climatic impact on agricultural productivity in Greek. Cobb-Douglas production model was used by Gupta *et al.* (2012) to investigate the climatic impact on rice, sorghum and millet productivity utilizing panel in India.

3.2.2. Econometric Model for Aggregate Value of Production

To analyze the impact of climatic and socio-economic factors on value of production, value of production of fifteen crops was calculated by farm harvest price (at constant price 1993-94). Cobb-Douglas production function model was incorporated. Per unit land productivity (in monetary term) as dependent variables was regressed with twelve different socio-economic and climatic factors utilizing panel for time period, 1985-2009.

$$ln\ (VP/AS)_{it} = \beta_0 + \beta_1\ ln\ (IA/AS)_{it} + \beta_2\ ln\ (TF/AS)_{it} + \beta_3\ ln\ (AL/AS)_{it} + \beta_4\ ln\ (TT/AS)_{it} + \beta_5\ ln\ (PS/AS)_{it} + \beta_6\ ln\ (FA/AS)_{it} + \beta_7\ ln\ (LR/AS)_{it} + \beta_8\ ln\ (RRL/AS)_{it} + \beta_9\ ln\ (GE/AS)_{it} + \beta_{10}\ ln\ (AARF)_{it} + \beta_{11}\ ln\ (AAMAXT)_{it} + \beta_{12}\ ln\ (AAMINT)_{it} + U_{it} \quad (5)$$

Where, *VP* is aggregate value of production for all crops and *t* is time period for each panel. *AS* is aggregate area for all crops; and *IA, TF, AL, TT, PS, FA, LR* and *RRL* are the aggregate irrigated area, fertilizers, agricultural labour, tractors, forest area, literacy rate and railway road length respectively. *GE* is aggregate government expenditure on agricultural and allied sector; rural development; irrigation and flood control. *AARF*, *AAMAXT*, and *AAMINT* are actual annual average rainfall, maximum and minimum temperature respectively; β_0 is constant term; $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}, \beta_{11}$, and β_{12} are regression coefficient for respective variables; and U_i is error term in equation (5) (Nastis *et al.*, 2012).

3.2.3. Generation of Food Security Index

Climate change and its impact on agricultural productivity and other sectors of the economy are multidimensional and complex. Agricultural productivity of any region in turn directly or indirectly affects food security of that region particularly for rural farming based households of all developing countries. Food security is again a complex concern which is impacted by socio-economic, geographical, political, climatic and many others variables. To identify the food security index, Z-score method was used by Shakeel *et al.* (2012); and Rukhsana (2011) in Uttar Pradesh (India). This method is based on descriptive analysis and this includes all components of the food security such as availability, accessibility and stability of food. However, we might not be able to include the utilization component of food security because of unavailability of food utilization related information. Simple descriptive method also was used to create global food security index by Economic Intelligence Unit in 2012 (GFSI, 2012).[1] To create the food security index (FSI), simple descriptive analysis is used in this study. If the parameters are the favorable for food security than following descriptive formulae was applied-

$$CI_i = \{(x_i – Min(x)) / (Max(x) – Min(x)\} \quad (6)$$

Where, *CI* is composite Z-score (*Z*- index) (GFSI, 2012)[2]; *Min (x)* and *Max (x)* are lowest and highest values in each series within states for same parameters respectively; *i* is indicates the i^{th} parameters. If the parameters are the unfavorable for food security than following descriptive formulae is applied-

$$CI_i = \{(x_i – Max(x)) / (Max(x) – Min(x)\} \quad (7)$$

Final food security index (FSI) is calculated by below formulae-

$$FSI_s = \sum CI_i/n \quad (8)$$

Where FSI is food security index, *s* is state and *n* is total number of parameters. Following variables were incorporated to create the state wise food security index.

[1] http://www.foodsecurityindex.eiu.com/
[2] http://www.foodsecurityindex.eiu.com/

Food Availability

(1) Number of livestock on per 1000 population (2) Per capita food grain availability (in Kg./Year). (3) Per capita calorie availability per day (in Calories). (4) Use of agricultural labour on per hectare cultivated land. (5) Per capita consumption expenditure per month (in Rs.). (6) Government expenditure (revenue + capital) on agricultural and allied sector, rural development, and irrigation and flood control (on per hectare cultivated land).

Stability of Food

(1) Yield of Food Grain (in Kg. /Hectare). (2) Consumption of fertilizers on per hectare cultivated land (in Kg. /Hectare). (3) Percentage of gross irrigated area to net sown area. (4) Cropping intensity (in %). (5) Ratio of literate population to gross sown area. (6) Percentage of forest area to gross sown area. (7) Storage capacity per 1000 population (in Quintal).

Accessibility of Food

(1) Percentage of main worker to the total population (in %). (2) Literacy rate (in %). (3) Road length (in Km) for per 1000 population. (4) Railway Road Length (in Km) for per 1000 population. (5) Per capita national domestic product (in rupees at constant prices). (6). Poverty (in %). (7) Urbanization (in %). (8) Gender ratio (in Number). (9) Population density (in Number). (10) Percentage of rural population to total population (in %). (11) Credit Deposits Ratio (CDR). (12) Infant Mortality Rate (IMR). (13) Rural Population on per unit land.

3.2.4. Econometric Model for Food Security Index (FSI) and Climatic and Non-climatic Parameters

In India, none of the studies were found to have analyzed the impact of climatic factors on food security index. Food Security Index (FSI) as dependent variable is regressed with climatic and non- climatic factors by simple multiple regression models for 13 major agriculturally intensive states of the country utilizing panel for time period, 1985-2009. This model assume that food security index is a function of many socio-economic and other demographic variables such as gross sown area, irrigated area, agricultural labour, tractor, pumpset, government expenditure on agricultural and allied activity. In mathematically this may be following form-

(FSI) = f {(CI), (LIV/GSA), (RL/GSA), (RRL/GSA), (PS/GSA), (TT/GS), (FA/GSA), (GIA/GSA), (AL/GSA), (RP/GSA), (TFC/GSA), (GE/GSA), (LP/GSA), (UR), (PD), (POV)} (9)

Where *FSI* is food security index; *GSA* is gross sown area; *CI* is cropping intensity; *LIV/GSA), (RL/GSA), (RRL/GS), (PS/GSA), (TT/GS), (FA/GSA), (GIA/GSA), (AL/GSA), (RP/GSA), (TFC/GSA); (GE/GSA);* and *(LP/GSA)* are ratio of gross sown area with gross livestock, gross road length, railway road length, total pumpset, total tractor, gross forest area, gross irrigated area, agricultural labour, rural population on per hectare land, consumption of total fertilizers; aggregate government expenditure (revenue + capital) on agricultural and allied sector; and total literate population respectively. *UR*, *PD* and *POV* are urbanization rate, population density and poverty respectively. After incorporating the climatic factors in above functional equation (9), it will be-

$$(FSI)_{st} = \alpha_0 + \alpha_1 (CI)_{st} + \alpha_2 (Liv/GSA)_{st} + \alpha_3 (RL/GSA)_{st} + \alpha_4 (PS/GSA)_{st} + \alpha_5 (TT/GS)_{st} + \alpha_6 (FA/GSA)_{st} + \alpha_7 (GIA/GSA)_{st} + \alpha_8 (AL/GSA)_{st} + \alpha_9 (TFC/GS)_{st} + \alpha_{10} (GE/GSA)_{st} + \alpha_{11} (LP/GSA)_{st} + \alpha_{12} (UR)_{st} + \alpha_{13} (PD)_{st} + \alpha_{14} (POV)_{st} + \alpha_{15} (RF)_{st} + \alpha_{16} (MAXT)_{st} + \alpha_{17} (MINT)_{st} + \alpha_{18} (MEANT)_{st} + \alpha_{19} (LAT*GSA)_{st} + \alpha_{20} (LON*GSA)_{st} + U_{st} \quad (10)$$

Where, *FSI* is food security index for cross sectional states of *s* and *t* is time period. *RF* is average annual rainfall. *MAXT*, *MINT* and *MEANT* are average annual maximum, minimum and mean temperature respectively. *LAT* and *LON* are latitude and longitude situation of each state. Other remaining variables are similar to equation (9); α_0 is constant coefficient term; α_1 to α_{20} are regression coefficient for respective variables. U_{st} is the error term. Similar model was used by Demeke *et al.* (2011) to investigate the impact of socio-economic and climatic factor on food security index, using primary survey of households in Ethiopia.

3.2.5. Econometric Model for Food Security Index and its Components

To find the Interlinkage between food security index and its components, simple multiple regression model is applied for time period, 1985 to 2009 utilizing panel. Constructed food security index as a response function is regressed with it components such as availability, stability and accessibility of food.

$$(FSI)_{st} = \theta_0 + \theta_1 (AVAF)_{st} + \theta_2 (STAF)_{st} + \theta_3 (ACCF)_{st} + \phi_{st} \quad (11)$$

Where, *FSI* is food security index. *AVAF*, *STAF* and *ACCF* are availability, stability and accessibility of food respectively; *s* and *t* are the cross sectional states and time period respectively; and θ_0 is constant coefficient; and θ_1, θ_2, and θ_3 are the regression coefficient for respective variables. ϕ_{st} is the error term in the model.

3.2.6. Econometric Model for Components of Food Security Index and Climatic and Socio-economic Variables

To identify the separate impact of climatic and non-climatic factors on components of food security index i.e. on availably, stability and accessibility of food following three multiple regression model (12, 13, and 14) were used-

$$(AVAF)_{st} = \Delta_0 + \Delta_1 (CI)_{st} + \Delta_2 (LIV/GSA)_{st} + \Delta_3 (RRL/GSA)_{st} + \Delta_4 (RP/GSA)_{st} + \Delta_5 (TT/GSA)_{st} + \Delta_6 (AL/GSA)_{st} + \Delta_7 (LP/GSA)_{st} + \Delta_8 (GE/GSA)_{st} + \Delta_9 (UR)_{st} + \Delta_{10} (IMR)_{st} + \Delta_{11} (POV)_{st} + \Delta_{12} (FGPH)_{st} + \Delta_{13} (RF)_{st} + \Delta_{14} (MAXT)_{st} + \Delta_{15} (MINT)_{st} + \Delta_{16} (MEANT)_{st} + \sigma_{st} \quad (12)$$

Where, *AVAF* is availability of food; and *IMR, FGPH,* and *RP/GSA* are infant mortality rate, food grain production per hectare, and rural population on per hectare land respectively. Other reaming parameters are discussed in equation (9). Δ_0 is constant coefficient and Δ_1 to Δ_{16} are the regression coefficient for respective parameters; and σ_{st} is error term in the model.

$$(STAF)_{st} = \lambda_0 + \lambda_1 (CI)_{st} + \lambda_2 (LIV/GSA)_{st} + \lambda_3 (RRL/GSA)_{st} + \lambda_4 (TT/GAS)_{st} + \lambda_5 (IA/GAS)_{st} + \lambda_6 (AL/GAS)_{st} + \lambda_7 (TFC/GAS)_{st} + \lambda_8 (LP/GAS)_{st} + \lambda_9 (PD)_{st} + \lambda_{10} (POV)_{st} + \lambda_{11} (RF)_{st} + \lambda_{12} (MAXT)_{st} + \lambda_{13} (MINT)_{st} + \lambda_{14} (MEANT)_{st} + €_{st} \quad (13)$$

Where, *STAF* is stability of food and λ_0 is constant coefficient and λ_1 to λ_{14} are the regression coefficient for respective variables; $€_{st}$ is error term in the model. Other parameters are discussed in equation (9).

$$(ACCF)_{st} = \xi_0 + \xi_1 (LIV/GSA)_{st} + \xi_2 (TT/GAS)_{st} + \xi_3 (AL/GAS)_{st} + \xi_4 (GE/GAS)_{st} + \xi_5 (PD)_{st} + \xi_6 (POV)_{st} + \xi_7 (RF)_{st} + \xi_8 (MAXT)_{st} + \xi_9 (MINT)_{st} + \xi_{10} (MEANT)_{st} + \tau_{st} \quad (14)$$

Where, *ACCF* is accessibility of food. Other reaming parameters are similar to equation (10). ξ_0 are intercept term and ξ_1 to ξ_{10} are the regression coefficient for respective independent variables; and τ_{st} error coefficient in the model.

3.2.7. Econometric Model for Poverty and Food Security Index (FSI)

Poverty as dependent variable is regressed with climatic and non- climatic factors from 13 major agriculturist intensive states of the country utilizing panel for time period, 1985-2009. To analysis the impact of food security index, socio-economic and other demographic variables on poverty following econometric model is applied-

$$(POV)_{st} = \beta_0 + \beta_1 (FSI)_{st} + \beta_2 (VP/GSA)_{st} + \beta_3 (LIV/GSA)_{st} + \beta_4 (RLL/GSA)_{st} + \beta_5 (PS/GSA)_{st} + \beta_6 (RP/GSA)_{st} + \beta_7 (TT/GS)_{st} + \beta_8 (GIA/GSA)_{st} + \beta_9 (AL/GSA)_{st} + \beta_{10} (GE/GSA)_{st} + \beta_{11} (LR)_{st} + \beta_{12} (UR) + + \beta_{13} (PD)_{st} + \beta_{14} (GR)_{st} + \beta_{15} (CDR) + \beta_{16} (IMR) + Z_{st} \quad (15)$$

Where *POV* is poverty; *s* and *t* are cross sectional states and time period respectively. *VP*, *LR*, *GR*, *CDR* and *IMR* are value of production on per unit land (in monetary value at constant price) literacy rate, gender ratio, credit deposit ratio and infant mortality rate respectively. Other variables are discussed in equation (9) and β_0 *is* constant term; and β_1 to β_{16} are the regression coefficient for respective variables and Z_{st} is error term in this equation.

Multiple regression analysis was run with econometric softwares like STATA, Minitab and SPSS to estimate best fit for the models proposed. Several regressions models were run for selection an appropriate model. Certain variables in different models were dropped from the regression models due to high insignificant level of respective variable. To identify the state effect and time effect in panel data fixed effect regression model is used (Gupta *et al.*, 2012). Random effect regression model was applied to identify the year and state impact on dependent variables (Gupta *et al.*, 2012). To check the quandary of fixed and random effect regression model, Hausman specification estimation and Breusch-Pagan Lagrange Multiplier (LM) is used. Pesaran's test was used to identify the cross sectional independence in panel data set. For group-wise heteroskedasticity, Modified Wald test is applied. For serial correlation/autocorrelation**,** Lagram-Multiplier test (Wooldridge test for autocorrelation) for serial correlation is used. To remove the presence of heteroskedasticity and multicollinearity, linear regression, correlated panels corrected standard errors (PCSEs) model is applied. Finally, to remove the presence of Heteroskedasticity, serial correlation, cross-sectional dependence and multicollinearity, Driscoll-Kraay standard errors estimation model is used in regression model.

3.2.8. Descriptive Results

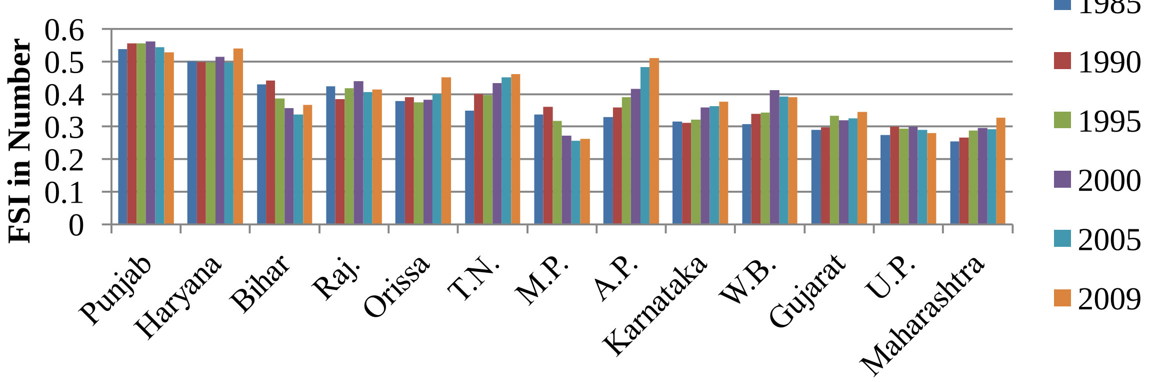
Table 1- Food security index in Indian states

States/ Year	1985	1990	1995	2000	2005	2009
Punjab	0.539 (1)	0.555 (1)	0.557 (1)	0.562 (1)	0.543 (1)	0.529 (2)
Haryana	0.501 (2)	0.498 (2)	0.496 (2)	0.515 (2)	0.497 (2)	0.540 (1)
Bihar	0.430 (3)	0.442 (3)	0.386 (6)	0.357 (9)	0.338 (9)	0.367 (9)
Rajasthan	0.424 (4)	0.385 (6)	0.417 (3)	0.439 (3)	0.407 (5)	0.414 (5)
Orissa	0.379 (5)	0.391 (5)	0.375 (7)	0.381 (7)	0.399 (6)	0.452 (5)
Tamil Nadu	0.349 (6)	0.401 (4)	0.396 (4)	0.434 (4)	0.451 (4)	0.462 (4)
M.P.	0.338 (7)	0.362 (7)	0.317 (11)	0.272 (13)	0.257 (13)	0.261 (13)
A.P.	0.32 8 (8)	0.359 (8)	0.390 (5)	0.416 (5)	0.483 (3)	0.510 (3)
Karnataka	0.316 (9)	0.311 (10)	0.322 (10)	0.358 (8)	0.364 (8)	0.376 (8)
W.B.	0.307 (10)	0.338 (9)	0.344 (8)	0.412 (6)	0.393 (7)	0.391(7)
Gujarat	0.291 (11)	0.298 (12)	0.334 (9)	0.319 (10)	0.325 (10)	0.345 (10)
U.P.	0.275 (12)	0.301 (11)	0.293 (12)	0.300 (11)	0.289 (12)	0.280 (12)
Maharashtra	0.255 (13)	0.266 (13)	0.287 (13)	0.295 (12)	0.291 (11)	0.327 (11)

Source - *Estimated by Authors and values in bracket represents the rank within states.*

The food security situation of major states of the country is presented in Table 1 Punjab and Haryana are most food secure states; it means that food security are mainly related with food grain production, consumption expenditure, calories availability and government expenditure on per hectare cultivated land because both states have higher position in all these parameters compared to other states of the country (Shakeel *et al.*, 2012). On the other hand, even with average food productivity levels due to other adverse socio economic and government policy variables and particularly higher poverty incidence Uttar Pradesh and Madhya Pradesh have the 12th and 13th position respectively, in food security index in 2009. This is very crucial that Uttar Pradesh is most agriculturally intensive state of the country; despite that this has 12th position in food security index in 2005 and 2009; and it means that this is second most food insecure state among thirteen states; and there are many reasons responsible for this like Uttar Pradesh is second most poorest state, lower agriculture productivity and this is one of the most vulnerable areas to climate related disasters like floods and drought in India. Madhya Pradesh is poorest state in food security because lower index for this state shows 13th rank in food security index. Bihar is another state which is continuous lagging behind in food security index compared to other states. While, Andhra Pradesh has achieved better position in food security index which has a third position in food security index in 2005 and 2009 after 2000, this needs to be investigated that other than food grain productivity what factors have essentially contributed to Andhra Pradesh's better performance in terms of food security over these three decades. Tamil Nadu also has a better position after 1985; it has fourth position in food security index. Rajasthan, Orissa, Tamil Nadu, Karnataka, West Bengal, Maharashtra and Gujarat are still struggling to achieve enough food security.

Figure 2:- Food Security Index in Indian States



Source - *Estimated by Authors*

Table 2- Pearson correlation coefficient for food security index (FSI) and its components

Variables	Food Security	Availability	Stability	Accessibility
Food Security	1	0	0	0
Availability	0.890*	1	0	0
Stability	0.761*	0.566*	1	0
Accessibility	0.403*	0.333*	0.229*	1

Note -*Correlation Coefficient at 1% significance level.*

Table 2 represents the correlation coefficients for food security index and its components and shows that availability of food is sole and significant component for food security; it is statistically significant at 1% significance level and it has high correlation coefficient. Stability of food is another main component for food security; it is statistically significant at 1% level. It means that all components of food security are interconnected to each other (Dev and Sharma, 2010).

4. 0. Empirical Finding

Table 3- Impact of different factor on food grain crops with linear regression, correlated panels corrected standard errors (PCSEs) model

Variable	Rice	Arhar	Gram	Wheat	Maize
IA	0.13896*	0.05926*	-0.03941*	0.20648*	-0.03049
TF	0.15737*	0.07661*	0.08743**	0.17846*	0.43965*
AL	-0.17752*	0.15245*	0.10196*	0.04909*	-0.35489*
TT	-0.00770	0.05464*	0.05013*	-0.01595	-0.03798
PS	0.04308*	-0.15606*	-0.08906*	-0.30162*	-0.00460
FA	-0.16288*	-0.19593*	-0.02900**	-0.12138*	0.11251*
LR	0.06093*	0.11466*	-0.08571*	0.08694*	-0.20191*
FHP	0.11793*	-0.07199*	0.07532*	0.25183*	0.38421*
AARF	-0.0625***	0.17180*	0.01576**	0.01747*	-0.16567*
AAMAXT	-2.63979*	0.05496	-0.14467	2.71730*	-2.73403*
AAMINT	0.04554	-0.77777*	-0.21814**	-1.73091*	-0.32091
Con. Term	4.59423*	0.28042	-0.20259	-1.85194*	5.75655*

Source -*Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.*

Table 3 shows the crop-wise regression results for food grain crops. Any increment in maximum temperature has a negative and statistically significant impact on wheat productivity. Increase in maximum temperature by 1% would negatively affect the wheat productivity by 2.63% and increase in irrigated area is important factor to increase the wheat productivity. Arhar productivity is negatively affected due to increase in minimum temperature; regression coefficient for minimum temperature is significant at 1% significance level; it means that 1% rise in minimum temperature has declined arhar productivity by 0.78%. Increase in irrigated area, fertilizer, agricultural labour and use of tractor are beneficial for arhar productivity. Gram productivity gets negatively affected due to any increment in minimum temperature; it is statistically significant at 5% significance level. Increase in maximum temperature also negatively affects to gram productivity. Fertilizer, agricultural labour and tractor positively affect the arhar productivity. Wheat productivity is also negatively affected due to rise in minimum temperature; the regression coefficient for minimum temperature is statistically significant at 1% significance level and it shows that 1%

increase in minimum temperature negatively affects the 1.73% wheat productivity. On the other hand, any increment in rainfall and maximum temperature positively affects the wheat productivity; both have positive and statistically significance impact on wheat food grain. Maize productivity is negatively affected due to increase in rainfall, maximum temperature and minimum temperature. Although, regression coefficient for minimum temperature is not significant but its negative sign with maize is showing that negative impact on maize productivity. 1% increase in rainfall and maximum temperature negatively affect the maize productivity up to 0.17 and 2.73% respectively because regression coefficient for both area statistically significant at 1% level.

Table 4- Impact of different factor on food grain crops with linear regression, correlated panels corrected standard errors (PCSEs) model

Variable	Bajra	Jowar (Sorghum)	Ragi	Barley
IA	0.23263*	0.0404*	-0.0270***	0.03733
TF	-0.03664	0.07268	0.44740*	0.11748*
AL	-0.09539*	-0.07125***	-0.00727	0.04879**
TT	0.01002	-0.01022	-0.08533*	0.01042
PS	0.00823	0.12935*	-0.00052	0.10112*
FA	-0.02726	0.21196*	-0.25283*	-0.18002*
LR	-0.02843	-0.38995*	0.05416	0.00537
FHP	0.26896*	0.12593*	-0.02809	0.00194
AARF	0.14105*	0.15904*	-0.08359	-0.05816*
AAMAXT	-0.91007*	-0.92748***	-0.82148	-0.76733***
AAMINT	0.59215	0.75937***	0.58385	-0.21894
Con. Term	-0.31097	-1.09437***	1.04984***	1.15438*

Source -*Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.*

Table 4 represents the crop wise regression results. Bajra productivity gets negatively affected due to rise in maximum temperature; it has a negative and statistically significant impact on bajra at 5% significance level; and shows that 1% increment in maximum temperature bajra productivity negatively affects up to 0.91%. Increase in Irrigated area, tractor, and pumpset for bajra cultivation has positive and statistically significance on bajra productivity. Increases in farm harvest price of bajra also a major factor to increasing the bajra food grain productivity. Sorghum productivity negatively affects due to any variation in maximum temperature; it has negative and statistically significant impact on sorghum at 10% significance level. Increase in minimum temperature and rainfall has positive relation with sorghum grain. Increase in irrigated area and total fertilizers also positively affect the sorghum crop. maximum temperature and rainfall have a negative relationship with ragi productivity; although regression coefficient for both are not significant but negative sign for maximum temperature and rainfall are showing negative impact on ragi. Any variation in minimum temperature has a positive relationship with ragi grain productivity. Use of fertilizers is beneficial for ragi; it has a positive and statistically significance impact on ragi grain productivity.

Table 5- Impact of different factor on non-food grain crops with linear regression, correlated panels corrected standard errors (PCSEs) model

Variable	Sugarcane	Potato	Cotton	Groundnut	Sesamum	Linseed	Soybeans
IA	-0.04169*	0.03702*	0.14255*	0.02185	0.0183914	0.0788***	-0.4539*
TF	0.08151*	0.15417*	0.18222*	0.02710	0.17176*	-0.0889	0.2628***
AL	-0.12575*	-0.02482	0.06020	-0.01824	-0.0741***	0.1756*	-0.1245
TT	-0.10924*	-0.10440*	-0.12900*	-0.09473*	-0.11487*	0.0570	0.1338
PS	0.02585***	-0.00988	-0.11519**	0.00909	-0.10145*	-0.2564*	-0.1259
FA	0.02381	-0.07642*	-0.27872*	-0.02591	-0.18545*	-0.1735*	0.8167*
LR	0.290705*	0.17970 *	0.24169*	0.09671*	0.28735*	0.2009*	1.6765**
FHP	0.12045*	0.10480*	0.14438*	0.19167*	0.25878*	0.1951*	-0.1722
AARF	-0.10640*	0.00603	0.06187	0.01594	0.248168*	-0.0050	-0.0318
AAMAXT	-1.62082*	0.49116	-1.53994**	-0.31800	-2.33288*	3.7795**	1.04319
AAMINT	1.02045*	-0.47589 *	2.06503*	-0.28261	0.71075	-1.6415*	5.0861***
Intercept	3.84209*	1.19988*	-0.29994	0.70255	1.96768*	-4.2757**	-13.100*

Source -*Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.*

Table 5 shows the empirical results for cash crops and indicates that any rise in maximum temperature have a negative and statistically significant impact on sugarcane, cotton and sesamum crops, while; it has a positive impact on linseed productivity. On the other hand, any variation in minimum temperature also has a negative and statistically significant impact on potatoes and linseed productivity. Sugarcane, cotton and soybeans productivity beneficial from increase in minimum temperature; it has a positive and statistically significant impact on these crops. Any increments in rainfall also negatively affect the sugarcane productivity and positive impact on sesamum productivity. In brief various climatic parameters negatively affect to all cash crop productivity in different way in India. Thus based above empirical findings we can predict that climatic factors negatively affect the cash crop productivity.

Table 6 -Impact of climatic and non-climatic variables on value of production by linear regression, correlated panels corrected standard errors (PCSEs) model

Number of Observation		325	R-squared		0.8405	
Wald chi2		4833.01	Prob > chi2		0.0000	
ln (TP/AS)	Reg. Coefficient	Panel Corr Std. Errors	Z	P > |z|	95% Confidence Interval	
IA	0.75776*	0.08891	8.52	0.000	0.58351	0.93201
TF	-0.11070**	0.05066	-2.19	0.029	-0.20999	-0.0114
AL	-0.00015*	0.00002	-8.05	0.000	-0.00018	-0.00011
TT	-0.05440**	0.02254	-2.41	0.016	-0.09858	-0.01021
PS	0.01232	0.01279	0.96	0.335	-0.01275	0.03739
FA	-0.07759*	0.02262	-3.43	0.001	-0.12191	-0.03326
LR	0.02448	0.05229	0.47	0.640	-0.07801	0.12697
RRL	-0.22523**	0.10226	-2.20	0.028	-0.42565	-0.02481
GE	0.89206*	0.03750	23.79	0.000	0.81857	0.96555
RF	0.28079 *	0.05561	5.05	0.000	0.17179	0.38979
AAMAXT	0.30227	0.53130	0.57	0.569	-0.73905	1.34360
AAMINT	-1.14154*	0.29284	-3.90	0.000	-1.7155	-0.56757
Intercept	3.68505*	0.83675	4.40	0.000	2.04506	5.32504

Source -*Estimated by Authors*

Table 6 shows the empirical findings for impact of climatic and non-climatic factors on value of production. Any increment in minimum temperature has negatively affects the value of production; it has a negative and statistically significance relationship with value of production. Rainfall has a positive and statistically significance impact on value of production and it means any increment in rainfall is beneficial for increasing value of production. The use of fertilizers, agricultural labour and mechanization negatively affect the value of production in India. Government expenditure on agricultural and allied sector; rural development; irrigation and flood control is a crucial factor that may mitigate the adverse effect of climate variability and it may increase the land productivity.

Table 7 -Impact of components of food security on food security index (FSI) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		325	R-squared		1.0000	
No. of States		13	Wald chi^2		2.66e+16	
No. of Obs./States		25	Prob > chi2		0.0000	
Variables	Reg. Coef.	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
AVAF	0.23077*	5.86e-09	3.9e+07	0.000	0.23077	0.23077
STAF	0.26923*	3.88e-09	6.9e+07	0.000	0.26923	0.2692
ACCF	0.5*	1.04e-08	4.8e+07	0.000	0.5	0.5
Con. Term	4.52e-09	3.97e-09	1.14	0.254	-3.25e-09	1.23e-08

Note - *Estimated by Authors.*

Table 7 reveals regression results among food security index and its components. The components of food security index are regressed on FSI to estimate their individual impact. Although the results are not reliable due to high multicollinearity however, it might be useful to see that each component is significant part for food security index (Dev and Sharma, 2010).

Table 8- Impact of climatic and non-climatic factors on food security index (FSI) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.8471	
No. of States		13	Wald chi^2		10940.29	
No. of Obs./States		25	Prob > chi2		0	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*z*	$P > \lvert z \rvert$	95% Confidence Interval	
CI	0.00124*	0.00024	5.22	0.000	0.00077	0.00170
LIV/GSA	0.00004*	4.48e-06	9.08	0.000	0.00003	0.00005
RL/GSA	0.00065	0.00052	1.24	0.215	-0.00038	0.00169
PS/GSA	-0.00042*	0.00012	-3.45	0.001	-0.00066	-0.00018
TT/GSA	-0.00055	0.00036	-1.52	0.130	-0.00126	0.00016
FA/GSA	0.00083*	0.00029	2.87	0.004	0.00027	0.00141
GIA/GSA	0.00220*	0.00021	10.28	0.000	0.00178	0.00262
AL/GSA	0.00002**	8.38e-06	2.17	0.030	1.80e-06	0.00003
TFC/GSA	0.00015	0.00010	1.54	0.124	-0.00004	0.00034
GE/GSA	0.70493*	0.25865	2.73	0.006	0.19798	1.21188
LP/GSA	5.00e-06*	9.17e-07	5.46	0.000	3.20e-06	6.80e-06
UR	0.00188**	0.00079	2.40	0.017	0.00034	0.00342
PD	-0.00028*	0.00002	-12.86	0.000	-0.00032	-0.00023
POV	-0.00117*	0.00025	-4.65	0.000	-0.00166	-0.00067
RF	-0.00001**	6.69e-06	-2.01	0.044	-0.00003	-3.68e-1
MAXT	-0.00306***	0.00167	-1.83	0.067	-0.00633	0.00022
MINT	-0.00060	0.00227	-0.26	0.792	-0.00505	0.00385
MEANT	-0.01749*	0.00386	-4.53	0.000	-0.02505	-0.00992
Con. Term	0.60374*	0.08470	7.13	0.000	0.43772	0.76974

Note - *Estimated by Authors*

Table 8 reveals that regression results for impact of climatic and other socio-economic variables on food security index. Any increment in rainfall, maximum and minimum temperature has negative and statistically significance impact on the food security index. Increase in minimum temperature has a negative relationship with food security index. In case of socio-economic variables like cropping intensity; ratio of gross sown area with gross livestock, gross forest area, gross irrigated area, agricultural labour, fertilizers, government expenditure and literate population has a positive and statistically impact on food security index; and these all are most crucial factor to increase the food security index. Government expenditure is a most important factor for increasing food security index among all socio-economic factors. Increase in population density and poverty has negative and statistically significance impact on food security index.

Table 9- Impact of climatic and socio-economic factors on availability of food (AVAF) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.8356	
No. of States		13	Wald chi^2		228.51	
No. of Obs./States		25	Prob > chi2		0.0000	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
CI	0.0002347	0.0006152	0.38	0.703	-0.00097	0.001440
LIV/GSA	0.0000709*	0.0000157	4.52	0.000	0.000040	0.000101
RRL/GSA	0.3357677**	0.1338376	2.51	0.012	0.073450	0.598084
RP/GSA	-0.0000777*	0.0000107	-7.24	0.000	-0.00010	-0.00006
TT/GSA	-0.003116**	0.0012978	-2.40	0.016	-0.00566	-0.00057
AL/GSA	0.0000646 *	0.0000237	2.72	0.006	0.000018	0.000111
LP/GSA	9.95e-06**	4.43e-06	2.24	0.025	1.26e-06	0.000020
GE/GSA	1.479172**	0.5895208	2.51	0.012	0.323733	2.634612
UR	-0.0084064*	0.0021369	-3.93	0.000	-0.01260	-0.00422
IMR	-0.001452**	0.0007243	-2.01	0.045	-0.00287	-0.00003
POV	-0.0012783	0.0013386	-0.95	0.340	-0.00390	0.001345
FGPH	0.0010616*	0.0002956	3.59	0.000	0.000482	0.001641
RF	-0.00003***	0.0000164	-1.76	0.078	0.000061	3.27e-06
MAXT	-0.0080108	0.0069679	1.15	0.250	-0.00565	0.021668
MINT	-0.0017315	0.0060878	-0.28	0.776	-0.01366	0.010201
MEANT	-0.044493**	0.0174588	-2.55	0.011	-0.07871	-0.01028
Con Term	1.449479*	0.5009792	2.89	0.004	0.46758	2.43138

Note - *Estimated by Authors.*

Table 9 shows regression results of impacts of climatic and non-climatic factor on availability of food. All climatic factors have a negative relationship with availability of food. Any variation in mean temperature and rainfall has a negative and statistically significant impact on this component of the food security. In case of another policy parameters like increment in cropping intensity and food grain production per hectare; and rise in livestock, agricultural labour, literate population, railway road length, government expenditure on per unit arable land are the crucial factor to increase the level of availability of food. On the other hand, rise in population and tractors on per unit land are not better to increase the availability of food. Urbanization, infant mortality rate and poverty also negatively affect the level of food availability in the economy.

Table 10- Impact of climatic and socio-economic factors on stability of food (STAF) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.9268	
No. of States		13	Wald chi^2		507.15	
No. of Obs./States		25	Prob > chi2		0.0000	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*Z*	*P* > |*z*|	95% Confidence Interval	
CI	0.0030901*	0.000558	5.54	0.000	0.00199	0.00418
LIV/GSA	0.000032*	0.000012	2.60	0.009	7.83e-06	0.00006
RRL/GSA	0.080615	0.119770	0.67	0.501	-0.15413	0.31536
TT/GAS	-0.00099	0.001452	-0.68	0.496	-0.00383	0.00186
IA/GAS	0.00471*	0.000765	6.15	0.000	0.00321	0.00621
AL/GAS	-0.00009*	0.000018	-4.81	0.000	-0.00012	-0.0001
TF/GAS	0.001372*	0.00037	3.71	0.000	0.00065	0.00210
LP/GAS	7.99e-06***	4.65e-06	1.72	0.085	-1.11e-06	0.00002
PD	-0.00033*	0.00007	-4.62	0.000	-0.00047	-0.0002
POV	0.001681***	0.00099	1.71	0.088	-0.00025	0.00361
RF	5.96e-06	0.00002	0.37	0.709	-0.00003	0.00004
MAXT	-0.01143***	0.00636	-1.80	0.072	-0.02396	0.00104
MINT	0.004020	0.00646	0.62	0.533	-0.00863	0.01667
MEANT	-0.01094	0.01686	-0.65	0.516	-0.04399	0.02211
Con Term	0.18275	0.48703	0.38	0.707	-0.77182	1.13732

Note - *Estimated by Authors.*

Table 10 represents the regression results for stability of food and its determinants. Rising maximum temperature is negatively affects the stability of food. While, rainfall is crucial variable and it positive affect the level of stability of food. In case of another socio-economic factor like cropping intensity; livestock, railway road length, fertilizers, irrigated area, literate population on per unit land are all positive associated with stability of food. On the other hand, rising population density and use of tractor has negatively affects to this component. This is very interesting that poverty has positively correlated with this, here there could be reason that poor people purchasing power parity very low and they are not able to buy more food product in local market resulting that stability will increase in particular region. Here we are able to say that increment in fertilizers, railway road length, irrigated area and literate population on per unit cultivable land would be the better idea to increase the level of stability in the economy.

Table 11- Impact of climatic and socio-economic factors on accessibility of food (ACCF) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.7282	
No. of States		13	Wald chi^2		127.74	
No. of Obs./States		25	Prob > chi2		0.0000	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
LIV/GAS	0.00002*	7.75e-06	2.32	0.020	2.81e-06	0.000033
TT/GAS	-0.00022*	0.00075	-0.30	0.766	-0.00170	0.00126
AL/GAS	0.00004*	0.00001	3.69	0.000	0.00002	0.00007
GE/GAS	1.58514*	0.32914	4.82	0.000	0.94005	2.23024
PD	-0.00024*	0.00004	-6.28	0.000	-0.00031	-0.00016
POV	-0.00220*	0.00060	-3.66	0.000	-0.00338	-0.00102
RF	0.00002	0.00001	1.58	0.115	-4.68e-06	0.00004
MAXT	-0.00004	0.004490	-0.01	0.993	-0.00884	0.00876
MINT	0.00344	0.00453	0.76	0.448	-0.00544	0.01232
MEANT	-0.0092	0.00873	-1.05	0.292	-0.0263	0.00792
Con Term	0.61562*	0.24259	2.54	0.011	0.14016	1.09108

Note - *Estimated by Authors.*

Table 11 presents the empirical findings about the climatic and non-climatic factor on the most important factor of food security i.e. accessibility of food. This also shows that any variations in maximum and mean temperature are negatively associated with accessibility of food. Although, the regression coefficient for climatic parameters are not significant but based negative sign of coefficient provide the clear evidence that this negatively affect the level of accessibility of food. Empirical results also show that we can lead the accessibility of food of the population through to increase the livestock, agricultural labour and government expenditure on per unit agricultural land. Finally poverty is most dangerous parameters and this negatively affects the level of accessibility of food. Thus we need to eradicate this to solve this matter in the economy.

Table 12- Impact of food security index and other socio-economic factors on poverty with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.8885	
No. of States		13	Wald chi^2		353.37	
No. of Obs./States		25	Prob > chi2		0.0000	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
FSI	-27.7784***	16.06851	-1.73	0.084	-59.2721	3.7152
VP/GSA	-0.0007	0.00164	-0.46	0.648	-0.00397	0.00247
LIV/GSA	0.00225***	0.00118	1.91	0.056	-0.00006	0.00456
RRL/GSA	-12.78144*	3.670874	-3.48	0.000	-19.9762	-5.5866
PS/GSA	0.02701	0.02833	0.95	0.341	-0.02853	0.08254
RP/GSA	0.00313*	0.00085	3.68	0.000	0.00146	0.00480
TT/GSA	0.32003*	0.09971	3.21	0.001	0.12460	0.51547
IA/GSA	-0.33601*	0.07869	-4.27	0.000	-0.49025	-0.1817
AL/GSA	-0.00696*	0.00164	-4.23	0.000	-0.01018	-0.00373
LR	-0.03511	0.11373	-0.31	0.758	-0.25802	0.18780
UR	-0.81985*	0.19445	-4.22	0.000	-1.20098	-0.43873
GE/GSA	-158.130*	56.2274	-2.81	0.005	-268.334	-47.9267
GR	-0.15112*	0.03970	-3.81	0.000	-0.22894	-0.07330
CDR	0.22236*	0.06038	3.68	0.000	0.10401	0.340713
IMR	0.14030*	0.05202	2.70	0.007	0.03834	0.24227
Con. Term	180.3451*	37.46922	4.81	0.000	106.9068	253.783

Note - *Estimated by Authors*

Table 12 represents that regression result for impact of food security and other socio-economic variables on poverty. Food security index is major factor for poverty eradication (Hollaender, 2010); it has negative and statistically significance impact on poverty; and it means that any improvement in food security index has declined poverty (ADB, 2012). Increased in irrigated area also an important factor to eradicate the poverty, it negatively affected the poverty; it means that increase in irrigated area has declined the poverty. Increase in agricultural labour and government expenditure on per hectare cultivated land has a negative and statistically significance impact on poverty. Urbanization and gender ratio also negative affect the poverty; it has a negative and statistically significance relationship with poverty. Credit deposit ratio and infant mortality rate has positive impact on poverty; it means any increment in credit deposit ratio and infant mortality rate has increased the poverty; this means that if credit deposit ratio and infant mortality rate increase than this may increase the extra burden on population. In case of mechanization like use of tractor and pumpset also leading poverty; there may be reason that increase in mechanization may reduce the employment opportunities. Food security and government expenditure on per unit cultivated land are most important factors to eradicate of poverty.

5.0. Conclusion and Policy Implication

In line with the empirical result findings of other studies for food grain crops the analysis presented in this study also show that any increments in maximum temperature has negative and impact on rice, maize, bajra, jowar (sorghum) and barley productivity and the impact is also statistically significant (Kalra *et al.*, 2008; and Geethalakshmi *et al.*, 2011). Gram and Ragi productivity also get negatively affected due to increase in maximum temperature, while arhar and wheat productivity is positively affected due to increase in maximum temperature. Arhar, gram, wheat and maize productivity is negatively affected due to increase in minimum temperature (Kumar and Parikh, 2001; and Hundal and Prabhjyot-Kaur, 2007). Any increment in rainfall has a negative relationship with rice, barley, ragi and maize productivity. Increase in irrigated areas is an important factor to increase the productivity of rice, arhar, wheat, bajra and jowar (sorghum). Any increment in consumption of fertilizers could be better to increase the productivity of rice, arhar, gram, wheat, maize, ragi, barley and jowar (sorghum).

In case of mechanization i.e. increase in number of tractors has a positive and statistically significant impact on arhar, gram, bajra and barley food grain productivity. Increase in forest area has negatively affects the productivity of mostly food grain crops like rice, arhar, gram, wheat, bajra, ragi and barley; it means that increases in forest area may lead decline in cultivated land resulting that productivity may decline. This could be due to the fact that the arable land availability in areas with widespread forests is lesser and therefore any expansion in bringing land under cultivation is not possible. Increase in farm harvest price of crops is a major factor to increase the productivity of major staple food grain crops like rice, gram, wheat, maize, bajra and sorghum crops; and it could increase the farmer's decision to select an appropriate crop for cultivation.

In brief: wheat, barley, sorghum, arhar and maize food grain crops get negatively affected due to climate sensitivity, these all are the major food grain crops of India. Hence, we can conclude that agricultural productivity in India is climate sensitive and the fluctuations in temperatures and rainfall pattern adversely affect the food grain crops productivity and thus it may threaten food security in India. Based on our empirical findings we can provide a policy implication that irrigation is an important factor that may mitigate the adverse effect of climate sensitivity of rice, wheat, sorghum, arhar and bajra productivity (Kar and Kar, 2008). Increase in fertilizers may be another option to increase the productivity of rice, wheat, barley, maize and gram crops in India, however, it can be suggested only for areas which are utilizing less than recommended doses of fertilizers; otherwise increase in fertilizer application would cause greater climatic and environmental damage (Ranuzzi and Srivastava, 2012; and Singh, 2012).

Empirical result for non-food grain (commercial) crops shows that any increments in maximum temperature have a negative and statistically significant impact on sugarcane, cotton and sesamum crops. Any variation in minimum temperature from normal has a negative and statistically significant impact on potatoes and linseed productivity. Any fluctuation in rainfall from average has negatively affects the sugarcane productivity. Based on empirical findings we can predict that climatic factors negatively affect the cash crop productivity. In case of exogenous and socio-economic variables like increase in irrigated area is an important factor to increase the productivity of potato, cotton and linseed crops and it may be better adaptation method to mitigate the adverse effect of climate change. More consumption of fertilizer for potato, cotton, sesamum, and soybeans cultivation could be a beneficial. Literacy rate and increase in farm harvest prices for all crops are another crucial factor to increase the productivity of all crops.

Regression result for impact of climatic and socio-economic on value of production is shown that any increment in minimum temperature has decreased the aggregate value of production. Increment in rainfall has increased the value of production and it is beneficial to increase value of production. Government expenditure on agricultural and allied sector; rural development; irrigation and flood control is crucial factor that may mitigate the adverse effect of climate variability and it could increase the value of productivity.

For climate change and its impact on food security index and its components, several conclusions can be drawn such as food security index and its components are inter-related to each other and highly correlated (Dev and Sharma, 2010). Any increment in rainfall; maximum and mean temperature has a negative and statistically significance impact on food security index and other components of food security also negatively get affect due to climate variability. Poverty has a negative impact on food security; and it means that poverty increase food insecurity and again food insecurity lead poverty. Thus poverty and food security has a cause and effect relationship to each other (ADB, 2012; and Hollaender, 2010). Based on empirical findings several suggestion could be draw to increase the level of food security in India such as cropping intensity; agricultural labour; and literate farmers may be better idea to improvement for food security. Cropping intensity may increase the rotation of crops resulting that more food production and this may increase the more employment opportunities. Policy maker may also need to increase more irrigation facilities, fertilizers and government expenditure on agricultural and allied sector to increase agriculture productivity as well as food security; and these may mitigate the adverse effect of climate change.

Regression results for poverty and food security index (FSI) indicate that food security is the most important factor to eradicate poverty. Improvement in food security, irrigated area; and increasing government expenditure are the crucial variables for poverty eradication in India. Similar participation of male and female in economy could be another option to reduce poverty (Cagatay, 1998). Finally empirical findings about poverty and other socio-economic variables like mechanization suggested that mechanization has done greater harm than benefit for rural households by effectively reducing the agricultural labour employment opportunities for unskilled landless labourers which made them food insecure. Lack of food security and poverty also coincide with higher incidence of infant mortality in India.

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Appendix A

Table 1- Impact of climatic and geographical factors on food security index (FSI) with linear regression, correlated panels corrected standard errors (PCSEs) model

No. of Observation		323	R-squared		0.6158	
No. of States		13	Wald chi^2		3118.50	
No. of Obs./States		25	Prob > chi2		0	
Variables	Reg. Coefficient	Panel Corr. Std. Errors	*z*	*P* > |*z*|	95% Confidence Interval	
RF	-0.00005*	9.90e-06	-4.87	0.000	-0.00007	-0.00003
MAXT	-0.00703*	0.00172	-4.10	0.000	-0.01039	-0.00367
MINT	0.00633*	0.00226	2.81	0.005	0.00191	0.01076
MEANT	-0.02275*	0.00414	-5.50	0.000	-0.03086	-0.01464
*LAT*GSA*	2.58e-07*	3.31e-08	7.79	0.000	1.93e-07	3.23e-07
*LON*GSA*	-1.87e-07*	1.01e-08	-18.41	0.000	-2.07e-07	-1.67e-1
Con. Term	1.23036*	0.09750	12.62	0.000	1.03928	1.42144

Note: - *Estimated by Authors.*

Table 2- Comparison of impact of climatic factors on food security index and its components

Components	*FSI (DP)*	*AVF (DP)*	*STAF(DP)*	*ACCF(DP)*
R-squared	0.2515	0.4104	0.3507	0.2369
Wald chi2(4)	8.29	20.25	6.79	10.06
Prob > chi2	0.0814	0.0004	0.1472	0.0394
No. of Obs.	323	323	323	323
No. of States/Group	13	13	13	13
MAXT	-0.01755***	-0.03555**	-0.02522***	-0.00512**
MINT	0.01606	0.02926***	0.00848	0.01404
MEANT	-0.03885***	-0.07555*	-0.09313***	0.00731
RF	-0.00007***	-0.00017*	8.87e-06	0.00006**
Con Term	1.69836 *	3.04442*	3.36803**	0.17805

Source: *-Estimated by Authors; and *, ** and *** indicates the 1%, 5% and 10% significance level of regression coefficient for respective variables in the table.*