Projected Productivity of Cash Crops in Different Climate Change Scenarios in India: Use of Marginal Impact Analysis Technique

Ajay K. Singh[1*] & Bhim Jyoti[2]

[1] *Assistant Professor, School of Liberal Arts & Management, DIT University, Dehradun, India*
[2] *Assistant Professor, Seed Science & Technology, V.C.S.G, UUHF, College of Forestry, Ranichauri, Tehri Garhwal, India.*
[*]Corresponding Author: a.k.seeku@gmail.com.

Doi: https://doi.org/10.38157/finance-economics-review.v3i1.281

Citation: Singh, A.K., & Jyoti, B. (2021). Projected Productivity of Cash Crops in different Climate Change Scenarios in India: Use of Marginal Impact Analysis Technique, *Finance & Economics Review*, 3(1), 63-87. Doi: https://doi.org/10.38157/finance-economics-review.v3i1.281

Research Article

Abstract

Purpose: *This study assesses the impact of climatic and geographical factors on the yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds using state-wise panel data in India during 1971-2013. Thereupon, it estimates the expected yield of aforesaid crops in different climate change scenarios.*

Methods: *Cobb-Douglas production function model is used to estimate the regression coefficients of climatic and geographical factors with the yield of aforesaid crops.*

Results: *The empirical result shows that maximum temperature, minimum temperature, rainfall, and precipitation have a significant impact on the yield of potato, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, sunflower seeds. The projected results indicate that yield of sesame, linseed, rapeseed & mustard, potato, and cotton crops may decline by 0.16%, 0.83%, 5.65%, 14.68%, and 23.31% respectively due to one unit change in average maximum and minimum temperature, actual precipitation, and rainfall during crop seasons.*

Implications: *The Agriculture department of the government should encourage farmers to implement crop-specific policies to mitigate the negative impact of climate change in agriculture.*

Limitations: *Application of fertilizer, quality of seeds, cost of cultivation, farm management practices, irrigated area, demographic factors (e.g., population growth, urbanization, industrialization, etc.), and ecosystem services (e.g., water, soil fertility, and land) have a significant impact on the yield of cash crops. However, these variables were not included to predict the yield of cash crops in this study. Thus, this study acknowledged this limitation and existing researchers can incorporate these variables in further study.*

Keywords: Crop yield; Climate change; Cobb-Douglas production function; India; Marginal impact analysis technique.

1. Introduction

It is observed that climate change has a negative impact on agricultural productivity, gross domestic product (GDP), food security, livelihood security, farmer's income, and production of Agro industries in developed and developing countries (Mendelsohn et al., 1994; Quiggin & Horowitz, 2003; Horowitz, 2009; Kumar et al., 2017; Singh & Sharma, 2018a; Imran et al., 2019; Singh & Jyoti, 2021). Subsequently, all economic activities are adversely affected due to climate change (Singh et al., 2019). Developing countries have lower economic and physical resources to mitigate the negative consequences of climate change in the agricultural production system as compared to developed countries (Kumar & Sharma, 2013; Kumar et al., 2015a; Kumar et al., 2016; Jyoti & Singh, 2020; Singh & Jyoti, 2021). Furthermore, developing countries are located at low latitudes, therefore, agricultural production activities are highly vulnerable due to climate change in these economies (Lee, 2009; Ahmad et al., 2011; Kumar, 2015; Jyoti & Singh, 2020). Furthermore, crop yields are expected to be decreased in developing countries, and crop yield would be increased in developed countries (Iizumi et al., 2017). It may, therefore, increase extensive disparities in food-grain and cereal yields across developed and developing countries (Parry et al., 2004; Fischer et al., 2005).

India is the second agricultural intensive country in the world. Despite that, it has the largest number of hungry and deprived people in the world and counts around 360 million undernourished people (Ahmad et al., 2011). In India, more people are suffering from chronic diseases due to lack of food consumption and poor quality of food (Kumar, 2015). As more than 52% Indian population depends on climate-sensitive sectors such as cultivation, forestry, and fishery; and natural resources (water, biodiversity, mangroves, coastal zones, grasslands) for their livelihoods (Kumar & Sharma, 2013; Kumar, 2015). Thus, agriculture is an important sector to sustain the livelihood security of the population as it provides food security and job security of agricultural laborers and reduce income inequality and poverty in India (Sathaye et al., 2006; Singh & Issac, 2018; Singh, 2020; Guntukula & Goyari, 2020). Moreover, low productivity of crops, high illiteracy and low economic capacity of farmers, insignificant support from financial organizations to the farmers, the low contribution of government in agricultural research & development, and low technological skills of farmers are making Indian agriculture more vulnerable (Singh & Sharma, 2018b). Also, arable land is declining due to high urbanization, population growth, and industrialization in India (Kumar et al., 2015b; Kumar et al., 2020). Aforesaid activities are also increasing the extensive burden on ecological services (i.e., water, air, land, forest, and rivers) and agricultural production system (Kumar et al., 2020; Singh & Singh, 2020). Also, climate change and its impact on the agricultural production system have created an extreme burden to sustain the livelihood security of Indian farmers. Further, it is also found that climate change has a negative impact on human health (Singh & Singh, 2020). India, thus, may be at high risk due to climate change in the near future (Kumar et al., 2015a; Chhabra & Haris, 2020).

The above-mentioned review clearly indicates that climate change has a negative impact on the agricultural production system in India. For this, most studies have considered yield of a specific crop as dependent variables, and climatic factors, socio-economic and demographic parameters as independent variables in empirical investigation (Saseendran et al., 2000; Attri & Rathore, 2003; Jha & Tripathi, 2011; Panda et al., 2012; Kumar & Sharma, 2013; Birthal et al., 2014; Kumar & Sharma, 2014; Mondal et al., 2014; Kumar et al., 2015a,b; Singh et al., 2017; Singh & Sharma, 2018b; Guntukula, 2019; Panda et al., 2019; Singh & Jyoti, 2019; Singh et al., 2019; Jyoti & Singh, 2020; Kelkar et al., 2020; Singh & Jyoti, 2021). Also, most studies have estimated the projected the yield of food-grain and cash crops due to climate change in India (e.g., Saseendran et al., 2000; Attri & Rathore, 2003; Bhatia et al., 2008; Srivastava et al., 2010; Singh et al., 2017; Singh & Sharma, 2018b; Panda et al., 2019; Sonkar et al., 2020; Jyoti & Singh, 2020; Singh & Jyoti, 2021). The empirical findings of these studies emphasized that productivity of food-grain and cash crops may be declined due to climate change in India. However, these studies could not consider geographical location in empirical models to estimate the expected yields of food-grain and cash crops in different climatic conditions.

Due to the aforesaid research gap, the present study is addressed the following research questions:

- Which cash crop is most vulnerable due to climate change in India?
- What is the relationship of latitude and longitude of a specific state with the yield of cash crops in India?
- What is the marginal impact of climatic factors on the yield of cash crops in India?

With concerns to aforesaid research questions, the present is attained following objectives:

- To assess the impact of climatic and geographical location on yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds crops using state-wise panel data in India using Cobb-Douglas production function approach.
- To examine the predicted yields of cash crops due to marginal change in climatic factors using marginal impact analysis techniques in India.
- To provide conclusive and viable policy suggestions to mitigate the negative consequences of climate change in Indian agriculture.

This study will be helpful to make a crop-specific policy to mitigate the climate change impact in a specific geographical region in India. It will be useful to increase the attention of policymakers, agricultural scientists, and farmers to take an effective and conducive climate policy action to avoid the expected negative impact of climate change on a particular crop in India. This study makes the projection of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds crops in different climate change scenarios in India. Therefore, empirical findings of this study will be useful for Agro industries to implement an effective climate action to increase the productivity of cash crops in India. After, the agricultural sector will be in position to meet the requirement of raw materials for these industries.

2. Literature Review

In India, several studies have assessed the influence of climatic and non-climatic factors on the gross domestic product (GDP), agriculture GDP, agricultural productivity, and production, cropped area, and yield of a specific crop using district, regional, state, and national level data in the form of time series and panel data (e.g., Attri & Rathore, 2003; Jha & Tripathi, 2011; Panda et al., 2012; Mondal et al., 2014). A brief summary of associated previous studies is given here: Zhai & Zhuang (2009) have reported that GDP may decrease up to 6.2% by 2080 in India. Ramulu (1996) has identified sugarcane yield affecting factors in Andhra Pradesh (India). Kumar et al. (2004) have inspected the association of production and yield of rice, wheat, sorghum, groundnut, sugarcane, and cereal and oilseed crops in Uttar Pradesh, Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu. Kavikumar (2009) has found that agriculture revenue is likely to be diminished by 9% per hectare land due to climate change in thirteen Indian states.

Ashalatha et al. (2012) have observed the impact of drought, rainfall, and temperature on the production and yield of groundnut, onion, cotton, and other crops in Karnataka. Kumar & Sharma (2013) have observed the impact of climatic and non-climatic factors on the productivity of potato, sugarcane, cotton, soybean, groundnut, and sesame and linseed crops in India. Birthal et al. (2014) have assessed the impact of temperature and rainfall on the yield of groundnut, rapeseed & mustard, and other food-grain crops in India. Kumar & Sharma (2014) have measured the climatic and non-climatic factors on sugarcane yield in India. Kumar et al. (2015a) have examined the influence of climatic and non-climatic factors on the mean yield of cotton, potato, groundnut, linseed, and sesame crops in India. Kumar et al. (2015b) have measured the influence of climatic and non-climatic factors on the yield of sugarcane crops in India. Yadav et al. (2016) have assessed the influence of CO_2 concentration and temperature on the productivity of various cash crops in Varanasi (India).

Ramachandran et al. (2017) have assessed the impact of climate change on the yield of rice, groundnut, and sugarcane crops in Tamil Nadu. Singh et al. (2019) have estimated the climatic and non-climatic factors on sugarcane farming in India. Singh & Jyoti (2019) have assessed the impact of climatic and non-climatic factors on production, yield, and cropped area of potato, cotton, groundnut, and sesame crops in India. Guntukula (2019) has evaluated the climate change impact on the yield of rice, wheat, pulses, rapeseeds & mustard, cotton, sugarcane, and groundnut crops in India. Praveen & Sharma (2019) have examined the impact of climate change on the yield of rice, wheat, Jowar, bajra, maize, ragi, barley, tea, cotton, groundnut, tea, cotton, groundnut, rapeseed & mustard, linseed, and sesame crops in India. Guntukula & Goyari (2020) assessed the impact of climatic factors on yield and yield variability of rice, cotton, jowar, and groundnut crops in Telangana. It found a negative impact of maximum temperature on the productivity of rice, cotton, and groundnut. A group of studies has projected the yield of various crops in various climatic conditions. For instance, Saseendran et al. (2000) have perceived that crop yield may be decreased due to an increase in temperature up to 5^0C in Kerala (India). Attri & Rathore (2003) forecasted the yield of wheat crop in India. Bhatia et al. (2008) assessed the potential yield of soybean crop in India. Srivastava et al. (2010) evaluated the vulnerability of sorghum crop due to climate change in India. Kelkar et al. (2020) have estimated the expected impact of climatic factors on sugarcane, cotton, and rice crops in Maharashtra (India).

Singh et al. (2017) have examined the impact of climatic and non-climatic factors on production, yield, and cropped area of potato, groundnut, sesame, and cotton crops in India. It also projected the marginal impact of climatic factors on production, yield, and cropped area of aforesaid crops. Singh & Sharma (2018b) have estimated the expected yield of rice, arhar, jowar, wheat, ragi, gram, and barley crops in different climate change scenarios in India. Panda *et al.* (2019) have examined the impact of climate vulnerability on crop yield in India. Jyoti & Singh (2020); Sonkar *et al.* (2020) have projected the sugarcane yield in India. Singh & Jyoti (2021) have observed the projected food-grain yield in different climatic conditions in India. The above literature indicate that the yield of food-grain and cash crops is expected to decline due to climate change in India. Despite this, there is a requirement to assess the impact of climatic factors and geographical location on the yield of cash crops which provide the raw material to Agro industries in India.

3. Research Method and Material

3.1. Description of Study Area

The present study includes the yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds crops as a dependent variable for 43 years (i.e., 1971-2013). However, for rapeseed & mustard, and sunflower seed crops the time period is limited to 38 years (i.e., 1977-2014). These cash crops provide the raw material to textile, oilseed, sugar, and other industries in India (Singh et al., 2017; Singh & Jyoti, 2019). Average maximum and minimum temperature, actual precipitation and rainfall during the crop season (sowing to harvesting time), latitude and longitude location of a specific state are considered as explanatory variables. Dependent and explanatory variables are compiled as state-wise panel data for an individual crop to assess the impact of climatic factors and geographical location on yield. For each crop following states are compiled as state-wise panel data:

Table 1: List of states that are considered under a specific crop

Crops	States	No. of sates
Potato	Andhra Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh	17
Cotton	Andhra Pradesh, Assam, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal	14
Groundnut	Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh	17
Sesame	Andhra Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh	18
Linseed	Andhra Pradesh, Assam, Bihar, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh	14
Sugarcane	Andhra Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal, Jharkhand, Chhattisgarh	18
Rapeseed & Mustards	Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal	14
Sunflower Seeds	Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal	10

Every group of states covers more than 90% of cropped area and production of each cash crop in India. State-wise area and production of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, sunflower seed crops are presented in Figures 1, 2, 3, 4, 5, 6, 7, and 8 respectively. Uttar Pradesh, West Bengal, and Bihar states have a larger share in potato production in India (See Figure 1).

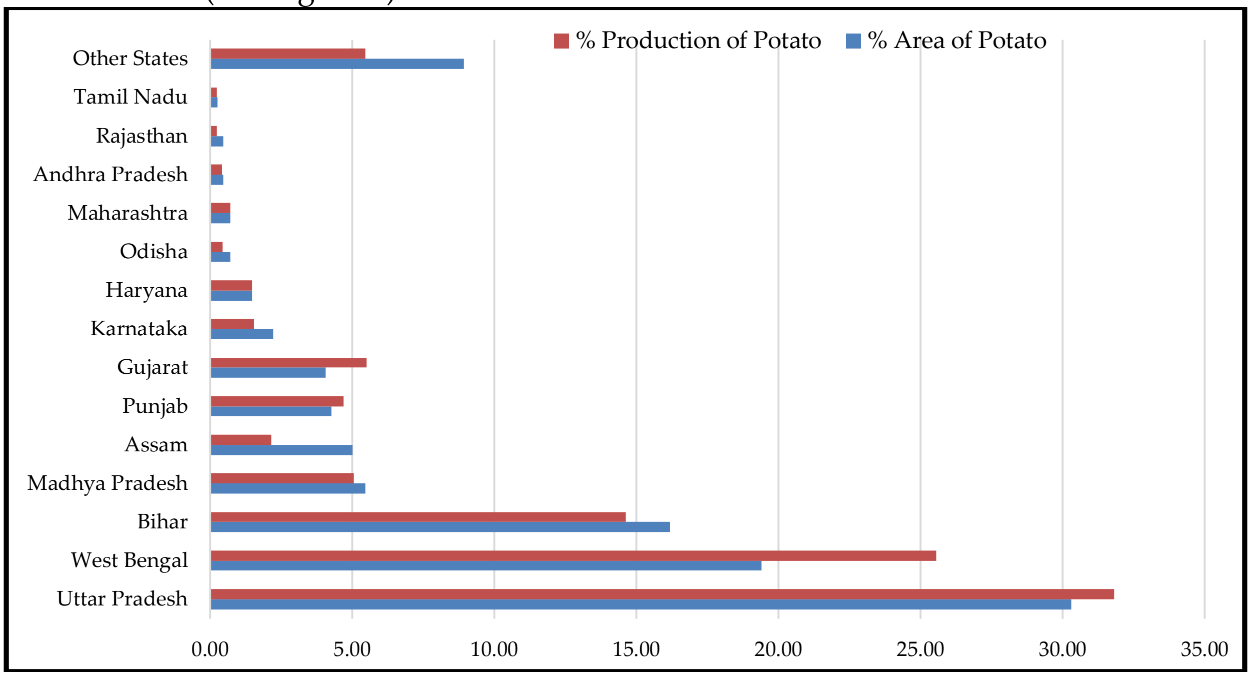

Figure 1: State-wise area and production of the potato crop in India in 2012-13

Source: CMIE.

Maharashtra, Gujarat, and Andhra Pradesh states are the largest producers of the cotton crop (See Figure 2). Maharashtra has the largest area under cotton crop, while Gujarat has the largest share in cotton production in India.

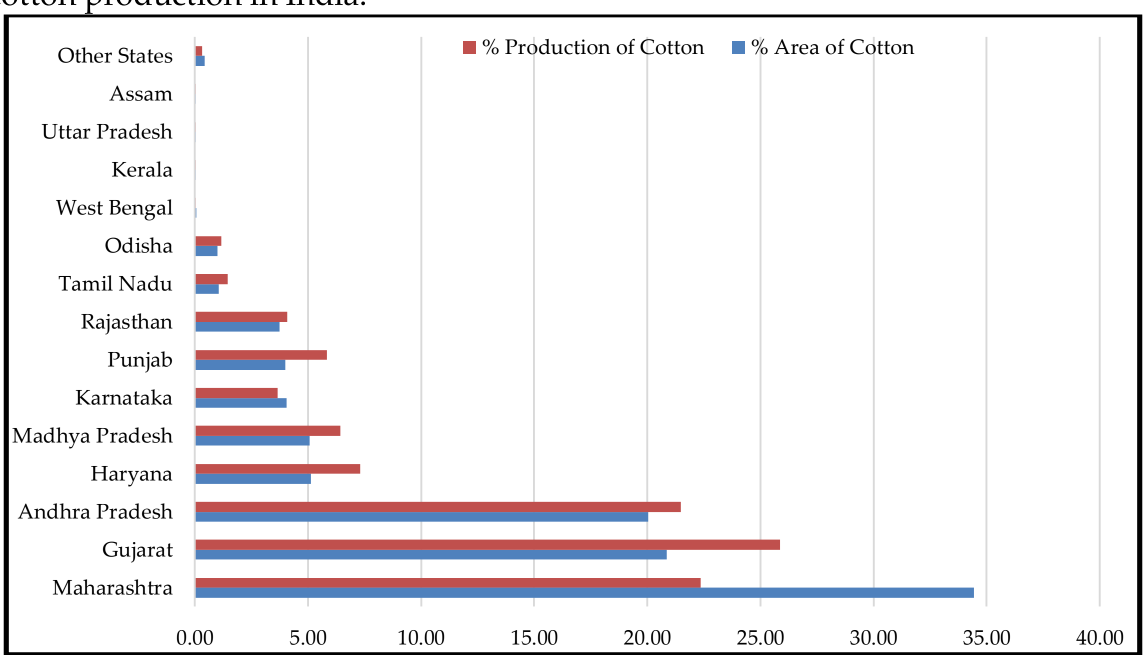

Figure 2: State-wise area and production of cotton crop in India in 2012-13

Source: CMIE.

Published by *Research & Innovation Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

Andhra Pradesh, Gujarat, and Rajasthan are the main groundnut-producing states of India (See Figure 3). Andhra Pradesh has the largest area of groundnut crop and the state contributes around 23.75% groundnut production of India.

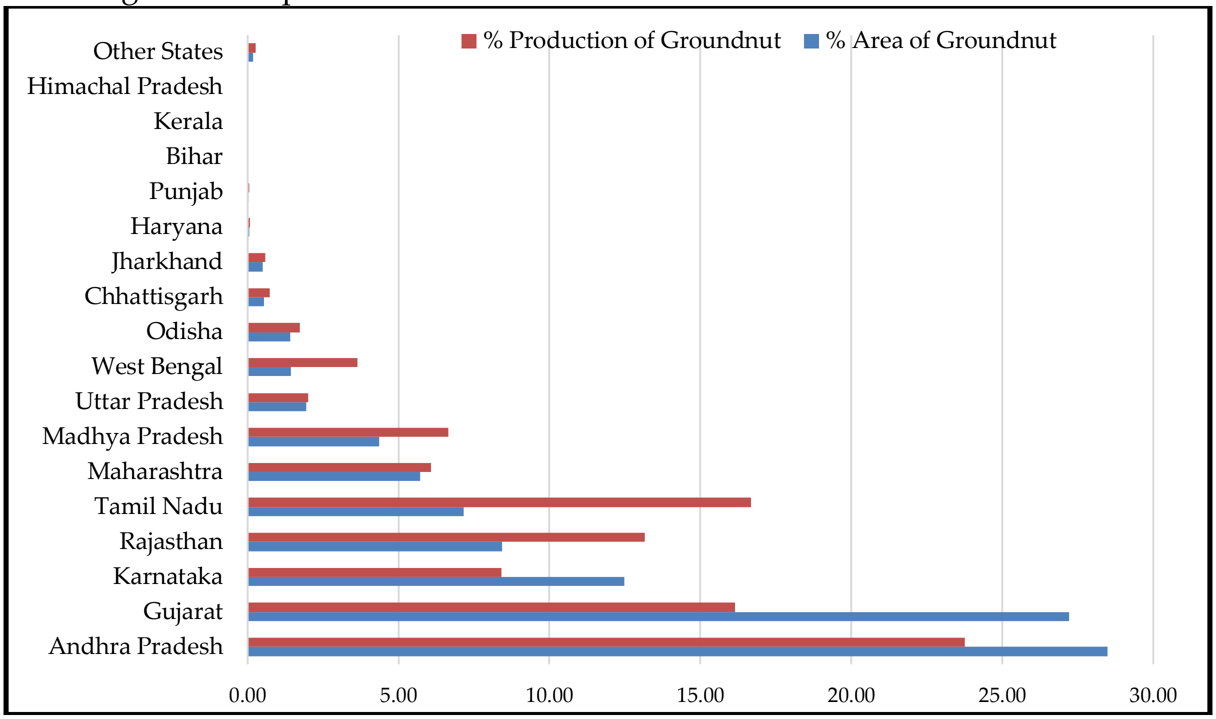

Figure 3: State-wise area and production of groundnut crop in India in 2012-13

Source: CMIE.

West Bengal, Madhya Pradesh, and Rajasthan have the dominant position in sesame production (See Figure 4). Rajasthan has the largest cropped area under sesame crop and West Bengal contributes around 27.04% of sesame production in India.

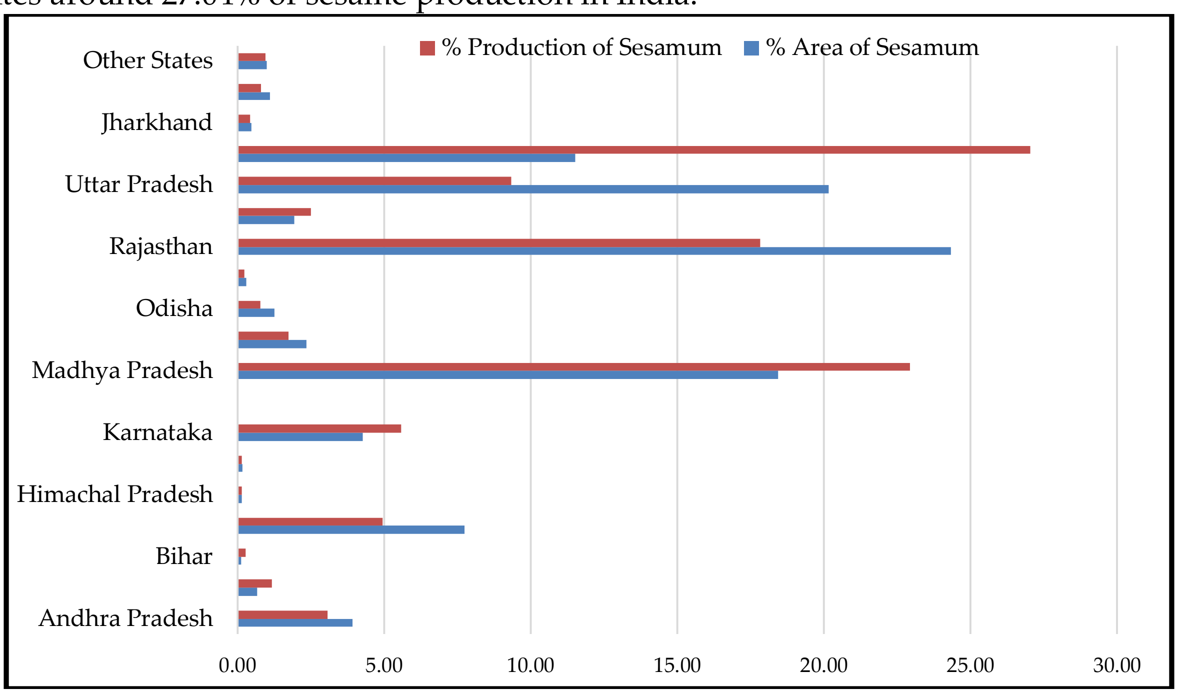

Figure 4: State-wise area and production of sesame crop in India in 2012-13

Source: CMIE.

Published by *Research & Innovation Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

Linseed crop grow in most Indian states (See Figure 5). However, Madhya Pradesh, Chhattisgarh, Uttar Pradesh, and Jharkhand have the greater contribution in cropped area and production of this crop in India.

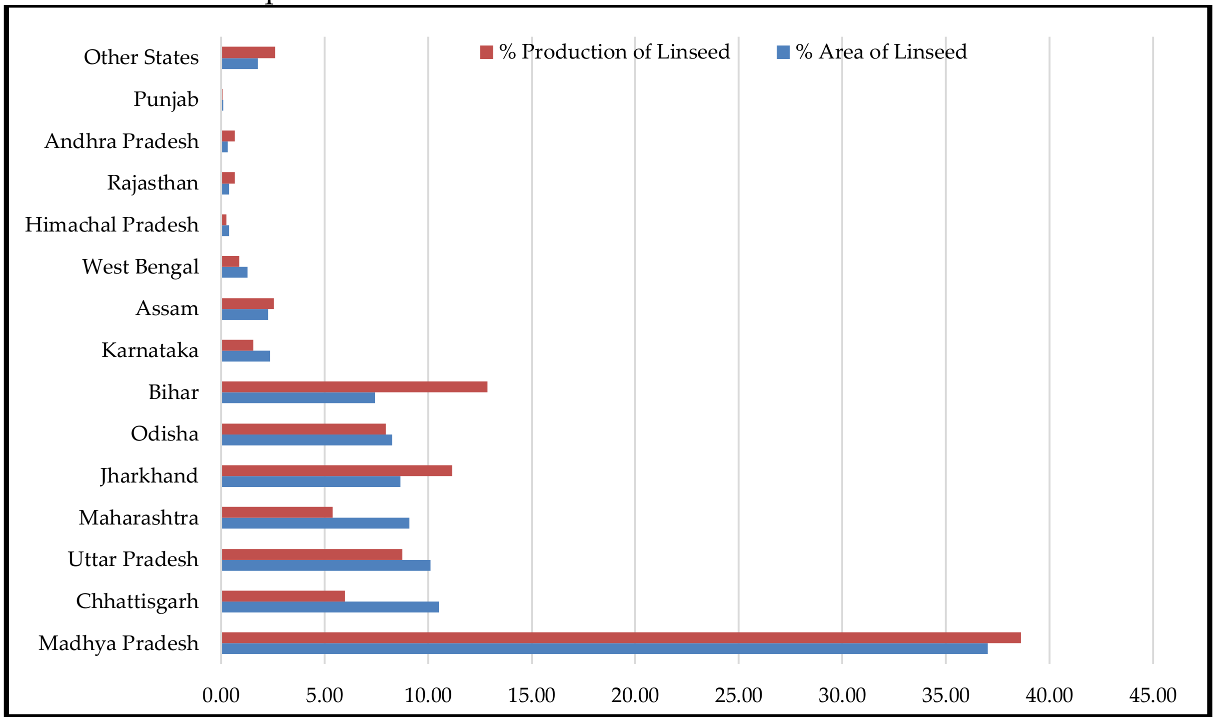

Figure 5: State-wise area and production of linseed crop in India in 2012-13

Source: CMIE.

Sugarcane is a very important cash crop and it grows in most states of India (See Figure 6). Uttar Pradesh, Maharashtra, and Karnataka have the largest contribution in the area and production of sugarcane crops in India.

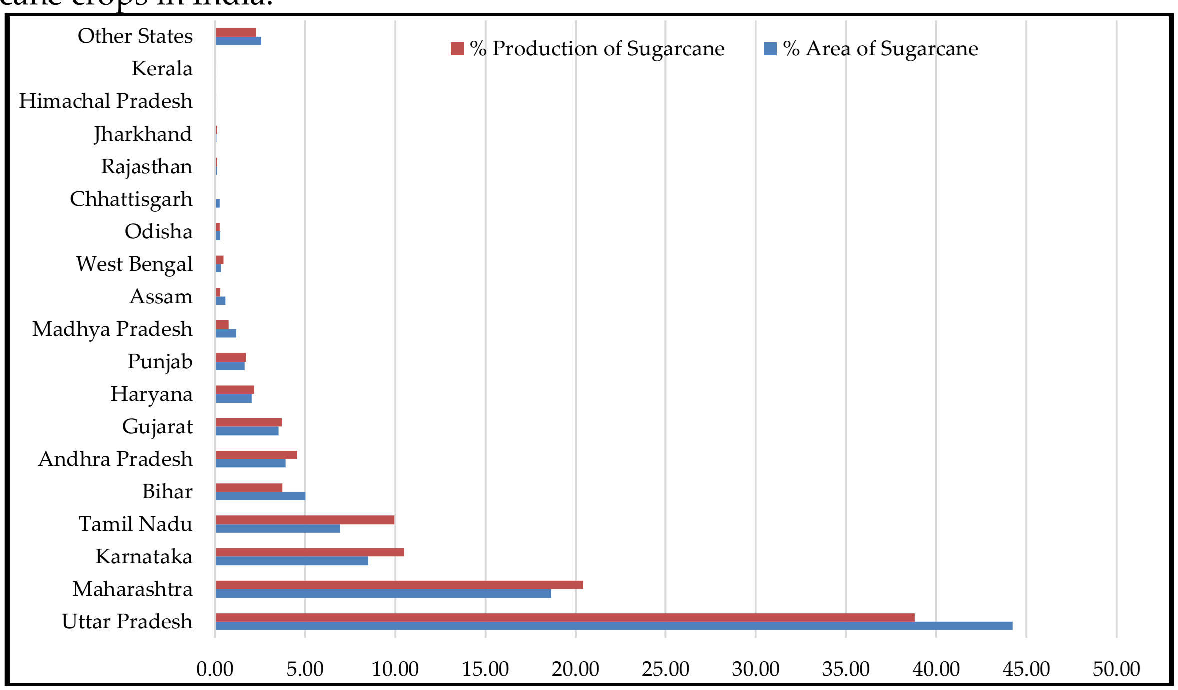

Figure 6: State-wise area and production of sugarcane crop in India in 2012-13

Source: CMIE.

Rapeseed & mustard is a crucial oilseed crop that grows in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, Assam, Gujarat, Bihar, Punjab, Odisha, Maharashtra, Andhra Pradesh, Karnataka, and Tamil Nadu. These states contribute more than 90% area and production of Rapeseed & mustard crops in India (See Figure 7).

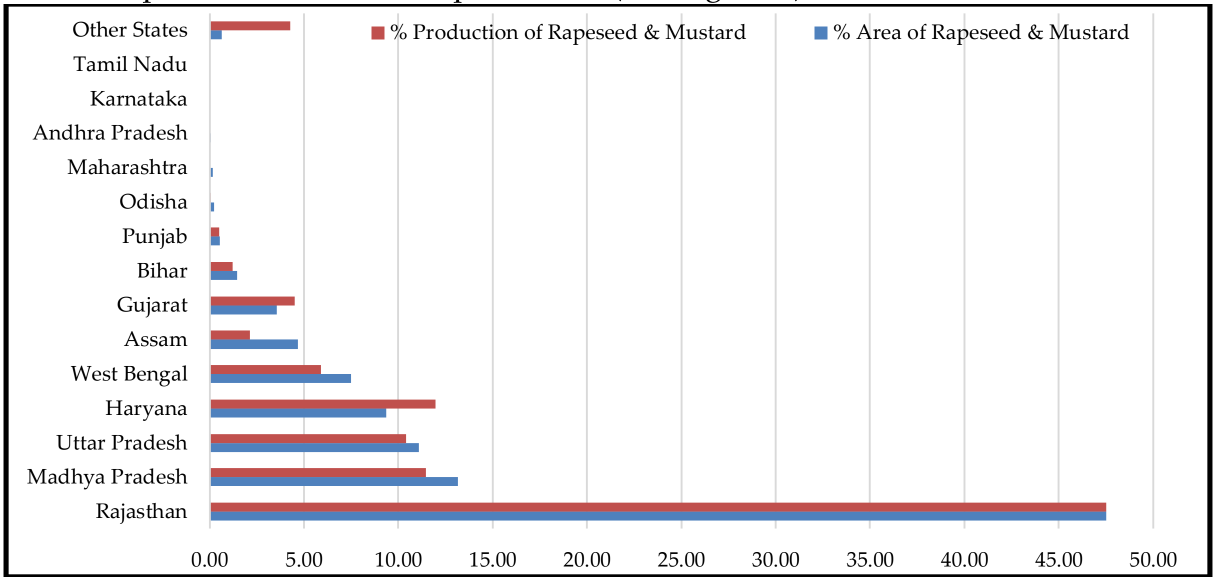

Figure 7: State-wise area and production of rapeseed & mustard crop in India in 2012-13

Source: CMIE.

Sunflower seed crop is also an oilseed crop which cultivates in Andhra Pradesh, Bihar, Karnataka, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal (See Figure 8). Karnataka and Andhra Pradesh have the largest share in the area and production of this crop in India.

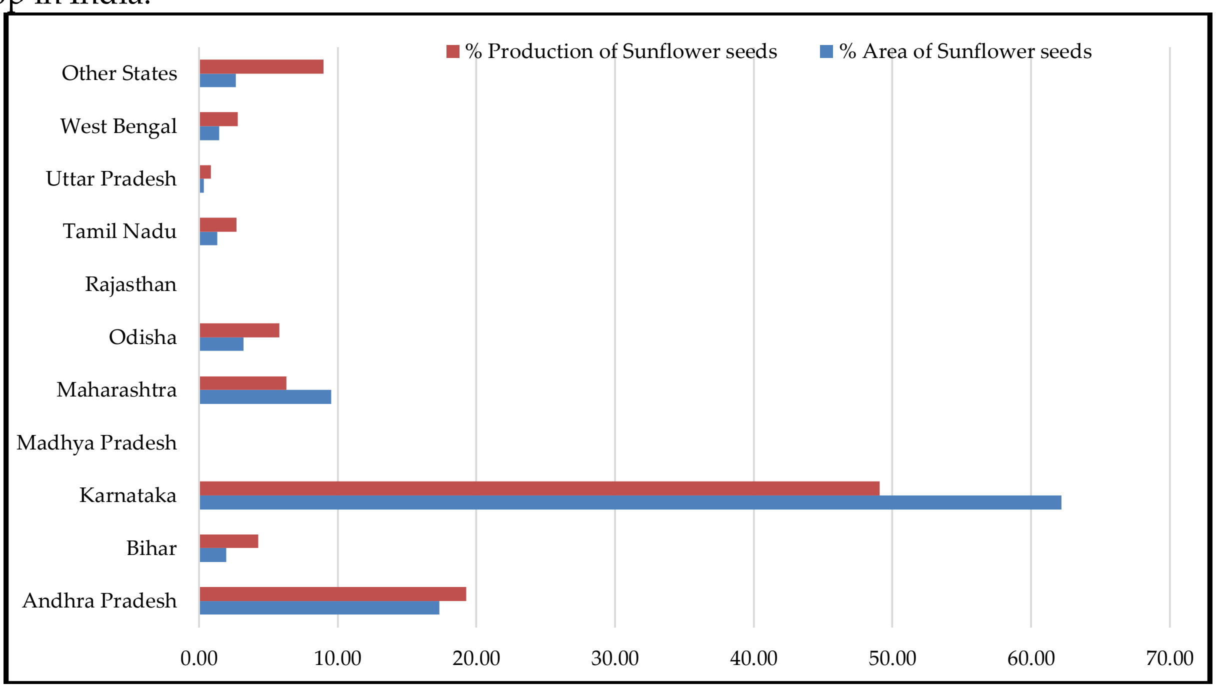

Figure 8: State-wise area and production of sunflower seed crop in India in 2012-13

Source: CMIE.

3.2 Explanation of Data Sources

The data for agricultural and climatic variables are taken from the following sources:

Agricultural Data: Yield, production, and area sown of selected crops are taken from the Centre for Monitoring Indian Economy (CMIE). The sowing, growing, and harvesting time of each crop is taken from the Indian Council of Agricultural Research (Crop Science Division).

Latitude and Longitude Information: The geographical location of all states is derived from https://www.distancelatlong.com/country/india and https://www.mapsofindia.com/lat_long/.

Climatic Data: Minimum and maximum temperatures are collected from the Indian Meteorological Department (GoI). These data are available at daily intervals with latitude and longitude information of specified monitoring stations. The stations pertaining to the specific latitude and longitude locations of cities are identified due to the absence of city-wise climatic data. Thereafter, the groups of different geographical regions are linked to arrive at the state-level data. Monthly district-wise rainfall information is taken from Hydromet Division, Indian Meteorological Department (GoI). District-wise precipitation is derived from the Geographical Information System statistical database. All data are converted into monthly averages city-wise, after that data is transformed at state-wise monthly maximum and minimum temperature. The SPSS statistical software is used to extract and bring data to excel format. Average minimum and maximum temperature; and actual rainfall and precipitation in crop duration (i.e., sowing time to harvesting time) is considered for empirical investigation. Interpolation and extrapolation techniques are considered to estimate the values for those variables which do have a few missing values (Kumar et al., 2015a; Kumar et al., 2017; Singh and Issac, 2018; Singh and Jyoti, 2019; Jyoti and Singh, 2020).

3.3. Econometric Analysis

Cobb-Douglas production function model is used to assess the impact of climatic factors (i.e., average maximum and minimum temperature, and actual precipitation and actual rainfall) and geographical factors (i.e., latitude and longitude) on the yield of cash crops. This approach is used by Kumar & Sharma (2013), Kumar & Sharma (2014), Kumar et al. (2015a), Kumar et al. (2016), Singh et al. (2017), Singh and Sharma, 2018b; Singh et al. (2019), Singh & Jyoti (2019), Kumar et al. (2020) to examine the climatic and non-climatic factors on yield of the individual crop and agricultural productivity at district, state and national level in India. In this study, the yield of individual crops is used as a dependent variable, and average maximum and minimum temperature, actual precipitation, and rainfall during crop season, latitude, and longitude location of a specific state are also considered as independent variables. For this, the proposed empirical model is used as:

$$\log(lanpro)_{st} = \beta_0 + \beta_1 (year)_{st} + \beta_2 \log(amaxtemtcs)_{st} + \beta_3 \log(amintemcs)_{st} + \beta_4 \log(aprecs)_{st} + \beta_5 \log(arfcs)_{st} + \beta_6 \log(lat*as)_{st} + \beta_7 \log(lon*as)_{st} + U_{st} \quad (1)$$

Here, the *log* is natural logarithm of associated variables, *lanpro* is land productivity, *amaxtemtcs* is average maximum temperature, *amintemcs* is average maximum temperature, *aprecs* is actual precipitation, *arfcs* is actual rainfall, *lat* and *lon* are latitude and longitude location of the respective state respectively, *as* is cropped area of respective crop, and *year* is time trend factor that is considered to capture the influence of technological change on yield of crops (Cabas et al., 2009; Kumar et al., 2015a,b; Singh & Sharma, 2018b; Singh & Jyoti, 2021). The *s* is cross-sectional states; *t* is time period; and β_0 is the constant coefficient, β_1, β_2,.., β_7 are the regression coefficients of corresponding variables, U_{st} is error term in equation (1). The summary of dependent and explanatory variables is presented in Table 2.

Table 2: Summary of the dependent and independent variables

Symbol	Variables	Unit
as	Area sown	000 Ha.
tp	Total production	000 tonne
lanpro	Land productivity	Tonne/Ha.
year	Time trend factor	Number
amaxtemtcs	Average maximum temperature during crop season	^{0}C
amintemcs	Average maximum temperature during crop season	^{0}C
aprecs	Actual precipitation during crop season	mm
arfcs	Actual rainfall during crop season	mm
*lat*as*	Latitude *Area sown	^{0}C*Ha.
*lon*as*	Longitude *Area sown	^{0}C*Ha.

3.4 Selection of Proper Model

The proposed regression model is run through STATA statistical software. Following processes are applied to select a proper model. Pesaran's test is used to identify the presence of cross-sectional independence in panel data (Kumar & Sharma, 2014; Kumar et al., 2017). The Wald test is used to identify the existence of group-wise heteroskedasticity in panel data of each crop (Kumar & Sharma, 2014; Kumar et al., 2016). The Wooldridge test is used to address the presence of autocorrelation (Singh et al., 2017). The Panels corrected standard errors estimation model is used to reduce the presence of serial correlation, heteroskedasticity, and cross-sectional autocorrelation for all crops (Kumar & Sharma, 2013; Kumar et al., 2015a; Singh et al., 2017).

3.5 Marginal Impact Analysis Technique

The marginal impact analysis technique is useful to examine the contribution of each input in crop yield (Coster & Adeoti, 2015; Singh et al., 2017; Singh, 2017; Singh & Sharma, 2018b; Jyoti & Singh, 2020). It also examines the percentage change in output due to marginal change in various inputs in production activities. In this study, therefore, a marginal impact analysis technique is used to predict the yield of cash crops due to marginal change in climatic factors, and cropped area for corresponding crops under a geographical location (Kumar et al., 2016; Singh & Sharma, 2018b). The projected yield of a crop is estimated as:

$$[\Delta(lanpro)]=\{\beta_1[\delta(lanpro)/\delta(year)]+\beta_2\ [\delta(lanpro)/\delta(amaxtemtcs)]\ +\beta_3\ [\delta(lanpro)/\delta(amintemcs)]\ +\beta_4\ [\delta(lanpro)/\delta(aprecs)]\ +\beta_5\ [\delta(lanpro)/\delta(arfcs)]\ +\beta_6\ [\delta(lanpro)/\delta(lat*as)]\ +\beta_7\ [\delta(lanpro)/\delta(lon*as)]\}*100 \quad (2)$$

Here, $\Delta(lanpro)$ is changed in yield of respective crops due to marginal change in all variables; β_1, β_2,.., β_7 are the regression coefficient of associated variables which is estimated through equation (1); *year*, *amaxtemtcs*, *amintemcs*, *aprecs*, *arfcs*, *lat*as* and *lon*as* are the mean values of respective variables under each crop across the state-wise panel.

4. Discussion on Descriptive Results

Potato Yield and Climatic Factors: The fluctuation in potato yield and climatic factors during 1971–2013 is presented in Figure 9. The correlation coefficients of potato with climatic and geographical variables are presented in Table 3. It infers that potato productivity is positively correlated with maximum temperature (*r*= 0.037), minimum temperature (*r*= 0.026), latitude (*r*= 0.386**) and longitude (*r*= 0.391**). Precipitation and rainfall are negatively associated with the yield of the potato. Thus, it shows that climatic and geographical factors are significantly associated with potato productivity.

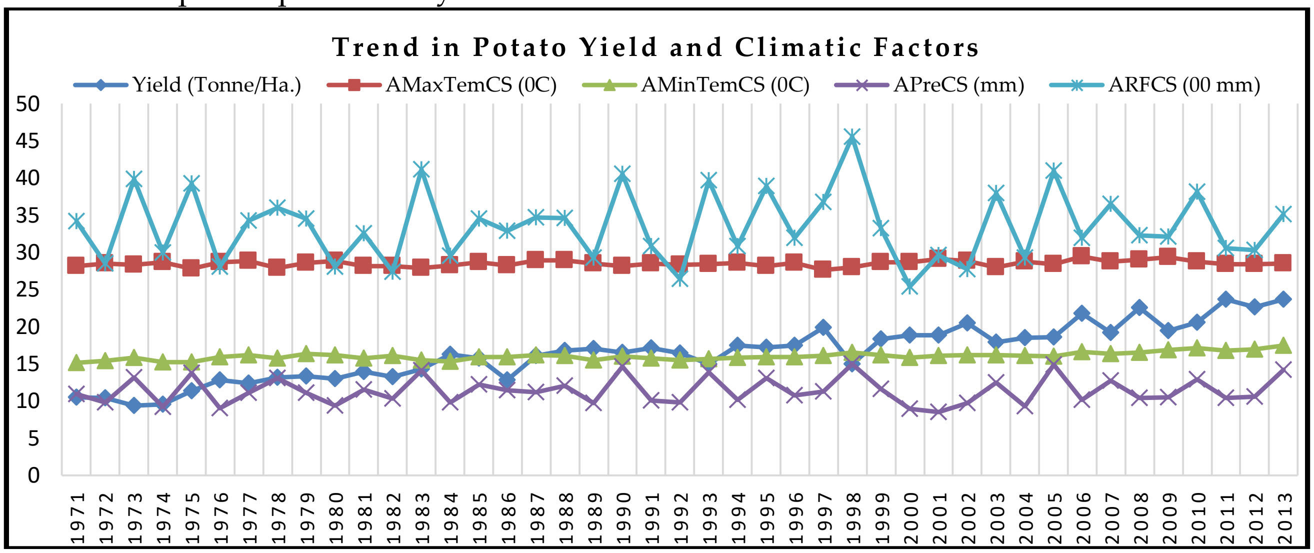

Figure 9: Fluctuation in potato yield and climatic factors during 1971-2013

Source: Author's estimation.

Table 3: Correlation coefficients of potato yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	0.037	0.026	-0.159**	-0.201**	0.386**	0.391**
amaxtemcs	0.037	1	0.880**	-0.130**	0.022	-0.098**	-0.065*
amintemcs	0.026	0.880**	1	0.249**	0.381**	-0.068*	-0.015
aprecs	-0.159**	-0.130**	0.249**	1	0.894**	0.006	0.056
arfcs	-0.201**	0.022	0.381**	0.894**	1	0.026	0.084*
*lat*as*	0.386**	-0.098**	-0.068*	0.006	0.026	1	0.988**
*lon*as*	0.391**	-0.065*	-0.015	0.056	0.084*	0.988**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

Cotton Yield and Climatic Factors: The trend in productivity of cotton yield and climatic factors is presented in Figure 10. The correlation coefficient of cotton yield with climatic and non-climatic factors is presented in Table 3. It is found that cotton yield is negatively correlated with minimum temperature (*r*= - 0.032), precipitation (*r*= - 0.197**) and actual rainfall (*r*= - 0.291**). As the correlation coefficient of latitude and maximum temperature with cotton yield is found positive, thus, cotton yield may increases as increase in both the factors.

Published by *Research & Innovation Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

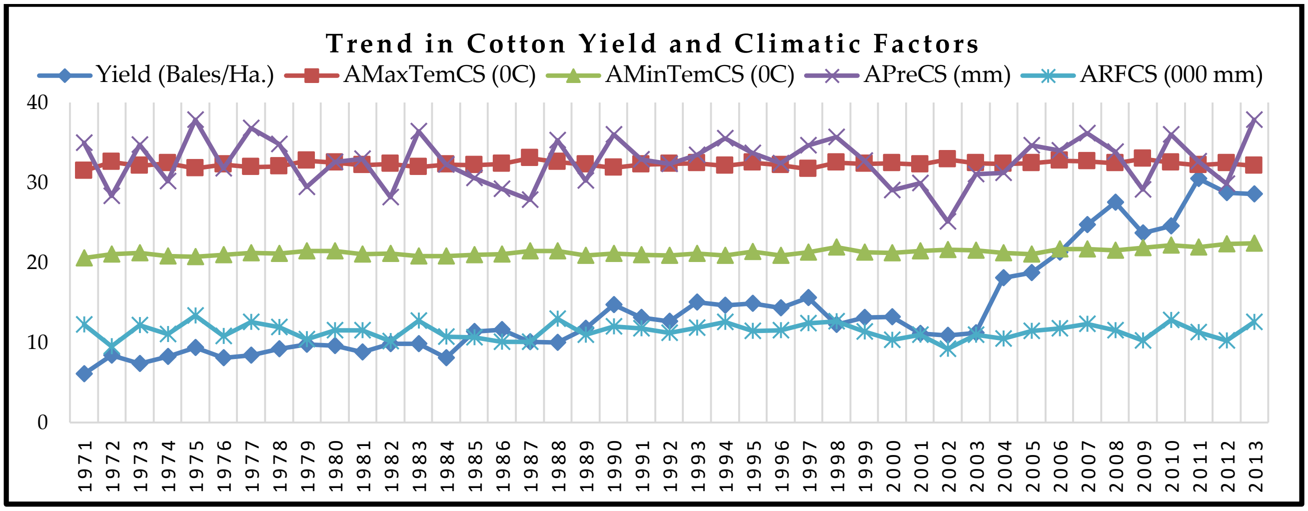

Figure 10: Fluctuation in cotton yield and climatic factors during 1971-2013

Source: Author's estimation.

Table 4: Correlation coefficients of cotton yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	0.142**	-0.032	-0.197**	-0.291**	0.105**	0.026
amaxtemcs	0.142**	1	-0.051	-0.728**	-0.808**	0.335**	0.250**
amintemcs	-0.032	-0.051	1	0.293**	0.256**	-0.257**	-0.184**
aprecs	-0.197**	-0.728**	0.293**	1	0.869**	-0.220**	-0.171**
arfcs	-0.291**	-0.808**	0.256**	0.869**	1	-0.424**	-0.349**
*lat*as*	0.105**	0.335**	-0.257**	-0.220**	-0.424**	1	0.978**
*lon*as*	0.026	0.250**	-0.184**	-0.171**	-0.349**	0.978**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

Groundnut Yield and Climatic Factors: The trend in groundnut yield and climatic factors are presented in Figure 11. It demonstrates that the productivity of groundnut is varied due to change in climatic factors during 1971–2013. The correlation coefficient of groundnut yield is positively correlated with maximum temperature (*r*= 0.049), minimum temperature (*r*= 0.148**) and precipitation (*r*= 0.009) (See Table 5). Actual rainfall (*r*= - 0.034), latitude (*r*= - 0.034) and longitude (*r*= - 0.014) are negatively associated with groundnut yield.

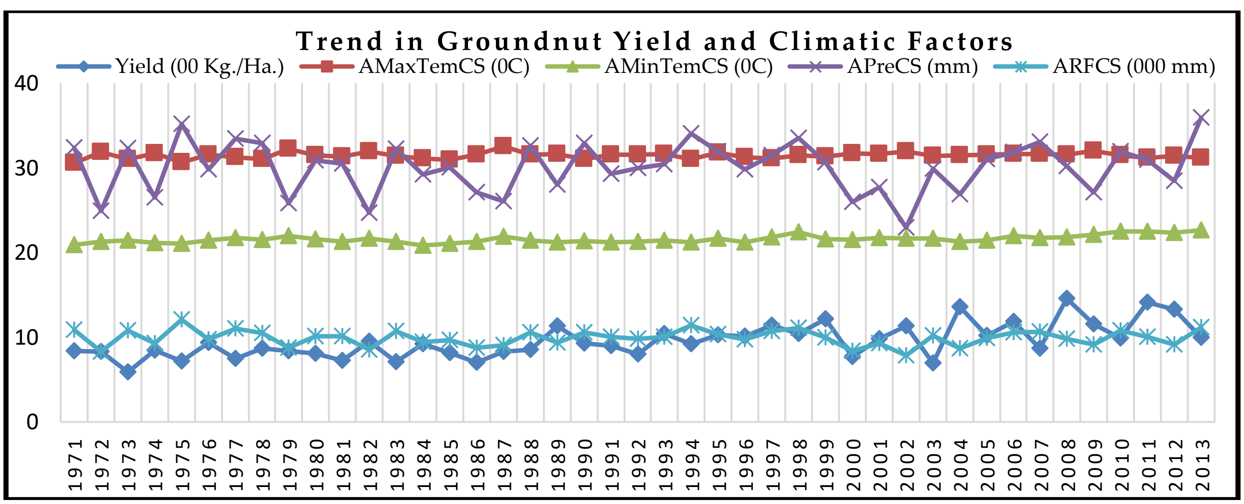

Figure 11: Fluctuation in groundnut yield and climatic factors during 1971-2013

Table 5: Correlation coefficients of groundnut yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	0.049	0.148**	0.009	-0.034	-0.034	-0.014
amaxtemcs	0.049	1	0.729**	-0.330**	-0.460**	0.287**	0.206**
amintemcs	0.148**	0.729**	1	0.187**	0.047	0.310**	0.297**
aprecs	0.009	-0.330**	0.187**	1	0.895**	-0.193**	-0.188**
arfcs	-0.034	-0.460**	0.047	0.895**	1	-0.199**	-0.155**
*lat*as*	-0.034	0.287**	0.310**	-0.193**	-0.199**	1	0.957**
*lon*as*	-0.014	0.206**	0.297**	-0.188**	-0.155**	0.957**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

Sesame Yield and Climatic Factors: The trend in sesame yield and climatic factors are presented in Figure 12. It shows that sesame yield is fluctuated due to variability in climatic factors. Correlation coefficient of sesame yield is positively associated with minimum temperature (*r*= 0.182**), precipitation (*r*= 0.138**) and rainfall (*r*= 0.190**) (See Table 6). While, other factors such as maximum temperature, latitude, and longitude are negatively correlation with sesame yield.

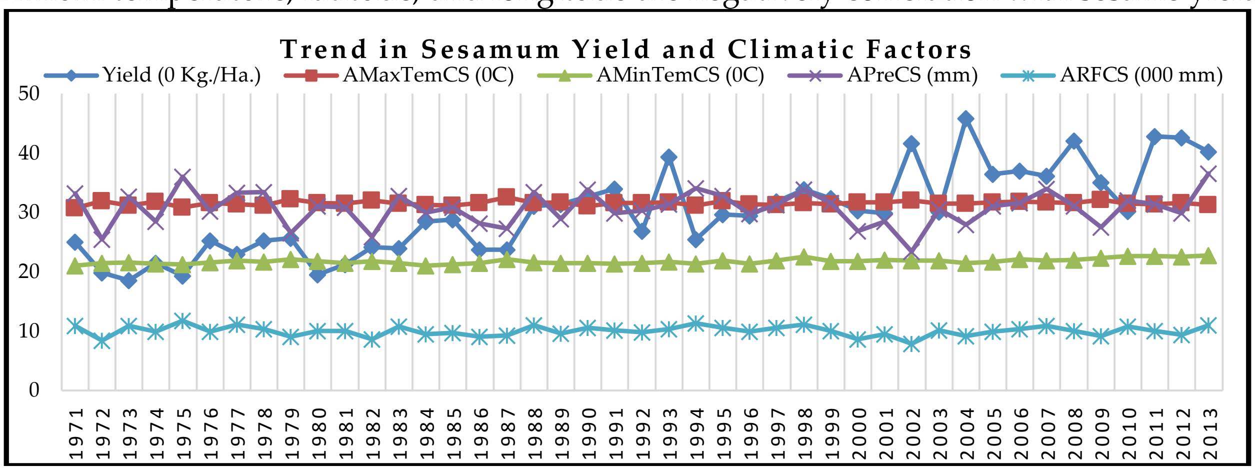

Figure 12: Fluctuation in sesame yield and climatic factors during 1971-2013

Source: Author's estimation.

Table 6: Correlation coefficients of sesame yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	-0.058	0.182**	0.138**	0.190**	-0.204**	-0.168**
amaxtemcs	-0.058	1	0.746**	-0.206**	-0.391**	0.304**	0.272**
amintemcs	0.182**	0.746**	1	0.272**	0.093**	0.093**	0.131**
aprecs	0.138**	-0.206**	0.272**	1	0.913**	-0.291**	-0.273**
arfcs	0.190**	-0.391**	0.093**	0.913**	1	-0.319**	-0.298**
*lat*as*	-0.204**	0.304**	0.093**	-0.291**	-0.319**	1	0.974**
*lon*as*	-0.168**	0.272**	0.131**	-0.273**	-0.298**	0.974**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

The trend in linseed yield and climatic factors is presented in Figure 13. It indicates that the productivity of linseed crop is significantly fluctuated due to change in climatic factors during 1971-2013. Furthermore, correlation coefficients of maximum temperature (*r*= -9.159**), minimum temperature (*r*= - 0.182**), precipitation (*r*= - 0.084*), rainfall (*r*= -0.066), latitude (*r*= - 0.274**) and longitude (*r*= - 0.303**) with linseed are seemed negative (See Table 7). Thus, the productivity of this crop is expected to decline as an increase in the aforementioned climatic factors and cropped areas under high latitude and longitude location of a state.

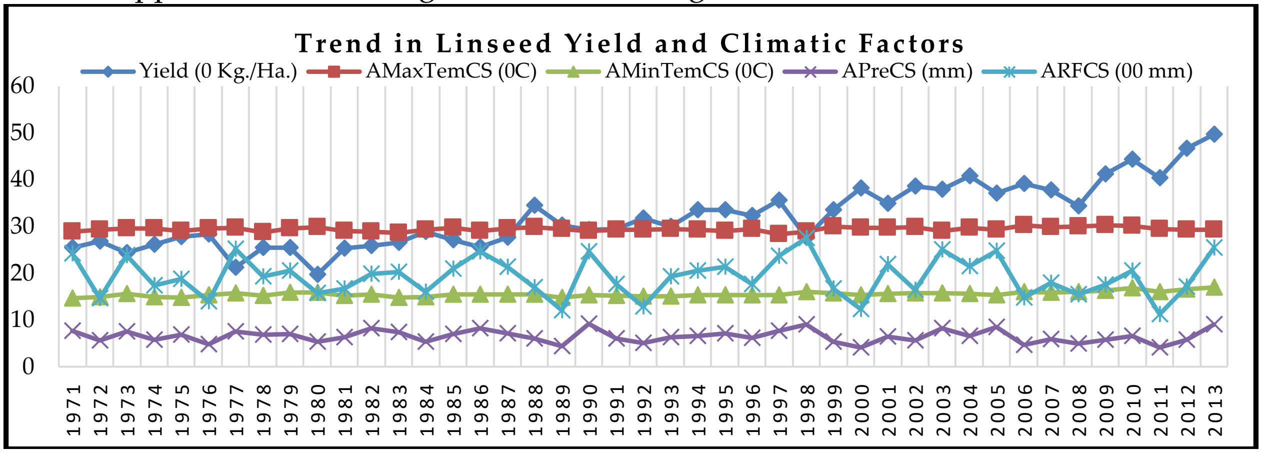

Figure 13: Fluctuation in linseed yield and climatic factors during 1971-2013

Source: Author's estimation.

Table 7: Correlation coefficients of linseed yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	-0.159**	-0.182**	-0.084*	-0.066	-0.274**	-0.303**
amaxtemcs	-9.159**	1	0.900**	-0.439**	-0.01	0.245**	0.278**
amintemcs	-0.182**	0.900**	1	-0.099**	0.318**	0.018	0.064
aprecs	-0.084*	-0.439**	-0.099**	1	0.806**	-0.367**	-0.358**
arfcs	-0.066	-0.01	0.318**	0.806**	1	-0.308**	-0.291**
*lat*as*	-0.274**	0.245**	0.018	-0.367**	-0.308**	1	0.994**
*lon*as*	-0.303**	0.278**	0.064	-0.358**	-0.291**	0.994**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

The trend in sugarcane yield and climatic factors is presented in Figure 14. It infers that sugarcane yield is varied as a change in climatic variables. The correlation coefficients of maximum temperature (r= 0.051), minimum temperature (r= 0.123**), precipitation (r= 0.359**) and actual rainfall (r= 0.526**) with yield of sugarcane crop is found positive (See Table 8). These variables, thus play a crucial role to increase the yield of sugarcane.

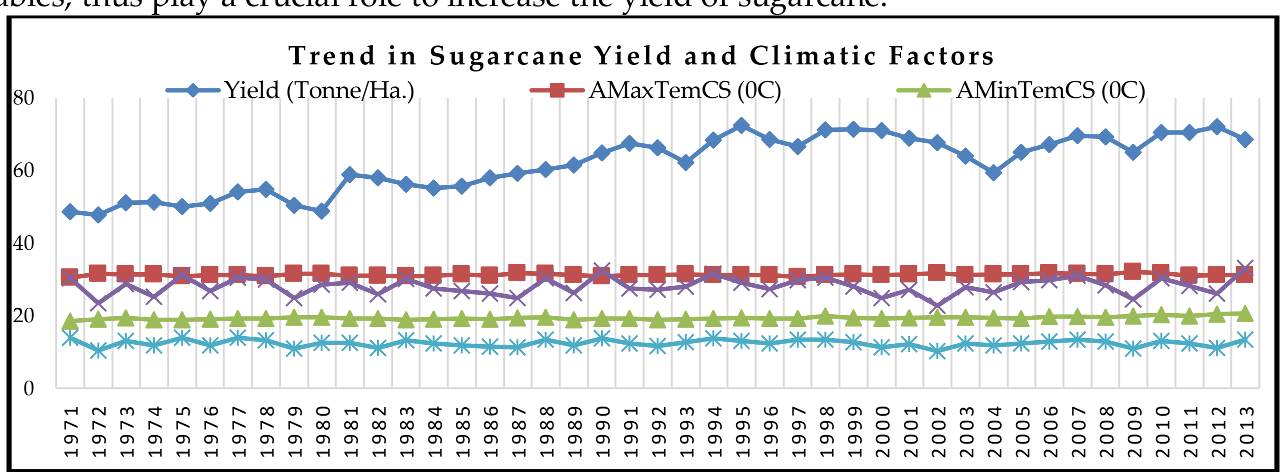

Figure 14: Fluctuation in sugarcane yield and climatic factors during 1971-2013

Source: Author's estimation.

Table 8: Correlation coefficients of sugarcane yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	0.051	0.123**	0.359**	0.526**	-0.147**	0.022
amaxtemcs	0.051	1	0.992**	0.087*	-0.037	-0.280**	-0.200**
amintemcs	0.123**	0.992**	1	0.112**	0.009	-0.282**	-0.200**
aprecs	0.359**	0.087*	0.112**	1	0.825**	-0.184**	-0.218**
arfcs	0.526**	-0.037	0.009	0.825**	1	0.099**	0.214**
*lat*as*	-0.147**	-0.280**	-0.282**	-0.184**	0.099**	1	0.652**
*lon*as*	0.022	-0.200**	-0.200**	-0.218**	0.214**	0.652**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

The trend in rapeseed & mustard yield and climatic factors is presented in Figure 15. It concludes that rapeseed & mustard yield fluctuated due to change in climatic variables during 1977-2014. The correlation coefficient of maximum temperature (*r*= 0.371**), minimum temperature (*r*= 0.375**) with the productivity of rapeseed & mustard yield are appeared positive (See Table 9). While, of rapeseed & mustard yield is negatively associated with precipitation (*r*= -0.451**), actual rainfall (*r*= - 0.586**), latitude (*r*= - 0.440**) and longitude (*r*= - 0.466**) with productivity of rapeseed & mustard crop is found positive.

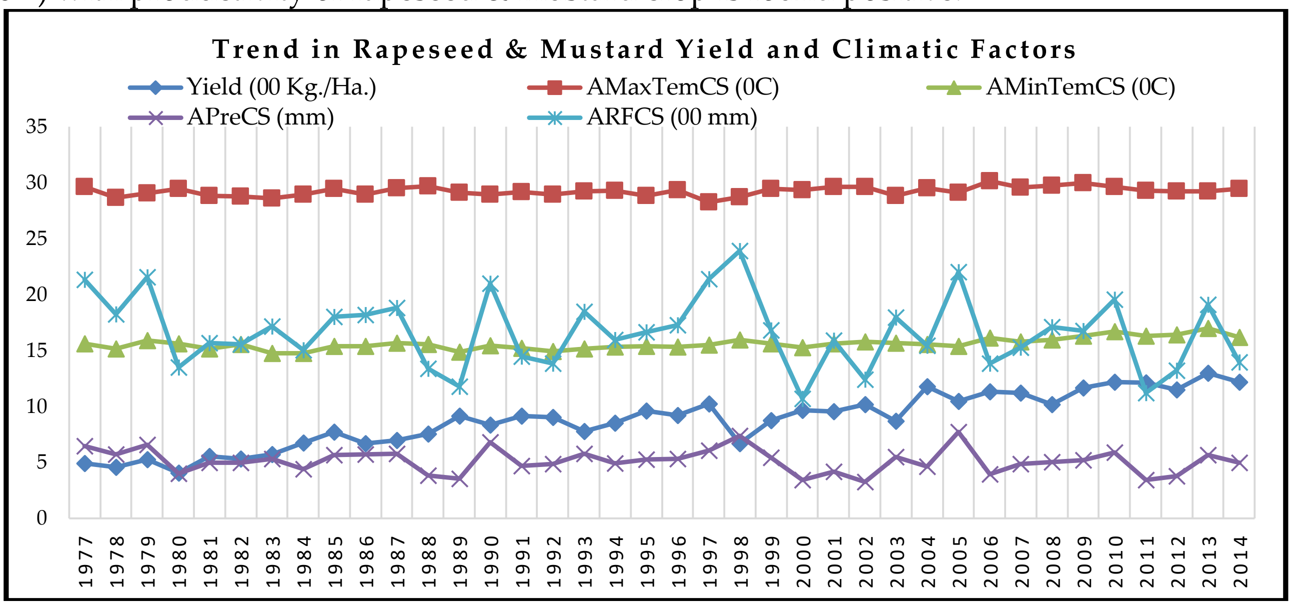

Figure 15: Fluctuation in rapeseed & mustard yield and climatic factors during 1977-2014

Source: Author's estimation.

Table 9: Correlation coefficients of rapeseed & mustard yield with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	0.371**	0.375**	-0.451**	-0.586**	-0.440**	-0.466**
amaxtemcs	0.371**	1	0.998**	-0.147**	-0.314**	-0.218**	-0.213**
amintemcs	0.375**	0.998**	1	-0.143**	-0.307**	-0.213**	-0.208**
aprecs	-0.451**	-0.147**	-0.143**	1	0.812**	0.072	0.113**
arfcs	-0.586**	-0.314**	-0.307**	0.812**	1	0.500**	0.531**
*lat*as*	-0.440**	-0.218**	-0.213**	0.072	0.500**	1	0.964**
*lon*as*	-0.466**	-0.213**	-0.208**	0.113**	0.531**	0.964**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

The trend in yield of sunflower seeds and climatic factors during 1977-2014 is presented in Figure 16. It shows that the productivity of sunflower seeds is varied due to high variability in climatic factors during the aforesaid period. The correlation coefficient of maximum temperature (*r*= - 0.137**), minimum temperature (*r*= - 0.144**) and precipitation (*r*= -0.006) with productivity of sunflower seed are seemed negative (See Table 10). Correlation coefficient of actual rainfall (*r*= 0.371**), latitude (*r*= 0.094) and longitude (*r*= 0.034) with yield of sunflower seed crop is observed positive.

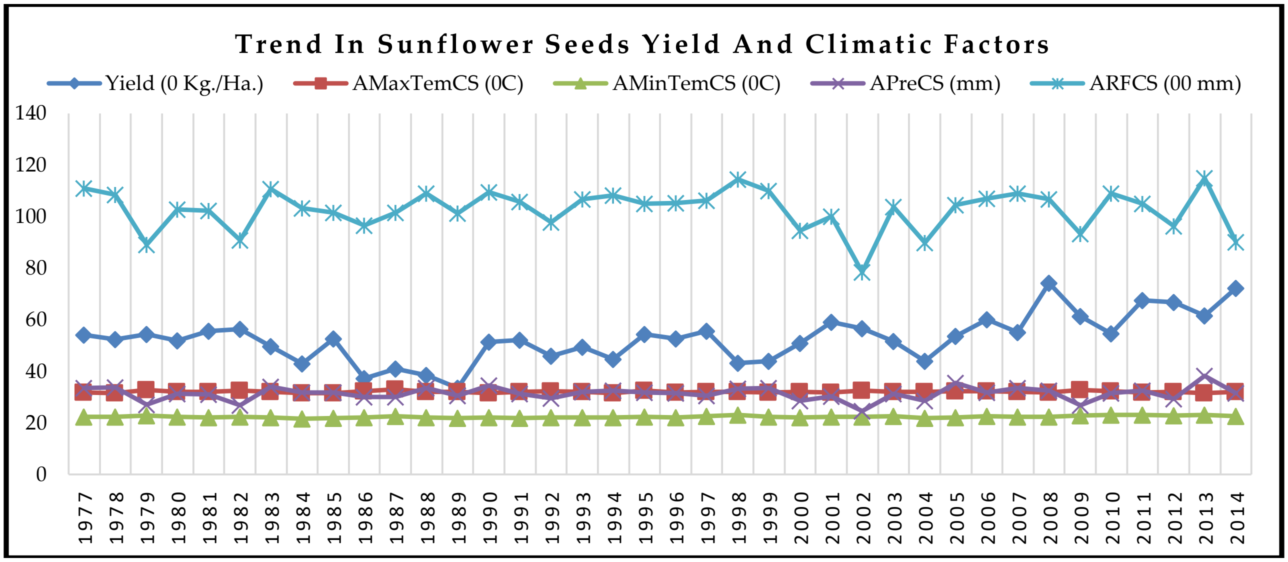

Figure 16: Fluctuation in sunflower seeds yield and climatic factors during 1977-2014

Source: Author's estimation.

Table 10: Correlation coefficients of sunflower seeds yield with with explanatory variables

Variables	*lanpro*	*amaxtemcs*	*amintemcs*	*aprecs*	*arfcs*	*lat*as*	*lon*as*
lanpro	1	-0.137**	-0.144**	-0.006	0.371**	0.094	0.034
amaxtemcs	-0.137**	1	0.981**	-0.561**	-0.521**	-0.058	0.186**
amintemcs	-0.144**	0.981**	1	-0.594**	-0.539**	-0.073	0.248**
aprecs	-0.006	-0.561**	-0.594**	1	0.468**	-0.368**	-0.623**
arfcs	0.371**	-0.521**	-0.539**	0.468**	1	0.251**	-0.032
*lat*as*	0.094	-0.058	-0.073	-0.368**	0.251**	1	0.789**
*lon*as*	0.034	0.186**	0.248**	-0.623**	-0.032	0.789**	1

Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% levels respectively.

5. Discussion on Empirical Findings

5.1 Influence of Climatic and Geographical Factors on Yield of Cash Crops

The regression coefficients of explanatory variables with the productivity of potato, cotton, sugarcane, groundnut, sesame, linseed, rapeseed & mustard, and sunflower seed crops are presented in Table 11. *R-square* values of rapeseed & mustards and cotton crops are found 54% and 72% respectively. Thus, 54% and 72% variation in yield of these crops can be explained by climatic factors and geographical location of respective states. The estimates also indicate that yield of rapeseed & mustard crops is highly climate-sensitive as compared to other crops.

Published by *Research & Innovation Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

***Time Trend Factor*:** The regression coefficient of time trend factor with yield of all crops is found positive. It shows that the use of technologies in cultivation will be effective to increase the yield of cash crops. This result is consistent with previous studies such as Singh & Sharma (2018b) which have also noticed the positive impact of technological change on the yield of crops in India.

Average Maximum Temperature: Maximum temperature shows a negative impact on the productivity of potato, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds. It infers that the productivity of these crops has a tendency to decline as increase in maximum temperature. Previous studies such as Kumar & Sharma (2013) have also observed the negative impact of maximum temperature on the yield of different cash crops in India. Kumar et al. (2015a) have also found a negative impact of maximum temperature on the yield of potato, cotton, groundnut, and sesame crops in India.

Table 11: Regression coefficients of explanatory variables with yields of cash crops

Crops	Potato		Cotton		Sugarcane		Groundnut	
No. of Obs.	731		602		774		688	
No. of groups	17		14		18		16	
R-squared	0.3891		0.3554		0.4654		0.1852	
Wald Chi²	531.54		303.08		21414.25		259.29	
Prob > Chi²	0.000		0.000		0.000		0.000	
Variables	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*
Year	0.0136* (0.001)	0.000	0.0225* (0.002)	0.000	0.0015 (0.001)	0.110	0.0128* (0.001)	0.000
amaxtemcs	-1.5495* (0.531)	0.004	-5.4274* (1.238)	0.000	-4.1997* (0.496)	0.000	-0.4935 (0.859)	0.566
amintemcs	0.5805** (0.246)	0.018	-1.2091 (0.747)	0.105	2.7427* (0.273)	0.000	0.4542 (0.433)	0.294
aprecs	0.0662 (0.056)	0.235	0.1588* (0.035)	0.000	-0.0844* (0.012)	0.000	0.2276* (0.063)	0.000
arfcs	-0.3248* (0.031)	0.000	-0.9763* (0.094)	0.000	-0.2668* (0.037)	0.000	-0.3849* (0.081)	0.000
latas	-0.3538* (0.090)	0.000	-0.1343 (0.113)	0.232	-0.5884* (0.039)	0.000	-0.2596* (0.070)	0.000
lonas	0.5280* (0.097)	0.000	0.1097 (0.102)	0.282	0.7213* (0.039)	0.000	0.2814* (0.066)	0.000
Con. Coef.	-20.4500* (2.767)	0.000	-13.4797* (5.085)	0.008	7.9876* (2.535)	0.002	-23.0562* (3.733)	0.000

Note: *, ** and *** indicate that regression coefficients are statistically significant at 1%, 5%, and 10% significance levels respectively. Values in the brackets are the standard error of the corresponding variables.

Average Minimum Temperature: The impact of minimum temperature on productivity of all crops (except cotton) are seemed positive. The estimates, therefore, indicate that an increase in minimum temperature will be useful to increase the productivity of these crops. Estimates are consistent with earlier studies such as Kumar & Sharma (2013) which have also observed a positive influence of minimum temperature on the yield of sugarcane, cotton, and sesame crops.

Actual Precipitation: The regression coefficients of precipitation with a yield of cotton, sesame, linseed, sugarcane, and rapeseed & mustard crops are found negative. Thus, the estimates show that yield of aforesaid crops may be declined as an increase in precipitation during the crop season.

Table 11: Conti…

Crops	Sesame		Linseed		Rapeseed & Mustard		Sunflower Seed	
No. of Obs.	774		602		528		436	
No. of groups	18		14		14		10	
R-squared	0.2429		0.3715		0.7249		0.3443	
Wald Chi²	252.11		486.79		1217.91		439.42	
Prob > Chi²	0.000		0.000		0.000		0.000	
Variables	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*	*Reg. Coef.*	*P>z*
Year	0.0071* (0.001)	0.000	0.0079* (0.001)	0.000	0.0125* (0.002)	0.000	0.0235* (0.002)	0.000
amaxtemcs	-5.6266* (0.773)	0.000	-1.107*** (0.629)	0.078	-3.0697* (0.443)	0.000	-4.7115* (1.488)	0.002
amintemcs	4.2103* (0.466)	0.000	0.8982* (0.282)	0.001	0.3584*** (0.199)	0.072	5.7486* (0.794)	0.000
aprecs	-0.6160* (0.084)	0.000	-0.2753* (0.076)	0.000	-0.0095 (0.065)	0.884	-0.1972*** (0.112)	0.079
arfcs	0.4127* (0.083)	0.000	0.2149* (0.072)	0.003	-0.2000* (0.064)	0.002	-0.0805 (0.101)	0.424
latas	0.26792* (0.060)	0.000	1.0996* (0.107)	0.000	0.1674 (0.107)	0.118	0.2528* (0.100)	0.011
lonas	-0.3588* (0.059)	0.000	-1.1923* (0.104)	0.000	-0.0474 (0.113)	0.676	-0.2579** (0.103)	0.012
Con. Coef.	-9.5963* (3.629)	0.008	-14.5964* (2.760)	0.000	-15.6109* (3.557)	0.000	-47.1474* (5.526)	0.000

Note: *, ** and *** indicate that regression coefficients are statistically significant at 1%, 5%, and 10% significance levels respectively. Values in the bracket are the standard error of the corresponding variables.

Actual Rainfall: Rainfall is an important natural resource to increase groundwater and to maintain the water level in the earth. However, extreme variability in rainfall has a negative impact on crop growth. Subsequently, crop yield may decrease due to change or shift in rainfall patterns during the crop period. Actual rainfall during crop season has a negative influence on the yield of potato, groundnut, sugarcane, rapeseed & mustard, and sunflower seeds crops. Thus, it indicates the productivity of these crops declines as a change in actual rainfall. The estimates are consistent with previous studies such as Kumar & Sharma (2013) which have observed the negative influence of actual rainfall on the yield of sugarcane and linseed crops in India. Kumar et al. (2015a) have also found a negative impact of rainfall on cotton and groundnut in India.

Latitude and Longitude: The regression coefficient of latitude of a state with the productivity of potato, cotton, groundnut, and sugarcane crops are found negative. The estimates show that productivity of these crops will not be beneficial for those states which are located at higher latitude. The longitude location of a state is also showed a negative impact on the productivity of sesame, linseed, rapeseed & mustard, and sunflower seeds crops. The estimates, therefore, clearly indicate that the geographical location of a state also has a significant contribution to crop production.

5.2 Expected Yield of Cash Crops

The expected yield of cash crops due to a marginal increase in climatic factors is presented in Figure 17. The expected yields of crops are estimated using marginal impact analysis techniques. The estimates demonstrate that sugarcane yield is likely to be increased by 23% due to 1% change in maximum and minimum temperature, actual precipitation, and actual rainfall in India. Jyoti & Singh (2020) is also observed that sugarcane yield is likely to be decreased as 1 unit change in climatic factors in India. However, this estimate is not similar to previous studies such as Ramachandran et al. (2017) which have noticed that sugarcane yield is predicted to decline by the end of the century due to climate change in Tamil Nadu. Kelkar et al. (2020) have also observed that sugarcane production will decline due to climate change in Maharashtra. The productivity of the sunflower seed crop is expected to be increased by 6.75% due to marginal change in climatic factors (i.e., average maximum temperature and minimum temperature, actual precipitation, and actual rainfall) during the crop season. Groundnut yield is also projected to be increased by 1.90% due to marginal changes in climatic factors in India. This result is highly contradictory with previous studies like Ashalatha et al. (2012) which have observed that groundnut yield has declined by 34.09 Kg/Ha in rainfed areas in Karnataka.

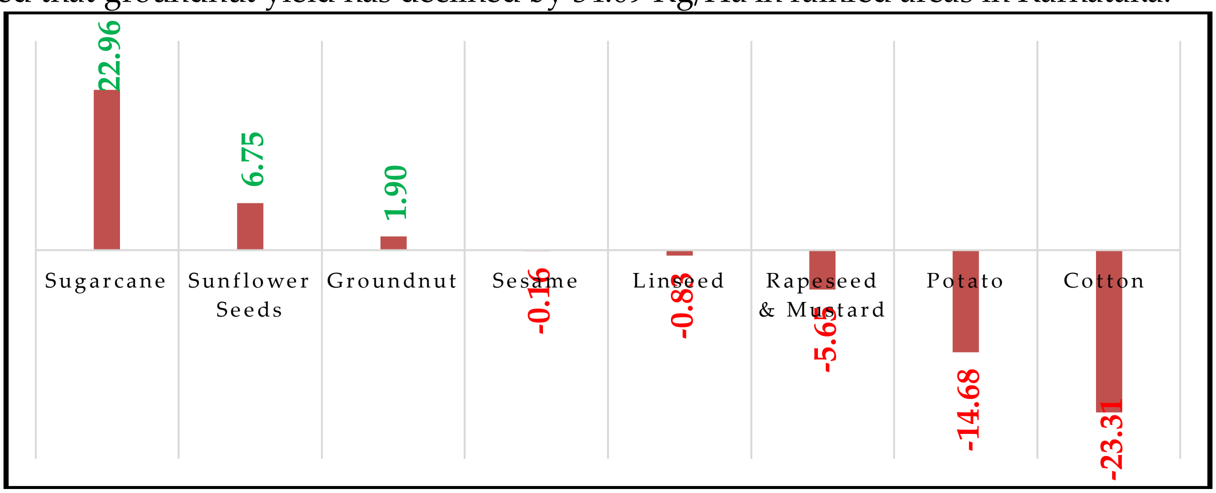

Figure 17: Predicted yield of crops due to marginal change in climatic factors

The productivity of sesame crop may decline by 0.16% due to an increase in 1^{0}C maximum and minimum temperature, and 1 mm actual precipitation and rainfall during crop period. The estimate is consistent with previous studies such as Singh et al. (2017) which have also observed that sesame yield is likely to decline due to marginal change in climatic factors. The productivity of linseed crop is expected to be declined by 0.83% due to a 1% change in maximum and minimum temperature, and actual precipitation and rainfall during the crop season. Furthermore, the yield of rapeseed & mustard crop may be declined by 5.65% due to marginal changes in climatic factors. Potato yield is expected to be decreased by 14.68% due to a marginal increase in climatic factors. Singh et al. (2017) have also reported that productivity and production of potato crop decline due to climate change in India. As cotton yield is predicted to

Published by *Research & Innovation Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

decrease by 23.33% due to a marginal increase in climatic factors, thus, the greater impact of climate change is appeared on the cotton crop as compared to other cash crops in India. Ashalatha et al. (2012) have also detected that cotton yield is likely to be decreased by 59.96 Kg/Ha in the rainfed area in Karnataka. Singh et al. (2017) have also found that cotton yield decreases due to climate change in India.

6. Conclusion and Policy Implications

The main objective of this study is to assess the impact of climatic and geographical factors on the yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds crop in India. For this, it includes the yield of an individual crop as a dependent variable, and average maximum and minimum temperature, actual precipitation and rainfall during crop season, and latitude and longitude location of corresponding states as explanatory variables. The Cobb-Douglas production function model is used to estimate the regression coefficient of explanatory variables with yield of crops. Accordingly, it examines the expected yields of the aforementioned crops using marginal impact analysis techniques. The empirical finding demonstrates that the impact of technological change on the yield of all crops are seemed positive. The yield of these crops, therefore, would be increased with the adoption of advanced technologies in cultivation. The maximum temperature has a negative impact on the yield of potato, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds crops. On contrary, the yield of all crops (excluding cotton) may be improved as an increase in average minimum temperature in India. Impact of actual precipitation on yield of cotton, sesame, linseed, sugarcane, and rapeseed & mustard crops are found negative. Effect of actual rainfall on yield of potato, groundnut, sugarcane, rapeseed & mustard, and sunflower seeds crops appeared negative. Furthermore, the yield of potato, cotton, groundnut, and sugarcane crops may be declined at highly latitude located states in India. Yields of sesame, linseed, rapeseed & mustard, and sunflower seeds crops are possible to be declined at highly longitude located states in India. The projected results based on marginal impact analysis technique show that yield of sesame, linseed, rapeseed & mustard, potato, and cotton crops may be decreased by 0.16%, 0.83%, 5.65%, 14.68%, and 23.31% respectively due to a marginal increase in average maximum and minimum temperature, actual precipitation, and rainfall during sowing time to harvesting time of corresponding crops.

Based on the above-mentioned finding, here, it can be determined that yield of most cash crops is adversely affected due to changes in climatic factors and geographical location in India. However, the impact of climatic factors and geographical location on yield are varied across crops. Potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, and sunflower seeds are the main cash crops that meet the requirement of raw material for agro-based industries in India. Climate change, therefore, has a negative impact on the production activities of agro-based industries, consumers, and crop producers in India (Kumar et al., 2015a; Singh et al., 2017; Singh & Jyoti, 2019). Subsequently, it would be also adversely affecting the livelihood security of cash crop producers in India (Singh et al., 2017). Policymakers, therefore, need to formulate crop-specific policies to mitigate the negative consequences of climate change in cash crops farming and to maintain the production activities of Agri industries in India.

Adoption of modern technologies such as a change in planting methods, mixed cropping pattern and irrigation methods may be an effective way to reduce the negative impact of climate change in cash crop farming (Kumar et al., 2016; Singh et al., 2019). Technologies can be used in terms of change in irrigation methods, use of organic fertilizer and pesticide, and change in planting method of seeds (Singh & Sharma, 2018b). Use of appropriate technology in cultivation may be another option effective to maintain the available ecosystem services which will be useful to increase agricultural sustainability in India. Furthermore, irrigated area is seen as a vital factor to increase the productivity of cash crops (Kumar & Sharma, 2014; Kumar et al., 2015a; Kumar et al., 2016). Thus, proper water management policies would be beneficial to enhance crop yield in India (Kumar et al., 2017). For this, water conservation schemes must be implemented at micro level (Kumar et al., 2016; Singh & Sharma, 2018a). Minimum use of fertilizer will be useful to increase crop productivity and to maintain the quality of soil, water, and air (Singh et al., 2019). Therefore, it may be useful to reduce the possibility of climate change in the near future. There also needs to provide credit facilities to farmers to increase their economic capacity to use organic farming, appropriate technologies, better irrigation facilities and high-yielding of seeds in farming in India (Kumar et al., 2016; Singh et al., 2019). India needs to increase extensive expenditure on agricultural R&D which would incentivize researchers and scientists to discover more varieties of seeds that can reduce the heat impact on crop growth (Kumar et al., 2016; Singh et al., 2017). Arrangement of regular training for farmers would be useful for them to increase their understanding of climate change and its impact on crop production in India (Kumar et al., 2016; Singh & Sharma, 2018a). Subsequently, farmers will be in a strong position to use different adaptation strategies to reduce the negative consequences of climate change in cultivation.

Agricultural Extension Offices and Rural Development Agencies must be taken effective policy action to mitigate the impact of climate change on agriculture and to increase the livelihood security of farmers in rural India (Kumar et al., 2016; Singh & Sharma, 2018a). Also, agricultural industries must be associated with researchers, agricultural scientists and farmers to reach a conclusive policy decision to maintain the agricultural production system in India. As the present study provides several policy perceptions to mitigate the negative consequences of climate change in cash crops farming at the macro level. However, micro-level study, therefore, will be greatly useful to get a better understanding of farmer's awareness towards climate policy action and their various adaptation strategies to mitigate the negative effect of climate change in crop farming. Thus, existing researchers and scientists may consider the micro level study to check the validity of the empirical finding of the present research.

Author Contributions: The research proposal was prepared by Dr. Ajay K. Singh. Required data from various sources are gathered by Dr. Ajay K. Singh. While the cleaning, segregation, and compilation of data in state-wise panel data are completed by Dr. Bhim Jyoti. Formulation of empirical models and investigation are undertaken by Dr. Ajay K. Singh. Finalization of empirical results and interpretation of results are discussed by both authors jointly. Documentation of the present article is done by Dr. Bhim Jyoti.

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

Ahmad, J., Dastgir, A., & Haseen, S. (2011). Impact of climate change on agriculture and food security in India. *International Journal of Agricultural Environmental and Biotechnology*, 4(2), 129-137.

Ashalatha, K. V., Gopinath, M., & Bhat, A. R. S. (2012). Impact of climate change on rainfed agriculture in India: A case study of Dharwad. *International Journal of Environmental Science and Development*, 3(4), 368-371.

Attri, S. D., & Rathore, L. S. (2003). Simulation of the impact of projected climate change on wheat in India. *International Journal of Climatology*, 23, 693–705.

Bhatia, V.S., Singh, P., Wani, S.P., Chauhan, G.S., Rao, A.V.R.K., Mishra, A.K., & Srinivas, K. (2008). Analysis of potential yields and yield gaps of rainfed soybean in India using CROPGRO-Soybean model. *Agricultural and Forest Meteorology*, 148(1), 1252-1252.

Birthal, P. S., Khan, Md. T., Negi, D. S., & Agarwal, S. (2014). Impact of climate change on yields of majors food crops in India: Implications for food security. *Agricultural Economics Research Review*, 27(2), 145-155.

Cabas, J., Weersink, A., & Olale, E. (2009). Crop yield response to economic, site, and climate variables. Climatic Change, 101(1), 599-616.

Chhabra, V., & Haris A.A. (2020). Climate variability, extreme rainfall, and temperature events over different agro-ecological zones of Bihar. *Journal of AgriSearch*, 2(3), 189-194.

Coster, A. S., & Adeoti, A. I. (2015). Economic effects of climatic change on maize production and farmer's adaptation strategies in Nigeria: a Ricardian approach. *Journal of Agricultural Science*, 17(5), 67-84.

Fischer, G., Shah, M., Tubiello, F. N., & Velhuizen, H. (2005). Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical Transactions of the Royal Society B*, 360(1), 2067-2083.

Guntukula, R. (2019). Assessing the impact of climate change on Indian agriculture: Evidence from major crop yields. *Journal of Public Affairs*, 20(1), 1-7.

Guntukula, R., & Goyari P. (2020). Climate change effect on crop yield and its variability in Telangana, India. *Studies in Microeconomics*, 8(1), 119-148.

Horowitz, J. K. (2009). The income-temperature relationship in a cross-section of countries and implications for predicting the effects of global warming. *Environmental Resource Economics*, 44(1), 475-493.

Imran, A., Hussain, Z., Shabbir, M., Waseem, L., & Naqvi, A. A. (2019). Climate change and its impact on the agriculture sector in selected South Asian countries. *Int. J. Econ. Environ. Geol.*, 10(4), 97-101.

Jha, B., & Tripathi, A. (2011). Isn't climate change affecting wheat productivity in India? *Indian Journal of Agricultural Economics*, 66(3), 353-364.

Jyoti, B., & Singh, A. K. (2020). Projected sugarcane yield in different climate change scenarios in Indian states: A stat-wise panel data exploration. *International Journal of Food and Agricultural Economics*, 8(4), 343-365.

Kavikumar, K. S. (2009). Climate sensitivity of Indian agriculture do spatial effects matter? South Asian Network for Development and Environmental Economics, Working Paper, 45-09.

Kelkar, S. M., Kulkarni, A., & Rao, K. K (2020). Impact of climate variability and change on crop productivity in Maharashtra, India. *Current Science*, 118(8), 1235-1245.

Kumar, K. K., Kumar, K. R., Ashrit, R. G., Deshpande, N. R., & Hansen, J. W. (2004). Climate impact of Indian agriculture. *International Journal of Climatology*, 24(1), 1375-1393.

Kumar, A., & Sharma, P. (2013). Impact of climate variation on agricultural productivity and food security in Rural India. Economics Discussion Papers, No. 2013-43, Kiel Institute for the World Economy, Germany.

Kumar, A., & Sharma, P. (2014). Climate change and sugarcane productivity in India: An econometric analysis. *Journal of Social and Development Sciences*, 5(2), 111-122.

Kumar, A., Sharma, P., & Ambrammal, S. K. (2015a). Effect of climatic factors on productivity of cash crops in India: Evidence from state-wise panel data. *Global Journal of Research in Social Sciences*, 1(1), 9-18.

Kumar, A., Sharma, P., & Ambrammal, S. K. (2015b). Climatic effects on sugarcane productivity in India: a stochastic production function approach. *International Journal of Economics and Business Research*, 10(2), 179-203.

Kumar, A. (2015). Effect of climatic factors on agricultural productivity and food security in India: An econometric analysis. Ph.D. Thesis, Indian Institute of Technology Indore, Madhya Pradesh (India).

Kumar, A., Sharma, P., & Joshi, S. (2016). Assessing the impacts of climate change on land productivity in Indian crop agriculture: An evidence from panel data analysis. *Journal of Agricultural Science and Technology*, 18(1), 1-13.

Kumar, A., Ahmad, M. M., & Sharma, P. (2017). Influence of climatic and non-climatic factors on sustainable food security in India: a statistical investigation. *International Journal of Sustainable Agricultural Management and Informatics*, 3(1), 1-30.

Kumar, A., Singh, B. J., & Sharma, P. (2020). Assessing the climate change impact on rice and wheat production in Uttar Pradesh and Haryana states of India. *Climate Change*, 6(21), 74-92.

Lee, H.-L. (2009). The impact of climate change on global food supply and demand, food prices, and land use. *Paddy Water Environmental*, 7(1), 321-331.

Iizumi, T., Fuuruya, J., Shen, Z., Kim, W., Okada, M., Fujimori, S., Hasegawa, T. & Nishimori, M. (2017). Responses of crop yield growth to global temperature and socioeconomic changes. *Scientific Reports*, 7(7800), 1-10.

Mendelsohn, R., Nordhaus, W., & Shaw, D. (1994). The impact of global warming on agriculture: A Ricardian analysis. *The American Economic Review*, 84(4), 753-771.

Mondal, P., Jain, M., Robertson, A., Galford, G. L., Small, C., & DeFries, R. S. (2014). Winter crop sensitivity to interannual climate variability in central India. *Climate Change*, 126, 61-76.

Panda, A., Sahu, N., Behera, S., Sayama, T., Sahu, L., Avtar, R., Singh, R. B., & Yamada, M. (2019). Impact of climate variability on crop yield in Kalahandi, Bolangir, and Koraput districts of Odisha, India. *Climate*, 7(126), 1-12.

Panda, R. K., Alam, J., & Nandgude, S. (2012). Effect of climate variability on maize yield and evaluation of coping strategies using the crop growth model. *The International Journal of Climate Change: Impacts and Responses*, 3(2), 71-94.

Parry, M. L., Rosenzweig, C. A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14(1), 53–67.

Praveen, B., & Sharma, P. (2019). Climate change and its impacts on Indian agriculture: An econometric analysis. *Journal of Public Affairs*, 20(1), 1-6.

Ramachandran, A., Praveen, D., Jaganathan, R., RajaLakshmi, D., & Palanivelu, K. (2017). Spatiotemporal analysis of the projected impact of climate change on the major C3 and C4 crop yield under representative concentration pathway 4.5: Insight from the coasts of Tamil Nadu, South India. *PLOS ONE*, 1-19. DOI: https://doi.org/10.1371/journal.pone.0180706.

Ramulu, M. (1996). Supply response of sugarcane in Andhra Pradesh. *Finance India*, 10(1), 116-122.

Sathaye, J., Shukla, P. R., & Ravindranath, N. H. (2006). Climate change, sustainable development, and India: Global and national concerns. *Current Science*, 90(3).

Saseendran, S. A., Singh, K. K., Rathore, L. S., Singh, S. V., & Sinha, S. K. (2000). Effects of climate change on rice production in the tropical humid climate of Kerala, India. *Climatic Change*, 44(4), 495-514.

Singh, A. K., Narayanan, K. G. S., & Sharma, P. (2017). Effect of climatic factors on cash crop farming in India: An application of Cobb-Douglas production function model. *International Journal of Agricultural Resources, Governance, and Ecology*, 13(2), 175-210.

Singh, A. K., Narayanan, K. G. S., & Sharma P. (2019). Measurement of technical efficiency of climatic and non-climatic factors in sugarcane farming in Indian states: Use of stochastic frontier production function approach. *Climate Change*, 5(19), 150-166.

Singh, A. K., & Issac, J. (2018). Impact of climatic and non-climatic factors on sustainable livelihood security in Gujarat state of India: A statistical exploration. *Agriculture and Food Sciences Research*, 5(1), 30-46.

Singh, A. K., & Sharma, P. (2018a). Implications of climatic and non-climatic variables on food security in developing economies: A conceptual review. *MOJ Food Processing & Technology*, 6(1):1-12.

Singh, A. K., & Sharma, P. (2018b). Measuring the productivity of food-grain crops in different climate change scenarios in India: An evidence from time-series investigation. *Climate Change*, 4(16), 661-673.

Singh, A. K., & Jyoti, B. (2019). Measuring the climate variability impact on cash crops farming in India: An empirical investigation. *Agriculture and Food Sciences Research*, 6(2), 155-165.

Singh, A. K., & Singh, B. J. (2020). Assessing the infectious diseases of students in different weather seasons in DIT University Dehradun, Uttarakhand (India). *Asian Journal of Multidimensional Research*, 9(3), 34-48.

Singh, A. K., & Jyoti, B. (2021). Projected production and yield in India: An evidence from state-wise panel data investigation during 1977-2014. *The Journal of Agricultural Sciences-Sri Lanka*, 16(1), 108-125.

Singh, A. K. (2017). An empirical analysis to assess the GDP projection of Gujarat State of India. *JNNCE Journal of Engineering and Management*, 1(1), 51-58.

Singh S. (2020). Agriculture development in India: A state-level analysis. *South Asian Journal of Social Studies and Economics*, 6(2), 17-34.

Srivastava, A., Kumar, S.N., Aggarwal, P.K. (2010). Assessment of the vulnerability of sorghum to climate changes in India. *Agriculture Ecosystem and Environment*, 138(1), 160-169.

Sonkar, G., Singh, N., Mall, R.K., Singh, K.K., Gupta, A. (2020). Simulating the impacts of climate change on sugarcane in diverse Agro-climatic zones of northern India using CANEGRO-Sugarcane model. *Sugar Tech*, 22(3), 460-472.

Yadav, M. K., Singh, R. S., Singh, K. K., Mall, R. K., Patel, C., Yadav, S. K., Singh, M. K. (2016). Assessment of climate change on pulse, oilseed, and vegetable crops at Varanasi, India. *Journal of Agrometeorology*, 18(1), 13-21.

Quiggin, J., & Horowitz, J. (2003). Costs of adjustment to climate change. *The Australian Journal of Agricultural and Resource Economics*, 47(4), 429-446.

Zhai, F., & Zhuang, J. (2009). Agriculture impact of climate change: A General Equilibrium Analysis with special reference to Southeast Asia. ADBI Working Paper Series No. 131.