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EFFECT OF CLIMATIC AND GEOGRAPHICAL FACTORS ON YIELDS OF CASH CROPS IN INDIA: A STATE-WISE PANEL DATA EXPLORATION

ABSTRACT: This study assesses the impact of climatic and geographical factors on yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard and sunflower seeds crops using state-wise panel data in India during 1971-2013. Regression coefficients of climatic and geographical factors with a yield of crops are estimated through Cobb-Douglas production function model. The yield of a specific crop is considered as a dependent variable, and average maximum and minimum temperature, actual precipitation and rainfall during crop season, and latitude and longitude of a certain state are used as an independent variable. Hence, it estimates the expected yield of individual crop due to a marginal increase in climatic factors. The empirical result shows that maximum temperature has a negative impact on the yield of potato, groundnut, sesame, linseed, sugarcane, rapeseed & mustard, sunflower seeds. Yields of all crops (except cotton) improve as an increase in minimum temperature. Precipitation has a negative effect on cotton, sesame, linseed, sugarcane, rapeseed & mustard and sunflower seeds. The yield of potato, rapeseed & mustard and sunflower seeds tend to be declined due to an increase in actual rainfall. Latitude and longitude have a significant impact on crops yields. Probable results infer that yield of sesame, linseed, rapeseed & mustard, potato and cotton may be declined by 0.16%, 0.83%, 5.65%, 14.68% and 23.31% on hectare land respectively due to marginal increase in average maximum and minimum temperature, actual precipitation and rainfall. Therefore, there needs to adopt

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a crop-specific climate action policy to mitigate the negative impact of climate change in Indian agriculture.

Keywords: Agricultural productivity; Climate change; Cobb-Douglas production function; Marginal impact analysis technique

JEL Codes: C01, C10, C33, O21

INTRODUCTION

Climate change has a negative impact on agricultural productivity and food security at word-wide (Kumar et al., 2017; Singh and Sharma, 2018a). All economic activities are being adversely affected due to climate change (Singh et al., 2019). It has become a serious concern for developing countries as these do have less economic and physical resources to mitigate the negative consequences of climate change in the agricultural production system (Kumar and Sharma, 2013; Kumar et al., 2015a; Kumar et al., 2016). Developing countries are located at lower latitudes, therefore these economies are highly prone to climate variations including rapid population growth, higher urbanization and large dependency of population on agriculture (Lee, 2009; Ahmad et al., 2011). Furthermore, crops yields are expected to be decreased in developing countries, and crop yield would be increased in developed countries. It may therefore will 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 (Ahmad et al., 2011). There are still more people who are suffering from chronic diseases due to lack of food consumption and low quality of food. As more than 52% of the 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. Thus, agriculture is an important sector to sustain the livelihood security of the population in India (Sathaye et al., 2006). Moreover, there are many other reasons such as low productivity of crops, high illiteracy and low economic capacity of farmers, insignificant support from financial organizations to farmers, the low contribution of government in agricultural research & development, and low technological skills of farmers that are making Indian agriculture more vulnerable (Singh and Sharma, 2018b). Also, arable land is declining due to high urbanization, population growth and industrialization in India (Kumar et al., 2020). These activities are also increasing the extensive burden on ecological services (i.e. water, air, land, forest, rivers) and agricultural production system (Kumar et al., 2020; Singh and Singh, 2020). Also, climate change and its impact on agricultural production system have created a wide-ranging burden to sustain the livelihood security of Indian farmers. Further, it is also found the climate change have a negative impact on human health (Singh and Singh, 2020). India thus may be at high risk due to climate change in the near future (Kumar et al., 2015a).

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. A summary of associated previous studies is given here: Zhai and Zhuang (2009) have reported the GDP may be decreased up to 6.2% by 2080 in India. Ramulu (1996) have identified that sugarcane yield affecting factors in Andhra Pradesh (India). 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). 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 states of India. Kavikumar (2009) have found that agriculture revenue is likely to be diminished by 9% on per hectare land due to climate change in thirteen Indian states.

Asha Latha et al. (2012) have observed the impact of drought, rainfall and temperature on production and yield of groundnut, onion, cotton and other crops in Karnataka. Kumar and Sharma (2013) have observed the impact of climatic and non-climatic factors on 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 and 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 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 crop in India. Yadav at al. (2016) has assessed the influence of CO_2 concentration and temperature on the productivity of various cash crops in Varanasi (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. Ramachandran et al. (2017) have assessed the impact of climate change on 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 and 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 Indian states. Guntukula (2019) have evaluated the climate change impact on the yield of rice, wheat, pulses, rapeseeds & mustard, cotton, sugarcane and groundnut crops in India. Praveen and Sharma (2019) have examined the impact of climate change on yield of rice, wheat, Jowar, bajra, maize, ragi, barley, tea, cotton, groundnut, tea, cotton, groundnut, rapeseed & mustard, linseed, and sesame crops in India. Kelkar et al. (2020) have estimated the expected impact of climatic factors on sugarcane, cotton and rice crops in Maharashtra (India).

The above-mentioned review 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 other demographic parameters as independent variables (Kumar and Sharma, 2013; Kumar and Sharma, 2014; Kumar et al., 2015a; Kumar et al., 2015b; Singh et al., 2017; Singh and Sharma, 2018b; Guntukula, 2019; Panda et al., 2019; Singh et al., 2019). However limited studies could estimate the impact of climatic factors and geographical location on the productivity of cash crops in India. Due to the aforesaid research gap, the present study is addressed in 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 a 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 achieved the following objectives:

- To assess the impact of climatic and geographical location on the yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard and sunflower seeds crops using state-wise panel data in India through Cobb-Douglas production function approach.
- To examine the predicted yields of cash crops due to marginal change in climatic factors using marginal impact analysis technique in India.

- To provide conclusive and viable policy suggestions to mitigate the negative consequences of climate change in Indian agriculture based on previous studies.

RESEARCH METHOD AND MATERIAL

Description of Study Area

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

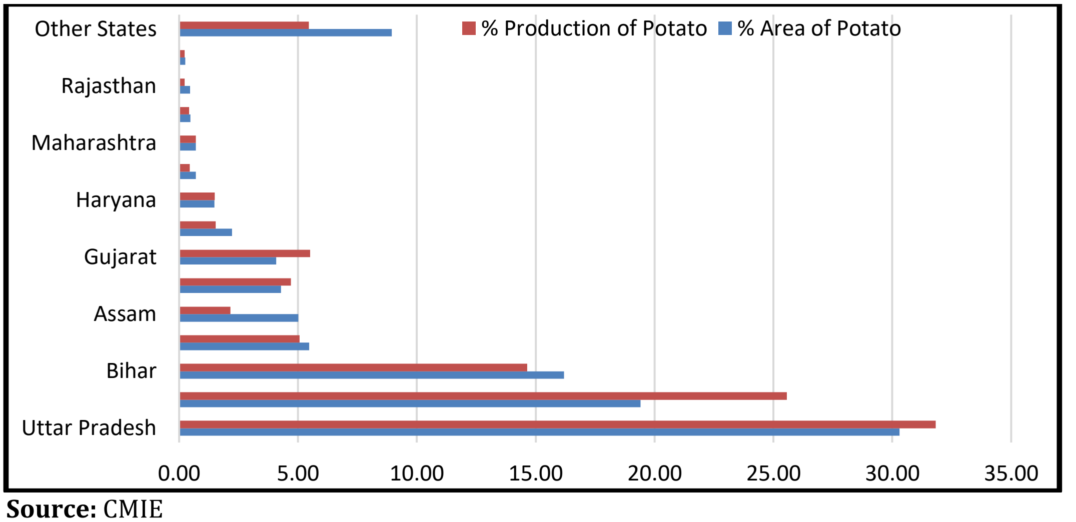
Table 1: List of states that are considered under a specific crop

Crops	States	No. of States
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 cover more than 90% 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 Figure 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).

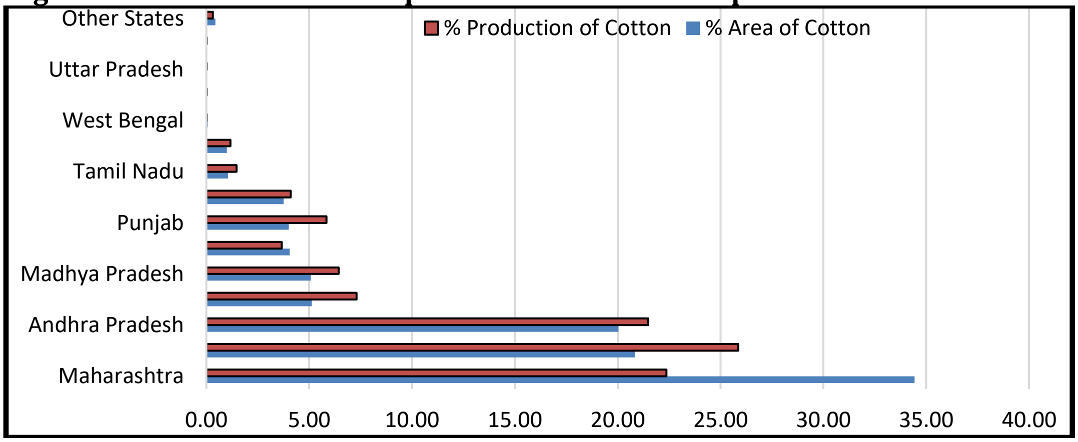
Figure 1: State-wise area and production of the potato crop in India in 2012-13



Source: CMIE

Maharashtra, Gujarat and Andhra Pradesh states are the largest producer 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.

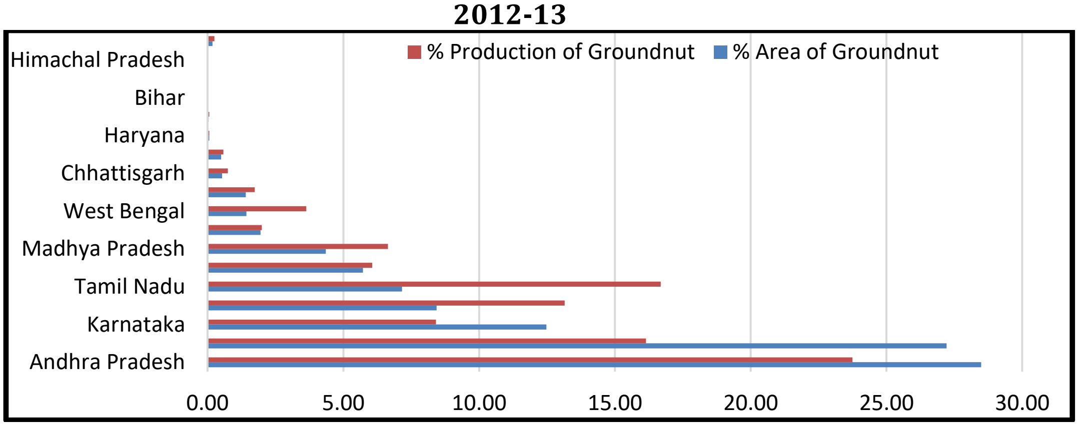
Figure 2: State-wise area and production of cotton crop in India in 2012-13



Source: CMIE

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

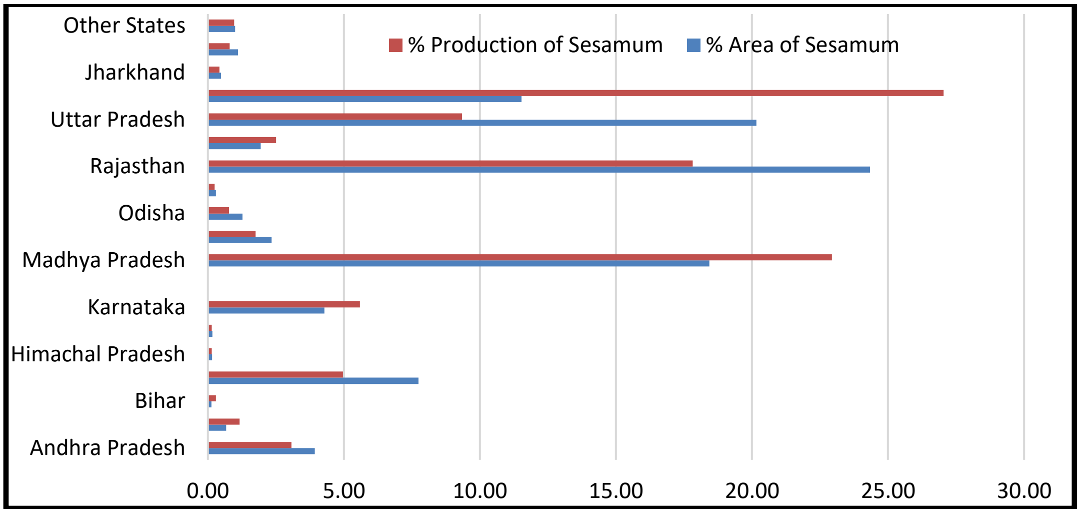
Figure 3: State-wise area and production of groundnut crop in India in 2012-13



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% sesame production in India.

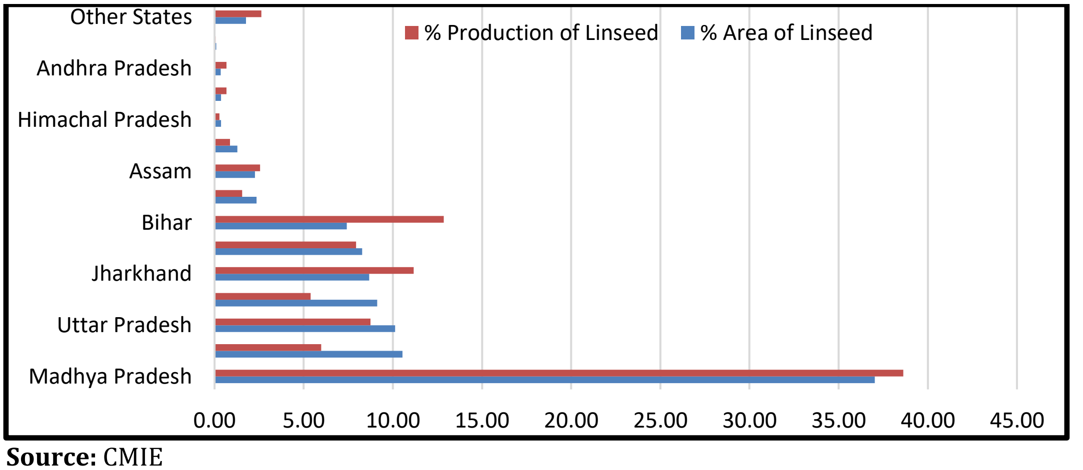
Figure 4: State-wise area and production of sesame crop in India in 2012-13



Source: CMIE

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

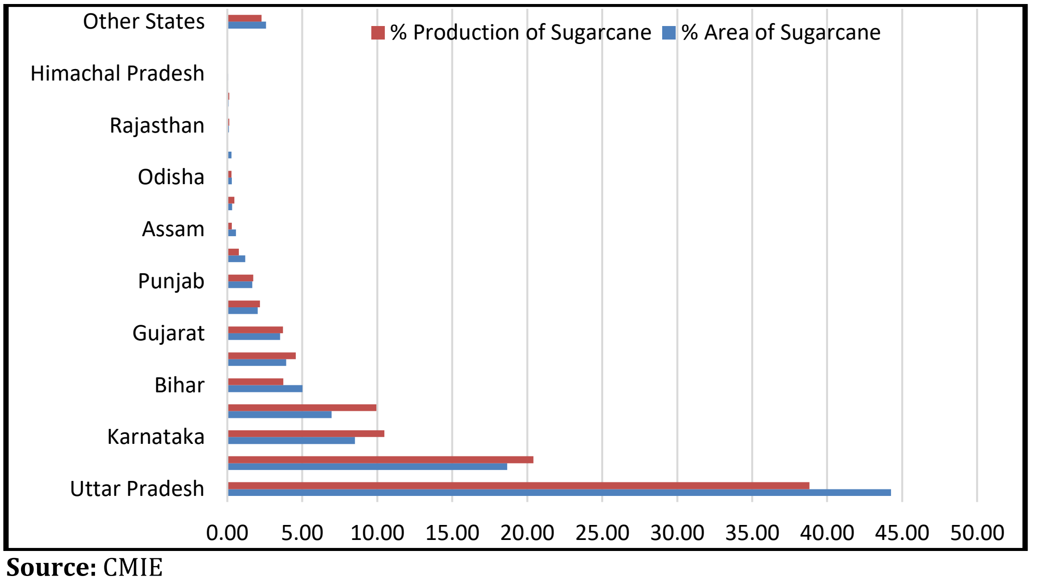
Figure 5: State-wise area and production of linseed crop in India in 2012-13



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 area and production of sugarcane crop in India.

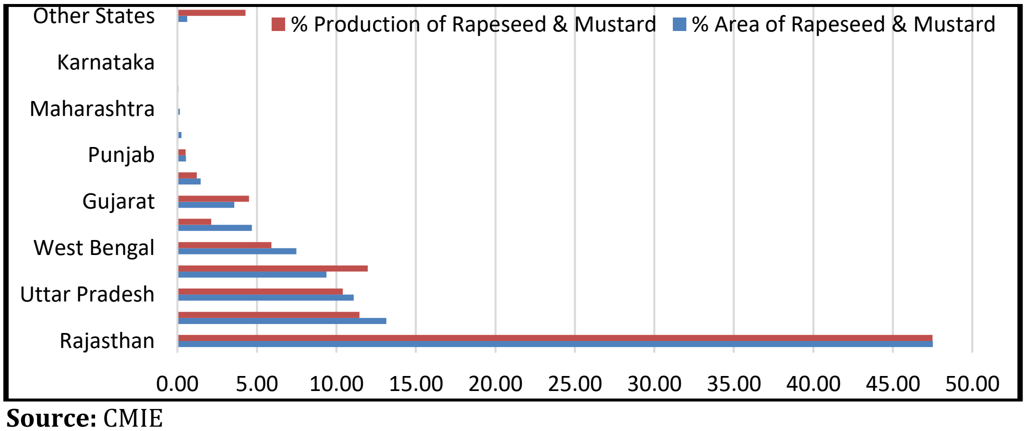
Figure 6: State-wise area and production of sugarcane crop in India in 2012-13



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 90% area and production of Rapeseed & mustard crop in India (See Figure 7).

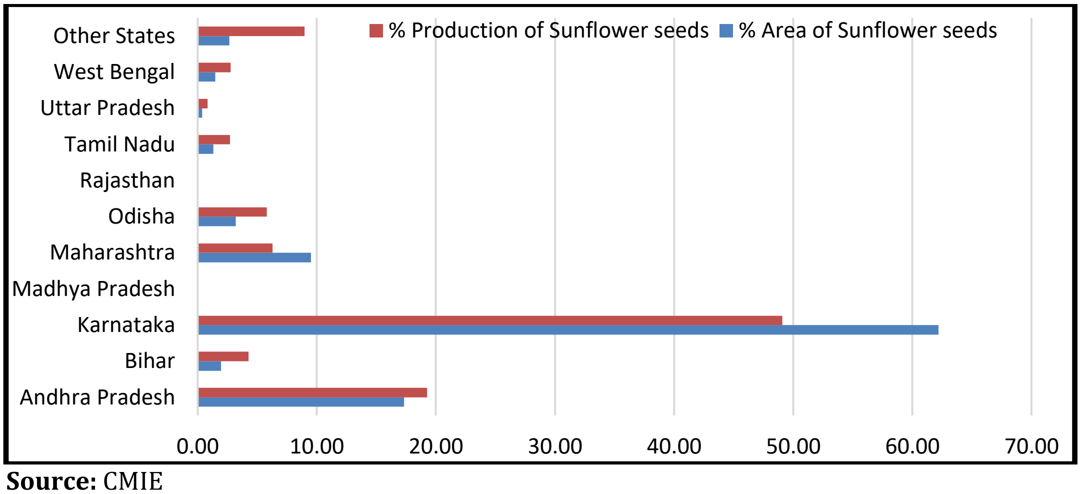
Figure 7: State-wise area and production of rapeseed & mustard crop in India in 2012-13



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 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

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 is taken from the Centre for Monitoring Indian Economy (CMIE). Sowing, growing and harvesting time of each crop is taken from 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 temperature are collected from the Indian Meteorological Department (GoI). These data are available on daily intervals with latitude and longitude information of specified monitoring stations. The stations pertaining to the specific latitude and longitude information of cities are identified due to absence of city-wise data of 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 Geographical Information System statistical database. Aforementioned 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 the few missing values (Kumar et al., 2015a; Kumar et al., 2017; Singh and Issac, 2018; Singh and Jyoti, 2019).

Econometric Modeling

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 and Sharma (2013), Kumar and Sharma (2014), Kumar et al. (2015a), Kumar et al. (2016), Singh et al. (2017), Singh and Sharma, 2018b; Singh et al. (2019), Singh and 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 an individual crop 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 is considered as an independent variable. For this, the proposed empirical model is used as:

$$\log(lampro)_{st} = B_0 + B_1(year)_{st} + B_2\log(amaxtemtcs)_{st} + B_3\log(amintemcs)_{st} + B_4\log(aprecs)_{st} + B_5\log(arfcs)_{st} + B_6\log(lat * as)_{st} + B_7\log(lon * as)_{st} + U_{st} \quad (1)$$

Here, the *log* is the 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 of 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 (Kumar et al., 2015a; Kumar et al., 2015b; Singh and Sharma, 2018b). s is cross-sectional states; t is time period; and β_0 is constant coefficient, β_1, β_2,.., β_7 are the regression coefficient 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.

Selection of Proper Model

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

Marginal Impact Analysis Technique

The marginal impact analysis technique is useful to examine the contribution of each input in crop yield (Coster and Adeoti, 2015; Singh et al., 2017; Singh, 2017; Singh and Sharma, 2018b). It also examines the percentage change in output due to the marginal change in various inputs in production activities. In this study, therefore 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 and Sharma, 2018b). The projected yield of the crop is estimated as:

$$[\Delta(lanpro)] = \{\beta 1[\delta(lanpro)/\delta(year)] + \beta 2\ [\delta(lanpro)/\delta(amaxtemtcs)]\ + \beta 3\ [\delta(lanpro)/\delta(amintemcs)]\ + \beta 4\ [\delta(lanpro)/\delta(aprecs)]\ + \beta 5\ [\delta(lanpro)/\delta(arfcs)]\ + \beta 6\ [\delta(lanpro)/\delta(lat*as)]\ + \beta 7\ [\delta(lanpro)/\delta(lon*as)]\} * 100 \qquad (2)$$

Here, *Δ*(*lanpro*) is change 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 state-wise panel.

DESCRIPTIVE RESULTS

Potato Yield and Climatic Factors: The fluctuation on potato yield and climatic factors during 1971–2013 is presented in Figure 9. The correlation coefficients of potato with climatic and geographical variables 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 yield of potato crop. Thus, it shows that climatic and geographical factors are significantly associated with productivity of potato.

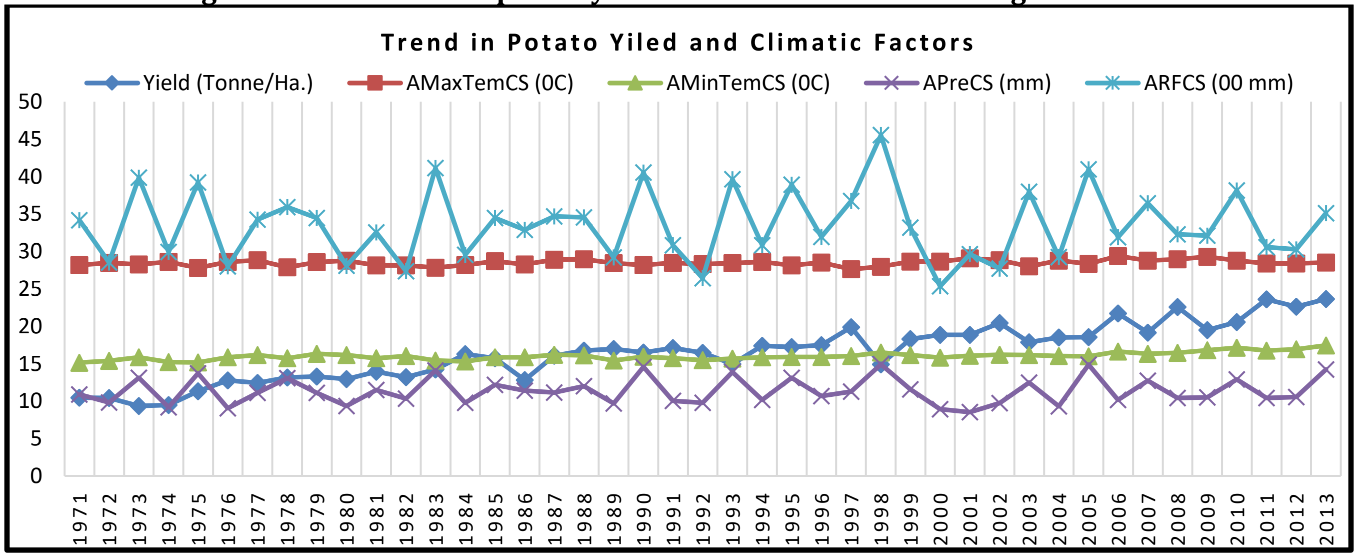
Cotton Yield and Climatic Factors: The trend in productivity of cotton yield and climatic factors are presented in Figure 10. The correlation coefficients cotton yield with climatic and non-climatic factors is presented in Table 3. It is found that cotton yield is negatively correlated with minimum temperature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

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% level respectively

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



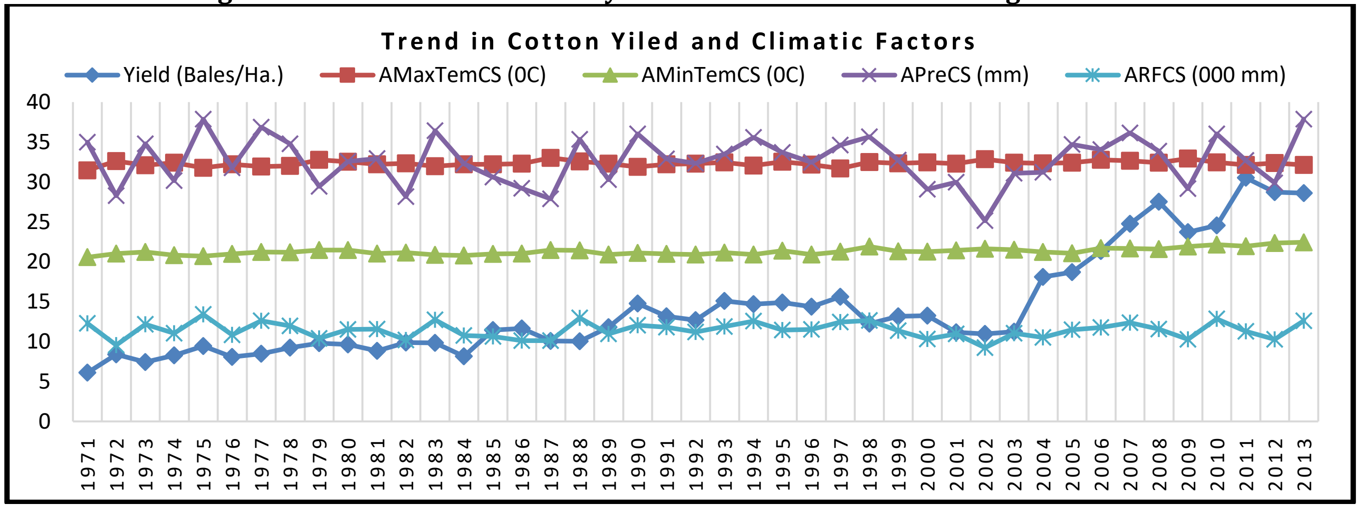
Source: Author's estimation

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% level respectively

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



Source: Author's estimation

Groundnut Yield and Climatic Factors: The trend in groundnut yield and climatic factors are presented in Figure 11. It demonstrates that 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.

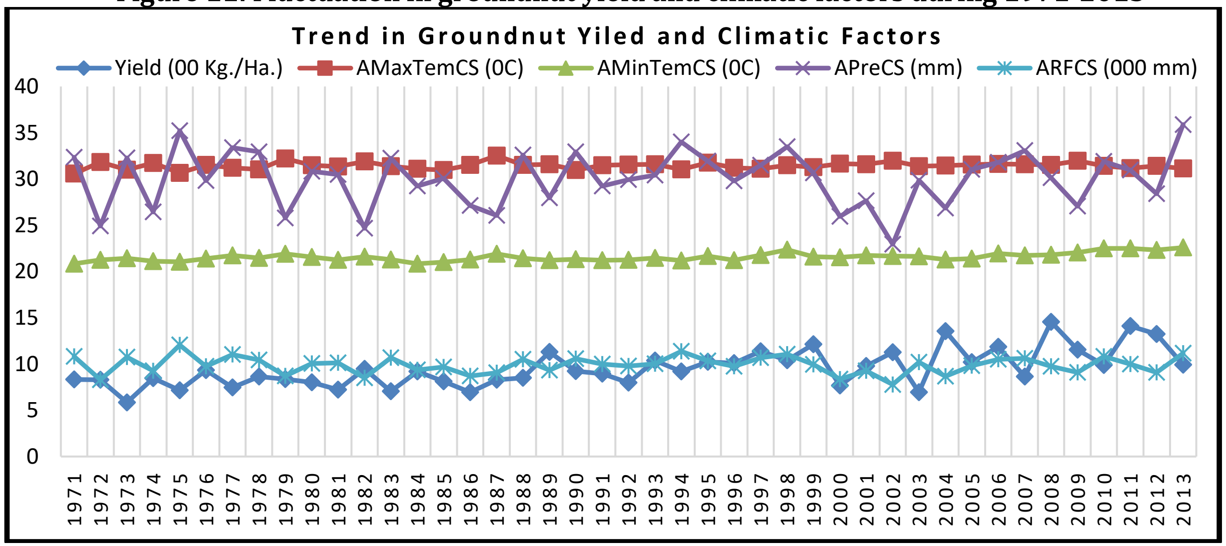
Sesame Yield and Climatic Factors: The trend in sesame yield and climatic factors is presented in Figure 12. It shows that sesame yield is fluctuated due to variability in climatic factors. Correlation coefficient of sesame yield is positively associated with minimum temperature (*r*= 0.182**), precipitation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

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

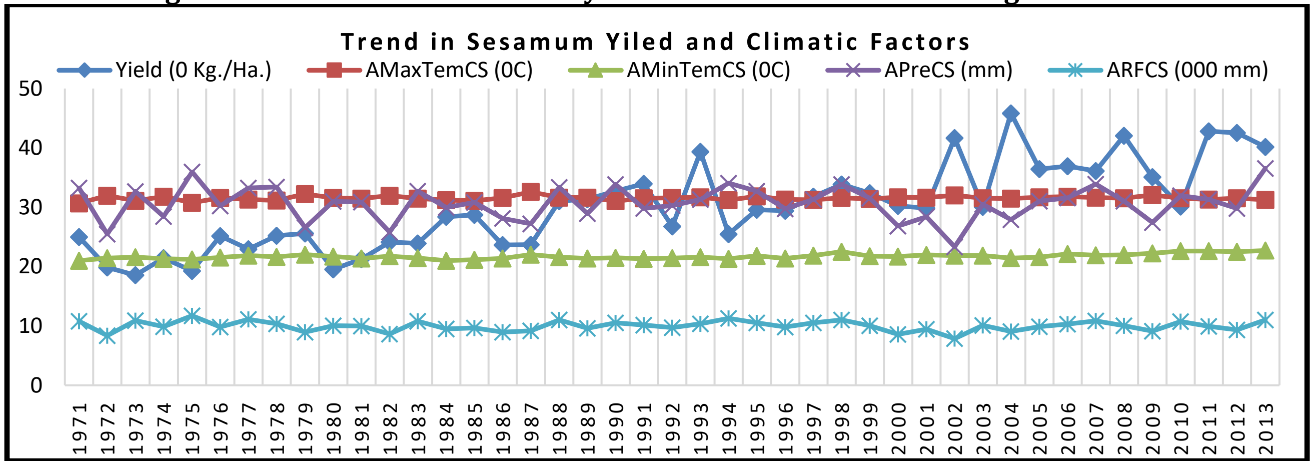
Note: ** and * imply that correlation coefficients are statistically significant at 1% and 5% level respectively

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



Source: Author’s estimation

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% level respectively

The trend in linseed yield and climatic factors is presented in Figure 13. It indicates that 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 be declined as increase in aforementioned climatic factors and more cropped area under latitude and longitude.

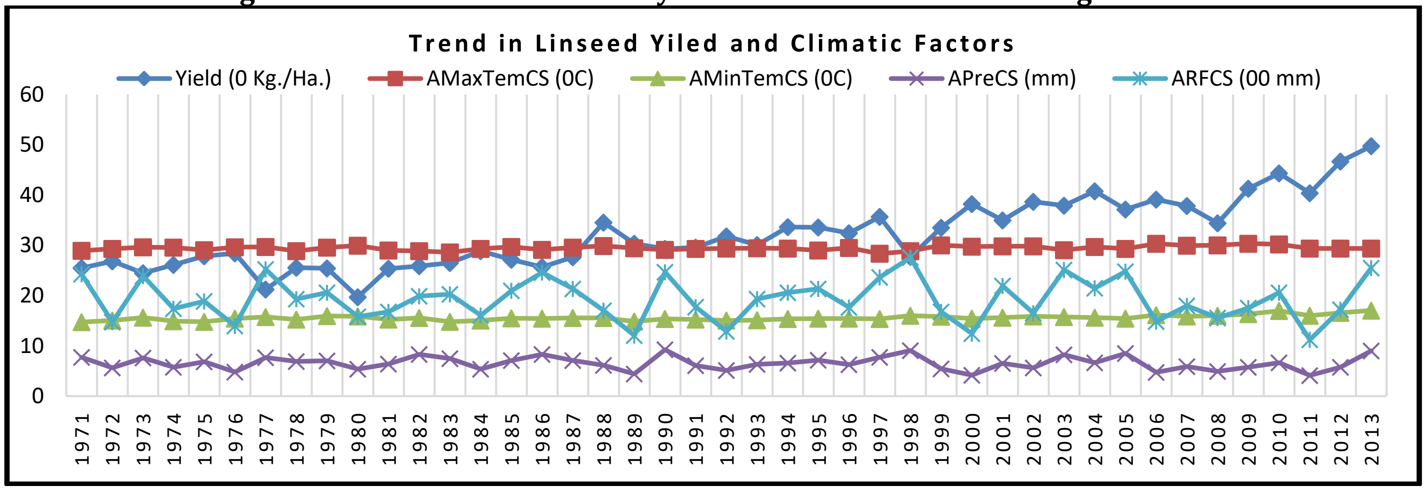
The trend in sugarcane yield and climatic factors is presented in Figure 14. It infers that sugarcane yield is varied as change in climatic variables. The correlation coefficients of maximum temperature (*r*= 0.051), minimum temperature (*r*= 0.123**), precipitation (*r*= 0.359**) and actual rainfall (*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 crop.

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% level respectively

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



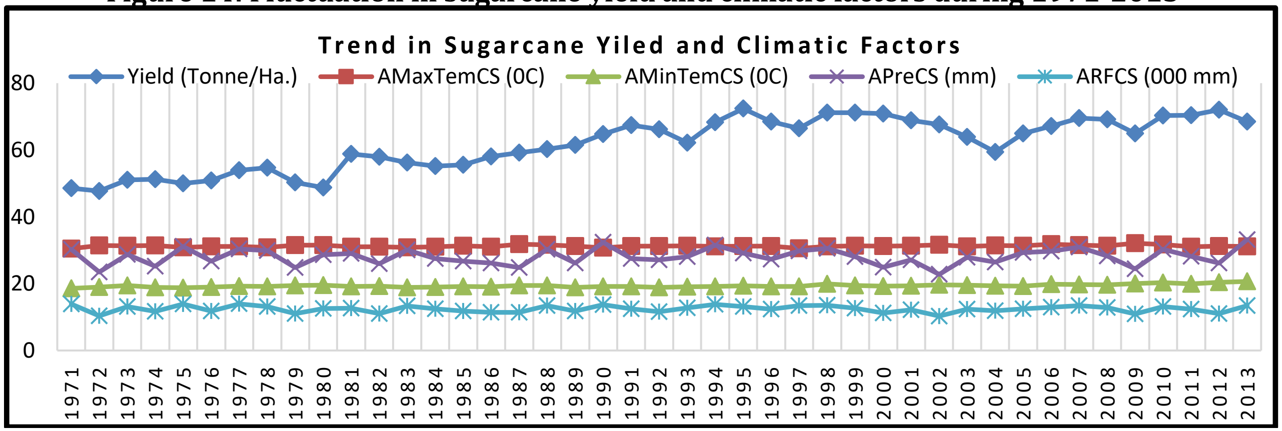
Source: Author's estimation

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% level respectively

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

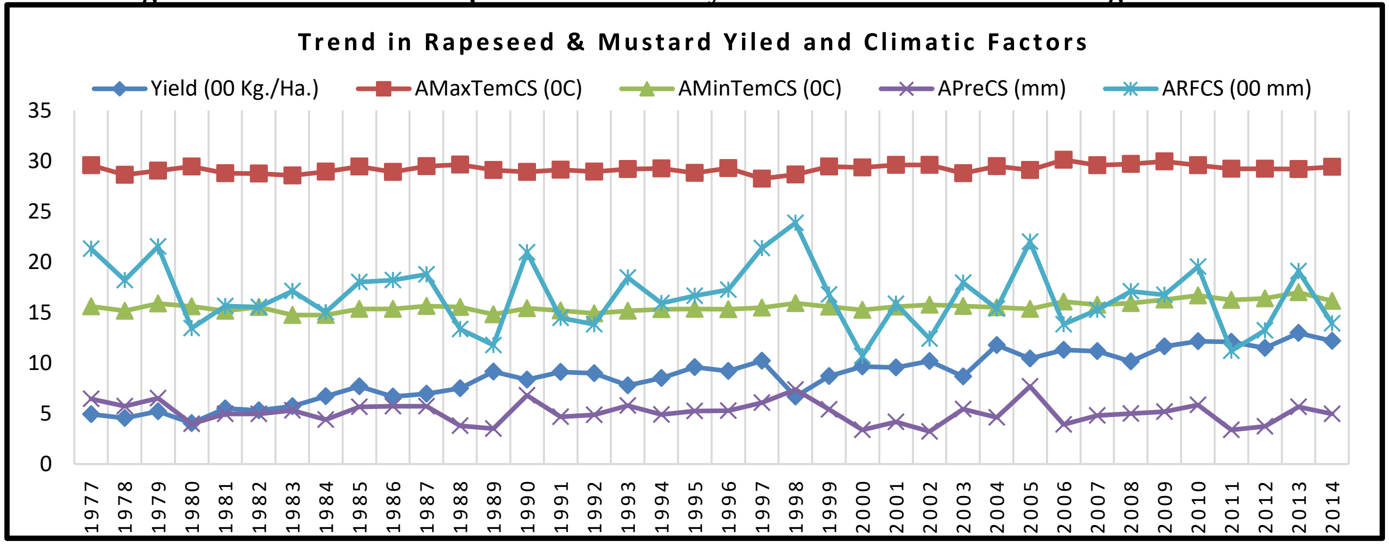


Source: Author's estimation

The trend in rapeseed & mustard yield and climatic factors is presented in Figure 15. It concludes that rapeseed & mustard yield is fluctuated as change in climatic variables during 1977-2014. The correlation coefficients of maximum temperature (*r*= 0.371**), minimum temperature (*r*= 0.375**) with productivity of rapeseed & mustard yield is appeared positive (See Table 9). While, of rapeseed & mustard yield 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.

The trend in yield of sunflower seeds and climatic factors during 1977-2014 is presented in Figure 16. It displays that 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 15: Fluctuation in rapeseed & mustard yield and climatic factors during 1977-2014



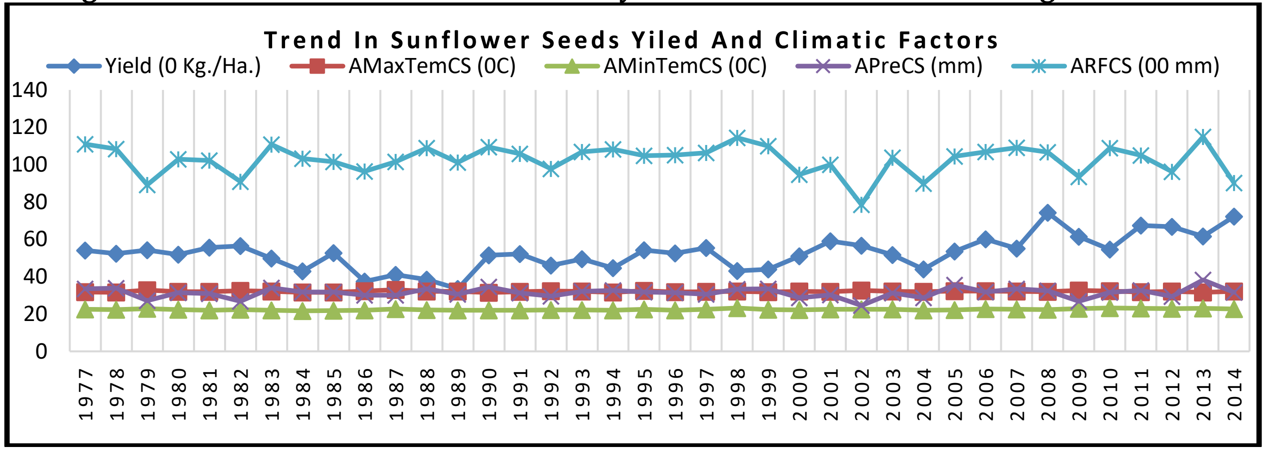
Source: Author's estimation

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% level respectively

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% level respectively

DISCUSSION ON EMPIRICAL FINDINGS

Influence of Climatic and Geographical Factors on Yield of Crops

Regression coefficients of explanatory variables with productivity of potato, cotton, sugarcane, groundnut, sesame, linseed, rapeseed & mustard and sunflower seed crops is 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 and geographical factors. Estimates also indicate that yield of rapeseed & mustard crop is highly climate sensitive as compared to other crops.

Time Trend Factor**:** Regression coefficient of time trend factor with yield of all crops is found positive. It shows that 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 and Sharma (2018b) which have also noticed positive impact of technological change on yield of crops in India.

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

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 Chi^2	531.54		303.08		21414.25		259.29	
Prob > Chi^2	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 level respectively. Values in bracket is standard error of the corresponding variables

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

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

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

Table 11: Continued.....

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 level respectively. Values in bracket is standard error of the corresponding variables

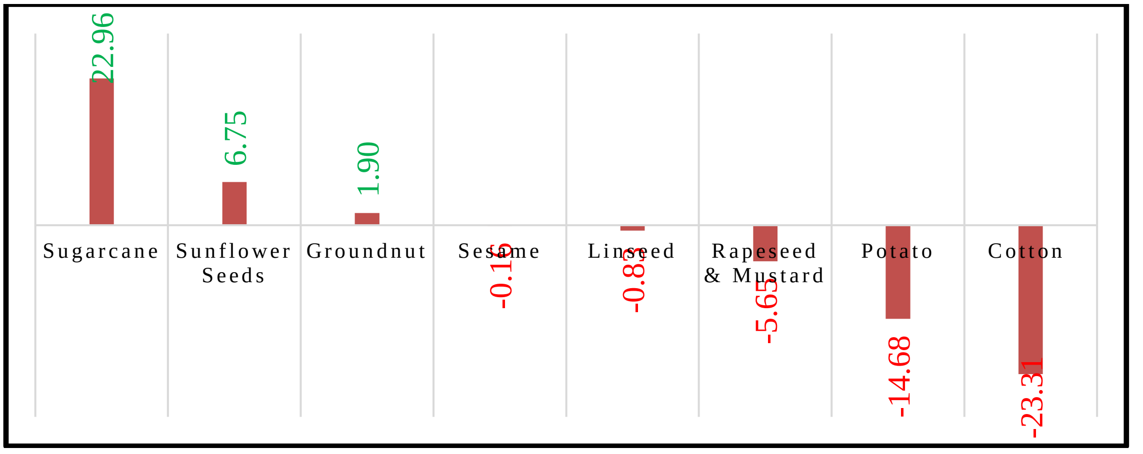
Latitude and Longitude: Regression coefficient of latitude with productivity of potato, cotton, groundnut and sugarcane crops are found negative. Estimates show that productivity of these crops will not be beneficial for those states which are located at high latitude. Longitude is showing a negative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

Expected Yield of Cash Crops

Expected yield of cash crop due to marginal increase in climatic factors is presented in Figure 17. Yield of crops are estimated using marginal impact analysis technique. Estimates demonstrate that sugarcane yield is likely to be increased by 23% on per hectare land due to 1% change in maximum and minimum temperature, actual precipitation and actual rainfall in India. However, this estimate is not similar with previous studies such as Ramachandran et al. (2017) which have noticed that sugarcane yield is predictable to be declined by the end of century due to climate change in Tamil Nadu. Kelkar et al. (2020) have also observed that sugarcane production will be declined due to climate change in Maharashtra. Productivity of sunflower seed crop is expected to be increased by 6.75% on per hectare land due to marginal change in climatic factors (i.e. average maximum temperature and minimum temperature, actual precipitation and actual rainfall) during crop season. Groundnut yield is also projected to be increased by 1.90% on per hectare land due to marginal change in undertaken climatic factors in India. This result is highly contradictory with previous study like Asha latha et al. (2012) which have observed that groundnut yield is declined by 34.09 Kg/Ha in rainfed area in Karnataka.

Productivity of sesame crop may be declined by 0.16% on per hectare land due to increase in 1^0C maximum and minimum temperature, and 1 mm actual precipitation and rainfall during crop period. Estimate is consistent with previous study such as Singh et al. (2017) which have also observed that sesame yield is likely to be declined due to marginal change in climatic factors. Productivity of linseed crop is expected to be declined by 0.83% on per hectare land due to 1% change in maximum and minimum temperature, and actual precipitation and rainfall during the crop season. Furthermore, yield of rapeseed & mustard crop may be declined by 5.65% on per hectare land due to marginal change in climatic factors. Potato yield is expected to be decreased by 14.68% on per hectare land due to marginal increase in climatic factors. Singh et al. (2017) have also reported that productivity and production of potato decline due to climate change. As cotton yield is predicted to be decreased by 23.33% on per hectare land due to marginal increase in climatic factors, thus the greater impact of climate change is appeared on cotton crop as compared to other cash crops in India. Asha latha et al. (2012) have also detected that cotton yield is likely to be decreased by 59.96 Kg/Ha in rainfed area in Karnataka. Singh et al. (2017) have also found that cotton yield decreases due to climate change in India.

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



Source: Author's estimation

CONCLUSION AND POLICY IMPLICATIONS

The main objective of this study is to assess the impact of climatic and geographical factors on yield of potato, cotton, groundnut, sesame, linseed, sugarcane, rapeseed & mustard and sunflower seeds crop in India. For this, it includes 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 of corresponding state as an explanatory variable. Cobb-Douglas production function model is used to estimate regression coefficient of explanatory variables. Accordingly, it examines the expected yields of aforementioned crops using marginal impact analysis technique. Empirical finding demonstrates that the impact of technological change on yield of all crops is seemed positive. Yield of these crops, therefore would be increased as adoption of advance technologies in cultivation. Maximum temperature has a negative impact on yield of potato, groundnut, sesame, linseed, sugarcane, rapeseed & mustards and sunflower seeds crops. In contrary, yield of all crop (excluding cotton) may be improved as increase in average minimum temperature. 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 are seemed negative. Furthermore, yield of potato, cotton, groundnut and sugarcane crops may be declined at highly latitude located states in India. Yield of sesame, linseed, rapeseed & mustard and sunflower seeds crops are possible to be declined at highly longitude located states in India. 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% on per hectare land respectively due to marginal increase in average maximum and minimum temperature, actual precipitation and rainfall during sowing time to harvesting time of corresponding crops.

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

Adoption of modern technologies such as 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 term of change in irrigation methods, use of fertilizer and pesticide, and change in planting method of seeds (Singh and Sharma, 2018b). Irrigated area is seemed as a vital factor to increase productivity of cash crops (Kumar and 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 considered (Kumar et al., 2016; Singh and 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 more possibility of climate change in near future. There also needs to provide credit facilities to farmers in India (Kumar et al., 2016; Singh et al., 2019). India needs to increase extensive expenditure on agricultural R&D (Kumar et al., 2016) and it would incentivize to researchers and scientists to discover more varieties of seeds which can tolerate the heat impact (Singh et al., 2017) and high yielding varieties of seeds (Kumar et al., 2016). Arrangement of regular training for farmers would be useful for them to increase their understanding on climate change and its impact on crop production (Kumar et al., 2016; Singh and Sharma, 2018a). Subsequently, farmers will be in a strong position to use different strategies to reduce the negative implications of climate change in cultivation.

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

REFERENCES

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

Asha latha K.V., Gopinath M. and 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.

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

Coster A.S. and 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. and 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.

Kavikumar K.S. (2009). Climate sensitivity of 61ndian agriculture do spatial effects matter? South Asian Network for Development and Environmental Economics, Working Paper, 45-09.

Kelkar S.M., Kulkarni A. and 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. and Hansen J.W. (2004). Climate impact of Indian agriculture. *International Journal of Climatology*, 24(1):1375-1393.

Kumar A. and 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. and 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. and 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. and 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., Sharma P. and 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. and 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. and 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.

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

Parry M.L., Rosenzweig C. A., Livermore M. and 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. and 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. and Palanivelu K. (2017). Spatiotemporal analysis of 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. and 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. and 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. and 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. and 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. and 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. and 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. and 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. and 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. and 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. (2017). An empirical analysis to assess the GDP projection of Gujarat State of India. *JNNCE Journal of Engineering and Management*, 1(1):51-58.

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.

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