Climate change impacts on agriculture

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ABSTRACT: *Agriculture plays a vital role in India's economy. 54.6% of the population is engaged in agriculture and allied activities and it contributes 17% to the country's Gross Value Added of agriculture. Total food grains production in India is estimated at 252.22 MTs which is marginally higher by 0.20 MTs tonnes than the 2014-2015 food grains production of 252.02 MTs. Production of pulses estimated at 16.47 MTs is lower by 0.68 MTs than their production during 2014-15. With a decline of 2.21 MTs over the last year, total production of oilseeds in the country is estimated at 25.30MTs. Agriculture production is directly dependent on global climate change and weather conditions. Climate change adversely affects the socio-economic sectors including water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health due to their vulnerability. Changes in temperature, precipitation and* CO_2 *concentration are expected to significantly impact on crop growth, which affects crop quality and productivity. Global mean temperatures have risen (0.6⁰C in the last century), with the last decade being the warmest on record, and global sea level rise is projected to be between 0.17 to 0.41m in the year 2050. IPCC expected that many of the observed changes due to climate change are unprecedented, and leads the challenges to farmers, who must produce enough food to feed a growing population expected to reach 9 billion by 2050 with a richer diet. Farmers will have to adapt their current practices to a different climate marked by extreme weather events and changing season patterns. The burgeoning population, along with human-induced climate change and environmental problems is increasingly proving to be a limiting factor for enhancing farm productivity and ensuring food security for the rural poor. Poor and vulnerable farming communities might need support to grow their incomes while also being resilient to an uncertain future. Climate change has about 4-9 % impact on agriculture each year, and climate change presumably causes about 1.5 % loss in GDP also. Climate change may have contributed to the suicides of nearly 60,000 Indian farmers and farmworkers over the past three decades, according to new research that examines the toll rising temperatures are already taking on vulnerable societies. Adaptive trials are to be taken in a timely fashion, both at the farmers and policymakers' level to enable the farmers to survive with the adversities of climate change. Improved agronomic strategies such as reforming plant types, changing cropping model/pattern, nutrient, water and watershed management, conservation agriculture, seed bank etc. are some of the innovative option to address climate-change issues in agricultural crops.*

Key Words: *Climate Change, Agriculture*

Introduction:

Agriculture represents a core part of the Indian economy and provides food and livelihood activities to much of the Indian population. In India, almost 70% of the population depends on agriculture for their livelihood. 23% of India's Gross National Product (GNP) representing agriculture sector alone, which plays a major role in the country's development and shall continue to hold an important place in the national economy (Khan *et al.*, 2009).Rising global temperature is not only causing climate change but also contributing to the irregular rainfall patterns. Uneven rainfall patterns, increased temperature, elevated CO_2 content in the atmosphere are important climatic parameters which affects the crop production and quality. Research studies indicate that weathering parameters influence strongly (67%) compared to other factors like soil and nutrient management (33%) during the cropping season. The Intergovernmental Panel on Climate Change (IPCC) projected that the global mean surface temperature will likely rise and may result into uneven climatic changes. It has been reported over 20th century that rising temperature plays an important role towards global warming as compared to precipitation. Researchers have confirmed that crop yield falls by 3% to 5% for every 1°F increase in the temperature. Further, it is predicted that the global mean surface temperature will likely be in the range of 0.3-0.7°C for the period 2016-2035 (IPCC, 2014). Hence, global warming can be considered as the major affecting parameter in changing the earth's climate.

Agriculture Matters-An Irony:

India is home to 16% of the world population, but only 4% of the world water resources. Agriculture is directly dependent on climate, since temperature, sunlight and water are the main drivers of crop growth.

While some aspects of climate change such as longer growing season and warmer temperatures may bring benefits in crop growth and yield, there will also be a range of adverse impacts due to reduced water availability and more frequent extreme weather conditions.The bounty of Indian agriculture idealized in that famous Manoj Kumar song—which also underlies the Prime Minister's goal of doubling farmers' incomes—increasingly runs up against the contemporary realities of Indian agriculture, and the harsher prospects of its vulnerability to long-term climate change. First, and foremost, agriculture matters in India for deep reasons, not least because the farmer holds a special place in Indian hearts and minds. The first salvo of Satyagraha was fired by Mahatma Gandhi on behalf of farmers, the indigo farmers exploited by colonial rule. Not unlike in early, Jeffersonian America (Hofstadter, 1955), history and literature have contributed to the farmer acquiring mythic status in Indian lore: innocent, unsullied, hard-working, in harmony with nature; and yet poor, vulnerable, and the victim, first of the imperial masters and then of indigenous landlords and middlemen. Film Industries has also played a key role in creating and reinforcing the mythology of the Indian farmer since ancient times in movies i.e. Mother India, Do Beegha Zameen, Upkaar, Lagaan, and Peepli Live (Economic Survey, 2017-18).In India, there is a need to understand the availability of water in terms of increase in population growth. A decline has been projected in mean per capita annual freshwater availability and growth of population from 1951 to 2050 (Mall *et al.,* 2005).
Indian agriculture consumes about 80-85% of the nation's available water. The quantity of water required for agriculture has increased progressively through the years as more and more areas were brought under irrigation. These impacts may put agricultural activities at significant risk. Climate change has already caused significant damage to our present crop profile and threatens to bring even more serious consequences in the future (Kumar and Gautam2014). Wheat yields are predicted to fall by 5-10% with every increase of 1°C and overall crop yields could decrease up to 30% in South Asia by the mid-21st century (IPCC, 2001). India could experience a 40% decline in agricultural productivity by the 2080s. Rise in temperatures will affect wheat growing regions, placing hundreds of millions of people at the brink of chronic hunger (IPCC, 2007).Tropical countries are likely to be affected more compared to the countries situated in temperate regions (Gondali and Bose, 2018).

Global Scenario:
Climate change is very likely to affect food security (food availability, reduce access to food, and affect food quality)at the global, regional, and local level.For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Increasing temperatures can contribute to spoilage and contamination. Internationally, these effects of climate change on agriculture and food supply are likely to be similar to those seen in the United States. However, other stressors such as population growth may magnify the effects of climate change on food security. In developing countries, adaptation options like changes in crop management or ranching practices, or improvements to irrigation are more limited than in the United States and other industrialized nations.Any climate-related disturbance to food distribution and transport, internationally or domestically, may have significant impacts not only on safety and quality but also on food access. For example, the food transportation system in the US frequently moves large volumes of grain by water. In the case of an extreme weather event affecting a waterway, there are few, if any, alternate pathways for transport.
Global sea level rise is projected to be between 0.17-0.41 m in the year 2050 (Brown *et al.,* 2015). It is observed that the rate of rising sea level has been larger than the mean rate during the previous two millennia, till the mid-19th century (Kemp *et al.,* 2011). IPCC reported that changes in precipitation will be non-uniform and its extreme events over most of the mid-latitude and wet tropical regions will become more intense and frequent (Kitoh *et al.,* 2016). Kundzewicz *et al.,*(2015) reported that the increasing trends in extreme precipitation lead to imply greater risks of flooding at regional scale.IPCC report states that the amount and rate of warming expected for the 21st century depends on the total amount of greenhouse gases that mankind emit.Climate change may increase or decrease the crop yield depending on the latitude of the area and irrigation application. Increasing temperature and varying precipitation may decrease the crop productivity in future (Shah and Srivastava, 2017).
Indian Scenario:
Like other countries, India has also started experiencing extreme weather events which lead to change the climate. The country's geographical dynamics and the presence of high level of poor and food insecure population add to its vulnerability to climate change. India is home to about 24.5% of the undernourished people in the world (Kaur and Kaur, 2017). In India, it is observed that the annual mean temperature has

increased at the rate of 0.42°C (Arora *et al.,* 2009). Indian agriculture system is based upon south-west and north-east monsoon. Almost 80% of the total precipitation comes from south-west monsoon in India. Any fluctuations and uncertainties in long range rainfall pattern may affect the agriculture sector and also lead to increase the frequency of droughts and floods at regional scale (Jain and Kumar, 2012). Several climatic factors which affect agriculture productivity are heat waves, high temperature (Van der Velde *et al.,* 2012), heavy and prolonged precipitation (Pathak *et al.,* 2013) and excess cold. These factors have positive as well as negative effects on crop production. Varied nature of such weather events tends to affect the crop growth cycle and plant physiological processes (Mahdi *et al.,* 2015).Studies predicted that changing trends in temperature and precipitation will continue to have significant impact on agriculture (Neenu *et al.,* 2013). A small rise in temperature (1-2°C), especially in the seasonally dry tropical regions (IPCC, 2007) would decrease crop yield (Lakshmikumar, 2012; Mahato, 2014).Indian agriculture is divided into two main seasons: Kharif and Rabi based on the monsoon. It is reported that overall temperature rise is likely to be much higher during winter (rabi) rather than in rainy season (kharif) reported by Aggarwal *et al.,*(2010). Moreover, it is predicted that the mean temperature in India will rise by 0.4-2.0°C in Kharif and 1.1-4.5°C in Rabi by 2070 (Khan *et al.,* 2009) Decline in agricultural productivity leads to increase food prices at state as well as at country level (Udmale *et al.,* 2014). Hence, temperature could be one of the significant affecting factor which results into greater instability in agriculture of India (Shah and Srivastava, 2017).
A significant increasing trend in rainfall was reported along the west coast, north Andhra Pradesh and North West India, and while significant decreasing trend was observed over parts of Gujarat, Madhya Pradesh and adjoining area, Kerala and northeast India (Jagannathan *et al.,*1973: Koteswaram *et al.,* 1969). North western region of India gets affected by western disturbances at small scale as such disturbances have impact only on rabi production (Chand *et al.,* 2015) only for not more than 20-30 days. Not only monsoon, but temperature has also shown its effect on agriculture. Extreme maximum and minimum temperature showed an increasing trend in the southern part whereas decreasing trend in the northern part of India (Jain and Kumar, 2012).Research studies show that with the increase in temperature, crop productivity is likely to decrease in future (Kang *et al.,* 2009). Hence, there is a need to study the dependency of temperature on crop productivity, stability, yield and quality to uplift the country’s economy.

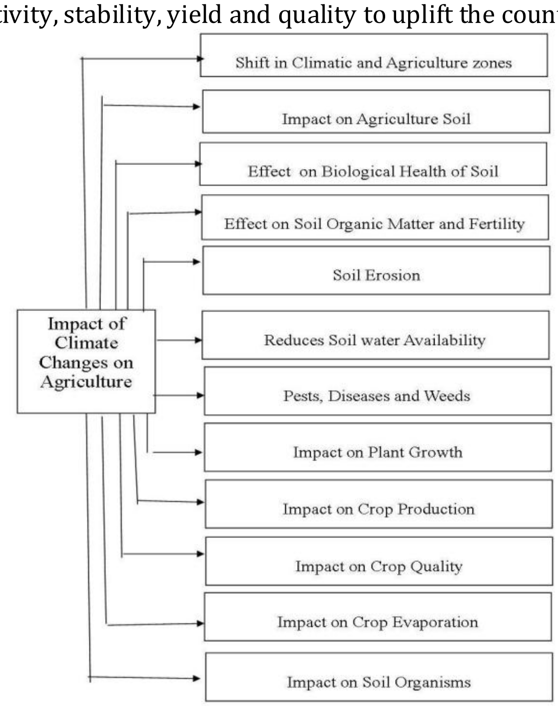


Fig. 1 Impact of Climate change on Agricultural Parameters

Crop Production Scenario in the year of 2016-17:

As per the Fourth Advance Estimates for 2016-17, production of rice is estimated at a new record of 110MTs (Million Tonnes). Rice production is 3.50 MTs higher than the previous record production of 106.65 MTs achieved during 2013-14 and has increased significantly by 5.74 MTs than the production of 104.41 MTs during 2015-16. Production of wheat during 2016-17 is also estimated at a record level of 98.38 MTs. The wheat production is higher by 2.53 MTs than the previous record production of 95.85 MTs during 2013-14. The wheat production is higher by 6.10 MTs as compared to the wheat production of 92.29 MTs in 2015-16.

Further, production of coarse cereals is estimated at a new record level of 44.19 MTs, which is higher than the previous record production of 43.40 MTs achieved during 2010-11 by 0.79 MTs and also higher by 5.67 MTs as compared to the production of 38.52 MTs achieved during 2015-16.As a result of significant increases in the area coverage and productivity of all major pulses, total production of pulses during 2016-17 is estimated at a record level of 22.95 MTs. The production during 2016-17 is higher by 6.61 MTs than the previous year's production of 16.35 MTs. Total food grain production during 2016-17 in the country is estimated at 275.68 MTs which is higher by 10.64 MTs than the previous record production of food grain of 265.04 MTs (2013-14) and also higher by 24.12 MTs than the foodgrain production in 2015-16.Total oilseeds production in the country in 2016-17 is estimated at 32.10 MTs which is higher by 6.85 MTs over the production achieved during 2015-16. Data related to other crops like Sugarcane, Cotton, Jute and Mesta is also given in table 1.

Table 1: Area, Production and Yield of Major Crops

Crops	Area (Lakh Hectare)			Production (Million Tonns)			Yield (Kg/ha)		
	2014-15	2015-16	2016-17*	2014-15	2015-16	2016-17*	2014-15	2015-16	2016-17*
Rice	441.1	434.99	431.94	105.48	104.41	110.15	2391	2400	2550
Wheat	314.65	304.18	305.97	86.53	92.29	98.38	2750	3034	3216
Coarse cereals	251.7	243.89	247.71	42.86	38.52	44.19	1703	1579	1784
Pulses	235.54	249.12	294.65	17.15	16.35	22.95	728	656	779
Food grains	1243	1232.18	1280.26	252.02	251.57	275.68	2028	2042	2153
Oil seeds	255.96	260.87	262.06	27.51	25.25	32.1	1075	968	1225
Sugarcane	50.66	49.27	43.89	362.33	348.45	306.72	71512	70720	69886
Cotton@	128.19	122.92	108.45	34.8	30.01	33.09	462	415	519
Jute and Mesta#	8.1	7.82	7.66	11.13	10.52	10.6	2473	2421	2490

(* 4th Advance Estimates@ Production in Million bales of 170 kg each#Production in Million bales of 180 kg each) Source: Annual Report (2017-18)

Production Scenario of Kharif during 2017-18 (as per the First Advance Estimate)

The comparative position of production of food grains, oilseeds, sugarcane and cotton during kharif 2017-18 vis-à-vis kharif 2016-17 is given in table 2.

Table 2:Production Scenario during Kharif 2017-18

Crops	2016-17	2017-18	Absolute Difference	Percentage Increase/ decrease
	4th Advance Estimates	1st Advance Estimates	2017-18 over 2016-17	2017-18 over 2016-17
Food grains	138.52	134.67	-3.86	-2.79
Oil seeds	22.4	20.68	-1.72	-7.68
Sugarcane	306.72	337.69	30.97	10.1
Cotton@	33.09	32.27	-0.82	-2.48
Jute*	10.09	9.83	-0.26	-2.6
Mesta*	0.51	0.5	-0.02	-3.35

@ Production in Million bales of 170 kg each* Production in Million bales of 180 kg each
Source:Annual Report (2017-18)

As per the First Advance Estimates, total production of Kharif foodgrains during 2017-18 is estimated at 134.67 MTs. This is lower by 3.86 MTs as compared tolast year's record kharif food grain production of 138.52 MTs (4th Advance Estimates). Total production of Kharif rice is estimated at 94.48 MTs. This is lower by 1.91 MTs than the last year's record production of 96.39 MTs. Production of maize is expected to be 18.73 MTs which is marginally lower by 0.52 MTs than that of last year's record production. The total production of coarse cereals in the country has decreased to 31.49 MTs as compared to 32.71 million tonnes during 2016-17 (4th Advance Estimates). The total production of kharif pulses is estimated at 8.71 million tonnes which is lower by 0.72 MTs than the last year's record production of 9.42 MTs. However, Kharif pulses estimated production is 2.86 MTs more than the last five years average production.The total production of Kharif oilseeds in the country is estimated at 20.68 MTs as compared to 22.40 MTs during 2016-17, i.e., a decrease of 1.72 MTs. Production of sugarcane is estimated at 337.69 MTs which is higher by 30.97 MTs than the last year's production of 306.72 MTs. Despite higher area coverage, lower productivity of cotton is estimated to have reduced to a level of production of 32.27 million bales (of 170 kg each) as compared to 33.09 million bales during 2016-17. Table 3 shows the total production of food grains (Kharif and Rabi) since 2008-09 to 2017-18.

Table 3: Production of Total Food Grains (Kharif and Rabi) since 2008-09 to 2017-18

Season	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17 4th Advance Est.	2017-18 (Target)	2017-18 1st Advance Est.
Kharif	118.14	103.95	120.85	131.27	128.07	128.69	128.06	125.09	138.52	137	134.67
Rabi	116.33	114.15	123.64	128.01	129.06	136.35	123.96	126.47	137.16	137.55	
Total	234.47	218.11	244.49	259.29	257.13	265.04	252.02	251.57	275.68	274.55	134.67

Source: Annual Report (2017-18)

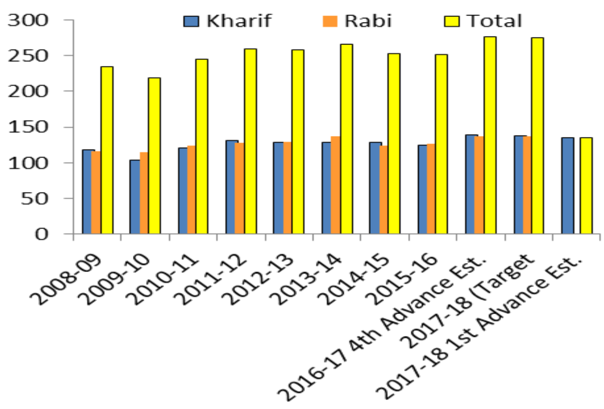
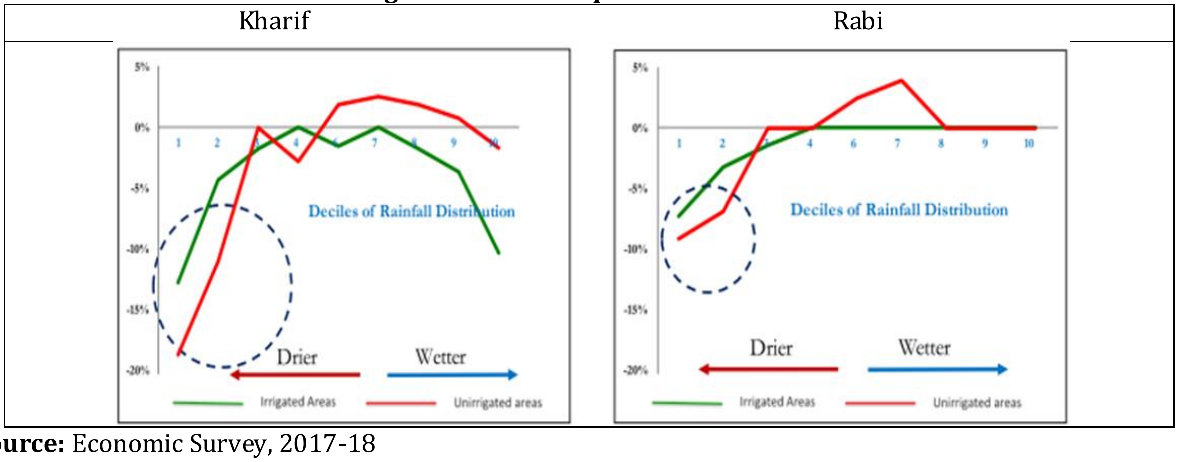


Fig. 2: Production of Total Food Grains (Kharif and Rabi) since 2008-09

Impact of Weather on Agricultural Productivity:

In Figures 3 and 4, the X-axis depicts deciles of temperature and rainfall, with the 5th decile being the middle category (normal temperature and rainfall) against which all comparisons are made. So, consider the left panel of Figure 3. If temperature was in the 10th decile of the temperature distribution (hottest possible), kharif yields in unirrigated areas (the red line) would be 10% lower than if temperature was normal (5th decile). Similarly, the left panel of Figure 4 shows that if rainfall were in1st decile (cases of drought and drought-like conditions), kharif yields would be 18% lower in unirrigated areas than if rainfall was normal (5th decile).

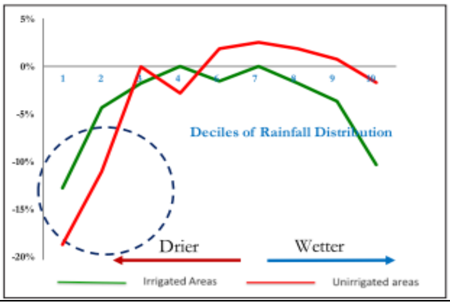
Fig 3: Effect of Temperature on Yields



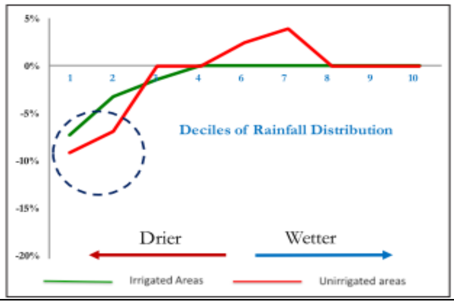
Source: Economic Survey, 2017-18

Fig 4: Effect of Rainfall on Yields

Kharif



Rabi



Source: Economic Survey, 2017-18

A detailed quantitative break-up of the effects of temperature and rainfall shocks between irrigated and unirrigated areas in the kharif and rabi seasons (Table 4). Using the insights gained from figures 3 and 4, the quantitative impact of extreme shocks on yields and revenues is estimated. Extreme temperature shocks, when a district is significantly hotter than usual (in the top 20 percentiles of the district-specific temperature distribution), results in a 4% decline in agricultural yields during the kharif season and a 4.7% decline in rabi yields.Similarly, extreme rainfall shocks, when it rains significantly less than usual (bottom 20 percentiles of the district-specific rainfall distribution). The result is a 12.8% decline in kharif yields, and a smaller, but not insignificant decline of 6.7% in Rabi yields.

Table 4: Impact of weather Shocks on Agricultural Yields

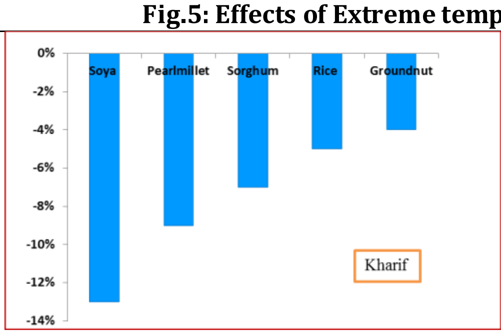
(Percentage declines in response to temperature increase and rainfall decreases)

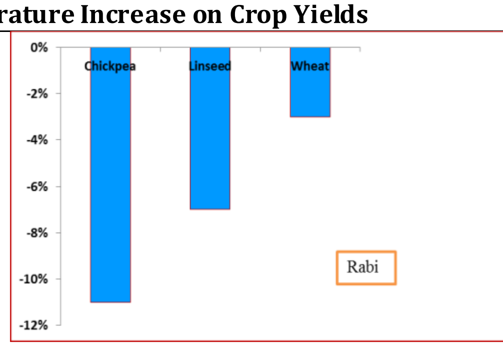
	Extreme Temperature Shocks	Extreme Rainfall Shocks
Average Kharif	4.0%	12.8%
Kharif, Irrigated	2.7%	6.2%
Kharif, Unirrigated	7.0%	14.7%
Average Rabi	4.7%	6.7%
Rabi, Irrigated	3.0%	4.1%
Rabi, Unirrigated	7.6%	8.6%

Source: Economic Survey, 2017-18

Unirrigated areas (where less than 50% of cropped area is irrigated) bear the brunt of the vagaries of weather. For example, an extreme temperature shock in unirrigated areas reduces yields by 7% for kharif and 7.6% for Rabi. Similarly, the effects of extreme rainfall shocks are 14.7% and 8.6% (for Kharif and Rabi, respectively) in unirrigated areas, much larger than the effects these shocks have in irrigated districts.The effects of extreme temperature and rainfall shocks on the yields of individual crops (Fig, 5 and 6). The clear pattern that emerges is that crops grown in rainfed areaspulses in both Kharif and Rabi, are vulnerable to weather shocks while the cereals both rice and wheatare relatively more immune.The impact of rainfall shocks in yields remains unchanged, but the effect of temperature shock increases threefold (relative to the first decade). However, since there is no secular trend in this impact, it cannot be ascertained whether the findings for the last decade are a one–off, or the start of a new long run trend with dramatically adverse consequences for Indian agriculture.

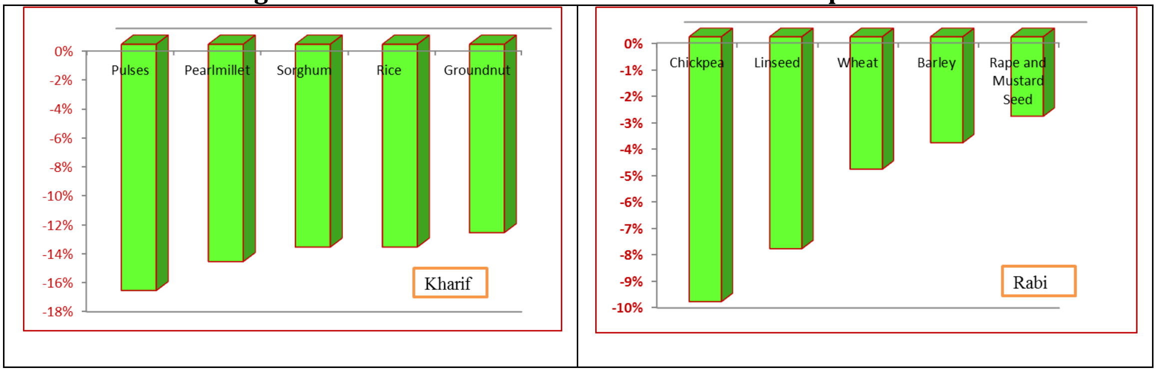
Fig.5: Effects of Extreme temperature Increase on Crop Yields





Source: Economic Survey, 2017-18

Fig.6: Effects of Extreme Rainfall Decrease on Crop Yields



Source: Economic Survey, 2017-18

Economic Survey and Impact on Farm Revenue:

The Economic Survey highlighted the impact of Climate Change on agricultural incomes. The survey said that extreme weather patterns can impact farm incomes in the range of 15% to 18% on average, and up to 20 to 25% for unirrigated areas. The survey says that the goal of doubling farmer's income by 2022 could face problems on account of the "contemporary realities of Indian agriculture, and the harsher prospects of its vulnerability to long-term climate change". The survey brings out two key findings such as (a) the impact of temperature and rainfall is felt only in the extreme; that is, when temperatures are much higher, rainfall significantly lower, and the number of "dry days" greater, than normal. (b) these impacts are significantly more adverse in unirrigated areas (and hence rainfed crops) compared to irrigated areas (and hence cereals).The impact of extreme shocks affects the farmer incomes, which is measured by the value of production.Extreme temperature shocks reduce farmer incomes by 4.3% and 4.1% during kharif and rabi respectively, whereas extreme rainfall shocks reduce incomes by 13.7% and 5.5% (Table 5). The results here clearly indicate that the "supply shock" dominates the reductions in yields lead to reduced revenues.

Table 5: Impact of weather Shocks on Farm Revenue

	Extreme Temperature Shocks	Extreme Rainfall Shocks
Average Kharif	4.30%	13.70%
Kharif, Irrigated	7.00%	7.00%
Kharif, Unirrigated	5.10%	14.30%
Average Rabi	4.10%	5.50%
Rabi, Irrigated	3.20%	4.00%
Rabi, Unirrigated	5.90%	6.60%

Source: Economic Survey, 2017-18

Agriculture also matters for economic reasons because it still accounts for a substantial part of GDP (16%) and employment (49%). Poor agricultural performance can lead to inflation, farmer distress and unrest, and larger political and social disaffection, all of which can hold back the economy. The Nobel Prize winner, Sir Arthur Lewis (among others), argued that economic development is always and everywhere about getting people out of agriculture and of agriculture becoming over time a less important part of the economy (not in absolute terms but as a share of GDP and employment). So the irony is that the concern about farmers and agriculture today is to ensure that tomorrow there are fewer farmers and farms but more productive ones. In other words, all good and successful economic and social development is about facilitating this transition in the context of a prosperous agriculture and of rising productivity in agriculture because that will also facilitate good urbanization and rising productivity in other sectors of the economy.

Conclusion:

Global climate change is not a new phenomenon. Climate is the primary determinant of agricultural productivity which directly impact on food production across the globe.Agriculture sector is the most prone sector as it will have a direct bearing on the living of 1.2 billion people. India has set a target of halving greenhouse gas emissions by 2050. There is an urgent need for coordinated efforts to strengthen the research to assess the impact of climate change on agriculture, forests, animal husbandry, aquatic life and other living beings.Increase in the mean seasonal temperature can reduce the duration of many crops and

hence reduce final yield. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases thereby reducing harvest ultimately affecting the food security of the country. The World Bank report warned that by the 2040s, India would see a significant reduction in crop yields because of extreme heat.
In the recent past, the number of studies for assessing its impact on agriculture has increased. Crop growth models have been modified and tested for various important crops under different climate change scenarios. But most of the results happen to be region specific and with certain assumptions. Identification of suitable agronomic management practices can be a potential solution to optimize agricultural production in the changed climate.Crop simulation technique offers an opportunity to link the climate change with the other socio-economic and bio-physical aspects. Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impact of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels to initiate the more agricultural policy and scientific researches.

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