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Climate Change Impact on Agriculture Globally and in India: A Case Study

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Abstract: ***Agriculture was discovered by humans a little over 10,000 years ago. With the help of agriculture, humans achieved subsistence, established trade relations, and a new economic system. The high intensity and workforce-intensive agriculture provided the base for the 'Industrial Revolution' in the 17th century which led to the prosperity of the society and transformed the society economically. But industrial revolution gave rise to the problem of 'Global warming'. The burning of fossil fuels, deforestation to set up industries added to the concentration of carbon dioxide, and greenhouse gas emissions which led to global warming which is just one aspect of a major problem- Climate change. Climate change has been the grim reality to which the world woke up in the last decade which proved to be the hottest decade. It is affecting human health, world economies, animal and marine lives adversely. But the worst affected sector from climate change is agriculture, which gave the base for the industrial revolution and ultimately which became the reason for climate change. Agriculture remains most vulnerable to climate change due to its size and sensitivity. Impact of climate change like warming conditions changed weather, and rainfall patterns are affecting the productivity and quality of the crops. Reduced productivity is giving rise to the problem of food insecurity while reduced quality is giving rise to the problem of increased incidences of malnutrition or undernutrition. In this case study discussion, we would analyze the impact of climate change on agriculture at three levels- global, continental, and national concerning India, the steps that were undertaken by the global leaders to mitigate the impact of climate change on agriculture and thereby study the scope of technology in mitigating the effects of climate change on agriculture.***
Keywords: Climate Change, Global Warming, Agriculture, Industrial Revolution, Technology.

I. INTRODUCTION

The decade (of 2010-2019) gone by has been recorded as the hottest decade in the last one and a half centuries of record keeping. 2019 is the second hottest year to be recorded ever. The average global temperature in 2019 was 0.98°C more than the average global temperature in the 1900s. There has been a rapid increase in the warming of the earth's surface in the past 30 years of which, 10 warmest years have occurred since 1998. Surprisingly, 9 out of these warmest 10 years have occurred since 2005. Human activities like the burning of fossil fuels and deforestation are making it worse and thereby increasing the concentration of greenhouse gases in the atmosphere which are the main drivers behind the continuous warming of the earth's surface or as we call it - global warming.

The effect of global warming has been more visible since the 20th century. Warmer conditions are resulting in the melting of polar ice caps and a rise in sea level leading to flooding of the coastal areas. Interestingly, global warming is just one aspect of a major phenomenon- Climate Change, which is affecting the planet on a larger scale.

Climate change has been the grim reality which the world is facing today. It is the process of shift in general weather, temperature, and rainfall patterns over several decades and has a significant negative impact on agriculture, water bodies, animal habitat, and even human health. It has threatened the life of several species whose survival is dependent on colder climate. The impacts of climate change are visible to the world and the impact has been comparatively severe on Antarctica. It has been one of the fastest-warming places on earth and this has resulted in the growth of green algae which is turning the snow green. The increasing temperature is giving just the favorable condition for the growth of this algae. Climate change has been leaving a widespread effect on every aspect, and the signs are visible to all.

Climate change has been the grim reality which the world is facing today. It is having a severe impact on agriculture. Any adverse impact on agriculture will affect all the 3 dimensions of food security: accessibility, affordability, and absorption. The sustainability of agriculture is of utmost importance for the food security of the world.

This paper shall attempt a study on how climate change is affecting the agriculture and food security of the world. Also, the aims and objectives of this paper are as follows:

1) To study the impact of climate change at the global, continental, and national levels.
2) To study the scope of technology in mitigating the effects of climate change on agriculture.
3) To recommend steps that can be undertaken to address the problem.

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A. Climate Change and Social Inequality

Climate change is expected to increase social inequality in the coming years. The less economically developed countries remain more vulnerable to the impacts of climate change. It has been estimated that by 2100, the poorest countries will face a 75% decline in their income forcing the vulnerable population to further reduce their standard of living. The report titled 'South Asia's Hotspots: The Impact of Temperature and Precipitation Changes on Living Standards' even highlighted the fact that climate change will impact almost half of South Asia's population living in vulnerable areas and will suffer from declining living standards due to reduced yield, labor productivity or related health impacts.

B. Climate Change and Human Health

The phenomenon of climate change is also affecting human health. Warmer conditions will give rise to conditions favorable for the spread of infectious diseases, increase incidences of existing diseases like respiratory disease and result in the emergence of new diseases.

With the temperature rise, infectious diseases like dengue, malaria will become more prevalent, increased cardiovascular and respiratory diseases due to extreme weather events like more intense heat waves due to warmer conditions. The arrival of the pandemics like the SARS and the COVID 19 are just reminders of the way that we have to travel.

C. Climate Change and Pest Attack

Human activities like deforestation, fossil fuel burning are only adding to the already existing content of carbon dioxide in the atmosphere and this increased content will adversely affect crop production. Higher carbon dioxide content makes the crops more prone and sensitive to pest attacks.

These pest attacks will only get severe and will have longer life cycles which will affect the crop yield and reduce productivity. Higher temperature produces a favorable condition for the plant pests which is the major reason for crop yield losses. Climate change has been estimated to alter the behavior of pests as a result of which, pest monitoring and control will become a difficult process.

These pest attacks will only get severe and will have longer life cycles which will affect the crop yield and reduce productivity. Not surprising, therefore, that the Locusts have created havoc in this part of the world!

D. Climate Change and food Security

Climate change is threatening another major aspect of human life survival: **food security.** The developing countries are still fighting with and trying to eliminate poverty. Climate change will only worsen the problem. With the population increasing exponentially, we will have a greater number of people to feed soon. But with the problem of increased pest attack affecting the crop yield adversely, it will be a difficult task to feed every individual. This will give rise to the problem of hunger, malnourishment, or under-nourishment.

Also, in agriculture, the timing for the growing and sale of crops is based on normal and long-established climatic patterns. But due to the impacts of climate change like higher temperature, rise in sea level, extreme weather events, and changing rainfall patterns, the farmers are finding it difficult to keep up with it. With increasing food insecurity and a higher number of people suffering from malnourishment or dying of hunger, it will only make our goal of attaining the Sustainable Development Goal 2 (SDG 2) of achieving zero hunger by 2030, a difficult task.

1) *Agriculture: Overview:* The origin of agriculture has been traced back to 10,000 years ago, that is in the Neolithic era by archaeologists. It is believed that agriculture developed in some parts of the world independently like the Fertile Crescent (a region in the Middle East), China, and Central America (JHCLF, 2019). Humans used to be hunter-gatherers and nomads before the discovery of agriculture. As the knowledge and skill of humans developed regarding the growth of plants and care of the soil, they started to advance and started to develop permanent villages. Several reasons forced the humans to switch from their living on hunted animals to agriculture. The growing population and changing climate made it difficult for humans to rely solely on wild resources for food. With the development of technology and to support the growing population, humans shifted to agriculture and started domesticating animals. Agriculture provided more food per acre of land while they obtained milk, meat, and hides from domesticated animals. Humans had surplus food and hence, they did not have to worry about the collection of food and could practice other roles like scholars, artists, etc. They started using the surplus food to barter with other cities or use it in case of crop failures. Trade of crops helped in the establishment of trade relations with other places which were more developed. Some of the trade relations became successful to an extent that some of the cities developed and civilizations developed around them.

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2) *Agriculture: Tool Towards Prosperity and Ending Hunger and Poverty:* Agriculture has played a crucial role in the development of economies and remains the primary source of livelihood for a major share of the population in developing countries. It is believed that the agricultural revolution in England provided the base for the industrial revolution. Due to the intensity of work and the difficulty involved in agriculture, the need for inventions and innovations that would ease the work, the intensity and difficulty involved in practicing agriculture was felt greatly and this need led to the Industrial Revolution which brought about changes in the agricultural field. These inventions led to a decline in the requirement of manpower and the production of food for the larger population was made possible. With the reduced requirement of labor in agriculture, the agricultural laborers migrated to the city to work in industries. This further fuelled the Industrial Revolution. As more industries were set up, a greater number of people could find employment in the industries. The technological changes introduced as a result of the industrial revolution helped in the mass production of goods and meet the growing consumption demand of goods. With mass production, the goods were cheaper and affordable by many. With the regular source of income available to many and cheaper goods, the standard of living raised and the society as a whole progressed leading the nation towards economic prosperity. The Food and Agricultural Organization (FAO) of the United Nations has declared agriculture as a tool that will end poverty and hunger (FAO, 2017). Agriculture is a powerful tool that can drive us towards a hunger-less and poverty-less world. FAO highlighted that investment in agriculture is of utmost importance as it will strengthen the rural communities where it is practiced on a large scale and where most of the poorest life. This is required to help us in attaining the Sustainable Development Goal of ending poverty and hunger by 2030. Strengthening agriculture will help in increasing the income of the family residing in rural areas and this will help in reducing poverty where poverty is very relevant. The population is estimated to increase by 2 billion in the next 30 years and by 2050 making it around 9.7 billion. This will make achieving zero hunger a difficult task as food production needs to increase by 60% by 2050 for current production to ensure food security along with practicing climate-resilient, efficient and sustainable agriculture. This will ensure meeting the requirements of nutritious and staple food as climate change is affecting the nutrition level of food making the population suffer from malnutrition or under-nutrition.

3) *Agriculture: Indian Scenario:* Globally, employment in agriculture stands at 26.85% but this figure stands at 54% in India (ILO, 2020). Indian economy is still an agrarian economy where agriculture forms the backbone of the national economy and a major part of the population still practices and relies on agriculture for their livelihood. With the advancement and industrialization of the economy, the dependence on agriculture for livelihood has decreased but still, a greater part of the population is engaged in agriculture. Agriculture and related activities had a contribution of 15.4% in the year 2018 (World Bank, 2018). It is not only the source of livelihood but also supports important industries of the country. Industries like cotton and jute textiles, sugar manufacturing, agro-based cottage, and plantation depend on agriculture and allied activities for their raw materials. In India, agriculture has come a long way since independence. Though its share in the GDP of the country has reduced to 15.4% in 2018 from 54% in 1947 the production and export of food grains have increased tremendously since 1947. The food grain production in India was only 50 million tonnes in 1947 which increased to 283.87 million tonnes of food grains during 2018-19 (PIB, 2019). With time, the area under agriculture declined, and increased production from land under production became an important aspect. Increased production of food grains was important due to two reasons: firstly, India wanted to reduce its dependence on imported food grains, and secondly, make the country self-sufficient. To facilitate this, the Government of India took several steps like the introduction of land reforms, improvisation of rural infrastructure, the introduction of a new agricultural strategy in the year 1966-67 to achieve the goal of self-sufficiency. All these steps helped in strengthening agriculture and attain high productivity which turned out to be successful.

E. Land Reforms

Land reforms were important after independence. Earlier, the land had collective ownership. With the British rule, three different types of land tenure systems were introduced namely the Zamindari system, the Mahalwari system, and the Ryotwari system. These land tenures exploited the farmers and the small tenants who were pushed further to poverty. The land was cultivated by the tenants but not owned by them, hence they were not motivated to increase production or make any improvements to the land. Further, the zamindars or the intermediaries under the land tenure system exploited the tenants by collecting heavy taxes from them. This necessitated introducing land reforms post-independence.

Post-independence, the Government of India introduced the land reforms, also called agrarian reforms, to regulate the rent and ensure ownership and provide security to the tenants. The first land policy was put forward by the Congress Agrarian Reform Committee, 1949 headed by J.C. Kumarappa.

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The committee stressed the regulation of rent and elimination of intermediaries under its policy. The motive behind the land reforms was to improve the condition of the agricultural sector, remove the concentration of land in few hands to making the tenants the real owners subject to certain conditions and thereby increase productivity and make India self-sufficient. As ownership was ensured to the tenants, they were motivated to improve the land and work to increase productivity. These land reforms provided the base for the necessary agricultural developments.

F. New Agricultural Strategies in 1966-67

The state of Bihar faced the situation of double calamity resulting in the declaration of famine in the state. Bihar had less-than-normal production of food grains due to which a situation of scarcity arose in few parts of the state. Many districts faced a severe drought during July-October 1966 which was the Kharif season. In addition to this, heavy floods occurred in North Bihar during August which did not prove to be helpful for the production of Rabi crops. The production was significantly below normal and by May 1967, 36% of the state was declared to be suffering from famine while 30% of the area was suffering from scarcity. In total, 34 million people were affected in the state (Brass, P.R. 1986). The condition of shortfall of food grains made the Government realize that considering the situation of producing food grains in the whole of India was of utmost importance. This would help in making up for the shortfall of production and hence prevent famine. C. Subramaniam, the then Minister of Food and Agriculture vouched for the adoption of scientific techniques and knowledge of agricultural production at all stages. He proposed the adoption of a high-yielding variety program (HYVP). This program comprised of adoption of a high-yielding variety of seeds of paddy and wheat to help India attain self-sufficiency. Ministry of Food and Agriculture adopted the HYVP as a package program since the success was dependent on the adoption and application of fertilizers, pesticides, insecticides, and adequate irrigation facilities. This marked the beginning of the Green Revolution. The HYV seeds coupled with modern technological inputs led to an increase in the production of food grains in the country. This helped India in increasing the production of food grains and decreasing its reliance on imports.

1) *Farmer's Plight:* India is the nation with the second largest population and has many mouths to be fed. The farmers provide food but despite this, they have been facing innumerable issues, the most prominent one being indebtedness. They have been treated as mere cultivators. The long march of the farmers in the national capital on 30th November 2018 highlighted the grim reality of the agricultural distress in the country. This was not the first protest by the farmers which the country was witnessing. There have been numerous small and large protests by the farmers, the most prominent one being the march by the farmers in Mumbai on 12th March 2018. This demonstrated that the farmers have been going through a rough patch or what can be been termed as the farmer's plight. There have been innumerable reasons for the plight the farmers are facing. Indebtedness in rural areas has been a major concern in India. Despite the provision of institutional credit for agriculture, the incidents of rural indebtedness did not decrease. Farmers were under the constant pressure of debt due to the rising cost of inputs required for agriculture and dependence on moneylenders for loans. The process of obtaining a loan from the banks is a tedious task. This deterred the farmers to prefer banks for loans in place of money lenders. The farmers take loans from money lenders at a high rate of interest and in case of failure of harvest, they are unable to pay back thus pushing them into indebtedness. Rising indebtedness and inability to pay back the loan are forcing the farmers to commit suicide. In the year 2018, National Crime Records Bureau (NCRB) reported that at least 10,348 farmers committed suicide which accounted for 7.7% of the total suicides in the country. The reasons cited were indebtedness and nonviable agriculture. States of Maharashtra, Telangana, Chhattisgarh, Madhya Pradesh, and Karnataka were the hotspots of farmer suicide where agrarian distress was much more severe. Income flow was continuously declining for the farmers due to the rising cost of cultivation and increased needs of the household. The shrinking income of the farmers made it difficult for them to repay the loan taken by them from the moneylenders. This problem was aggravated by drought for 2 consecutive years- 2014 & 2015- which worsened the problem of the farmers. The government of India took various measures to address the problem of agrarian distress and farmer's suicide. After the drought of two consecutive years, the Government of India launched the Pradhan Mantri Krishi Sichai Yojana in 2015 and Pradhan Mantri Fasal Bima Yojana in the year 2016 to resolve the problem of farmers.

G. Pradhan Mantri Krishi Sichai Yojana

Agriculture in India is primarily dependent on the monsoon. Water is an important input for successful agriculture here. Water availability may be possible artificially through human efforts while in other parts, water is available naturally through rainwater. But due to drought-like conditions and irregular monsoon, the crops have been affected adversely. The practice of intensive agriculture requires more irrigation facilities to ensure sufficient food availability for the ever-increasing population of India. The lack of irrigational facilities was affecting agriculture and productivity adversely.

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Hence to resolve the problem of dependence on monsoon rains and ensure round-the-year water availability for crops, the Government of India launched the Pradhan Mantri Krishi Sinchai Yojana in the year 2015 with the motto 'Har Khet Ko Pani' or 'Per Drop More Crop'. The program was implemented to expand the area under cultivation with assured irrigation, reduced water wastage along improved efficiency of water usage (PMKSY, GOI, 2019).

H. Pradhan Mantri Fasal Bima Yojana

The central government's crop insurance scheme- Pradhan Mantri Fasal Bima Yojana was launched in 2016. It was a replacement for National Agricultural Insurance Scheme and Modified National Agricultural Scheme. The scheme aims to provide financial support to the farmers against crop failure and hence ensure income stability so that they continue practicing agriculture. It was earlier compulsory for loanee farmers who had availed loan for the crops notified but voluntary for the other farmers. In February 2020, the Central Government modified the PMFBY making it optional for all the farmers including the loanee farmers.

II. LITERATURE REVIEW

Mendelsohn (2009) in his paper titled 'The Impact of Climate Change on Agriculture in Developing Countries' focussed on the economic impact of climate change on agriculture. In his paper, Mendelsohn signified that agriculture is vulnerable to the effects of climate change due to its size and sensitivity. The study highlighted that tropical and subtropical agriculture are comparatively more prone to warming and any further warming would only damage the crops. In addition to warming, any changes in the rainfall pattern would also damage the crops.

The study concluded that small farmers may be less vulnerable to warming than commercial farmers. Further, the impact of climate change depends largely on the local climate and how the local climate changes along with other conditions of places like market access and soil condition. The author suggested that irrigation can prove to be an effective tool to counter the harmful effects of warming and can negate the adverse effects of warming.

Stevanovic et al (2016) in their paper titled 'The Impact of High-end Climate Change on Agricultural Welfare' studied the impact of climate change on agricultural welfare.

The authors used the impact modeling chain to study the distributional effects of high-end climate change impacts across the geographic region and economic agents. They signified the detrimental effect of climate change on agriculture welfare post-2050 due to losses in consumer surplus that will outweigh gains in producer surplus. They concluded that climate change would create a positive trend in global producer surplus but a negative trend in global consumer surplus by the end of the century. Producers would who would intensify their production or expand the cultivation area which will increase the marginal cost and as a result, the consumers will have to pay more for the same quantity of goods and thus would lose surplus on their part.

Hans (2014) in his paper titled 'Impact of Climate Change on Indian Agriculture' studied the impact of climate change on Indian agriculture, suggested ways to mitigate the problem and challenges lying ahead. The author signified that with the increase in temperature, by 2080-2100, loss in crop production is estimated to be around 10-40 percent. Further, there would be a reduction in the yield of wheat by 10 percent in high-yielding states like Punjab, Haryana, and Uttar Pradesh which are referred to as wheat belts. The author highlighted the fact that agriculture is estimated to become more capital-intensive which will force the small and marginal farmers to leave agriculture and this will give rise to inequality. The author suggested to encourage organic farming, use of bio-fertilizers; preventing the misuse of SEZs, that is, Special Economic Zones, etc.

Adams et al (1998) in his paper titled 'Effect of Global Climate Change on Agriculture: An Interpretative Review' studied the physical effects of climate change on agriculture, like livestock yields and crop yields. The authors signified that an increase in temperature and concentration of carbon dioxide will harm the quality of crop and crop yield particularly cereal and feed grains. The increased rainfall due to climate change may prove to be beneficial for the arid or the semi-arid regions but may destroy the crops in regions that are already having an excess of water.

The paper also highlighted the economic impact of climate change on agricultural supply. Due to decreased production and supply, the price of those crops will rise which will adversely affect consumer welfare. Affordability will become difficult due to increased prices.

The study concluded that there may be winners and losers from climate change but the countries in low-lying, warmer areas will suffer comparatively more due to decreased crop yields as a result of higher temperature. The authors suggested adaptation to climate change by farmers such as changed crop plantation and irrigation practices. These steps would reduce the adverse impact of climate change and may even reverse the economic effect.

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In a scenario-based study, Assad et al (2013) in their paper titled 'Impact of Climate Change on the Agricultural Zoning of Climate Risk for Cotton Cultivation in Brazil' studied the effect of temperature increase on agricultural zoning of production of cotton in Brazil. The authors predicted that temperature increase may not be beneficial for Brazil and the present area under cotton cultivation may reduce to 71 million ha by 2040 from 83 million ha in 2010.

The study concluded that an increase in temperature may undermine the yield of cotton in the North-eastern region of Brazil which was the largest producer of cotton.

The study suggested that the development of cotton genetic variants may prove to be an alternative to responding to climate change and even may be suitable for higher temperatures and water deficit areas. Also, second-generation transgenic plants may be an alternative that is more adaptable to environmental stress, more tolerant to the herbicide, and more resistant to insects.

In their paper titled 'Climate Effects on Food Security: An Overview', Burke and Lobell (2010) studied the aspects of food security namely availability, accessibility, and utilization, and thereby study how climate change may affect these aspects. As climate change affects crop productivity, the net income earned by the households will be affected which will ultimately have an impact on food security. In addition to this, climate change is also estimated to affect the health of humans which will harm the ability to utilize the food effectively.

The paper emphasized the aspects that determine the ability of an individual to utilize food which are namely: nutrition and disease. Climate change threatens the nutrition content of crops by affecting their quality and nutrition content. As a result, the probability of insufficient nutrition level in the body increases leading to an increased risk of malnutrition in the human body. The authors also highlighted that warming temperatures provide a favorable condition for vector-borne diseases like malaria and dengue. All these aspects will affect the food utilization capacity of the individual.

Amutha and Juliet (2017) in their paper titled 'Impact of Climate Change on Human Health in India' studied the impact of climate change on human health and identified the major health threats due to climate change.

The authors highlighted that humans may experience a rise in the number of climate-related health problems like extreme weather-related health effects, air pollution-related problems, vector-borne diseases, psycho-social impacts on displaced populations, etc. the study suggested the adoption of mitigation measures like strengthening the health infrastructure and the service delivery systems with the help of disease surveillance or early monitoring, adoption of health insurance to counter them. The author highlighted that investment in research and development, health risk assessment studies, scenario modeling, and adoption of clean development mechanisms are important aspects that should be taken into account at the moment.

Report for World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics (2012) on 'Turn Down the Heat: Why a 4°C Warmer World Must be Avoided' pointed to the fact that without any commitments to reduce the emissions, the world would witness a rise in temperature by 3°C above the pre-industrial climate. Even with the help of current mitigations, there is a probability of a rise in temperature by 4°C by 2100.

The report even pointed to the fact that not all regions would experience an equal impact of climate change. Some regions may suffer more while some may experience less effect, the poorest regions being the most vulnerable. The high sensitivity of crops to temperature can lead to severe losses in crop yields which was experienced in several regions that were studied in the report namely Africa, United States, Australia, and India.

Dietz (2020) in his paper titled 'Climate Change and Malnutrition: We Need to Act Now' studied the relation between climate change and malnutrition. In his paper, Dietz signified that climate change and malnutrition in all its form along with obesity and undernutrition pose as the greatest threat to planetary and human health. The author emphasized the need for change in dietary habits of the US residents. Meat-based food products are the single largest contributor to greenhouse gas emissions. A lower consumption would reduce the emissions.

The author suggested for opting for dietary recommendations by the EAT-Lancet Commission would not only be beneficial for the planet but also for human health; moving towards sustainable land use and reducing the reliance on fossil fuels which also tend to be a contributor to greenhouse gas emissions.

In their paper titled 'Addressing the Challenges of Climate Change and Biofuel Production for Food and Nutrition Security, Tirado et al (2009) studied the current and the projected effects of climate change on nutrition and proposed recommendations for policy to address the challenges.

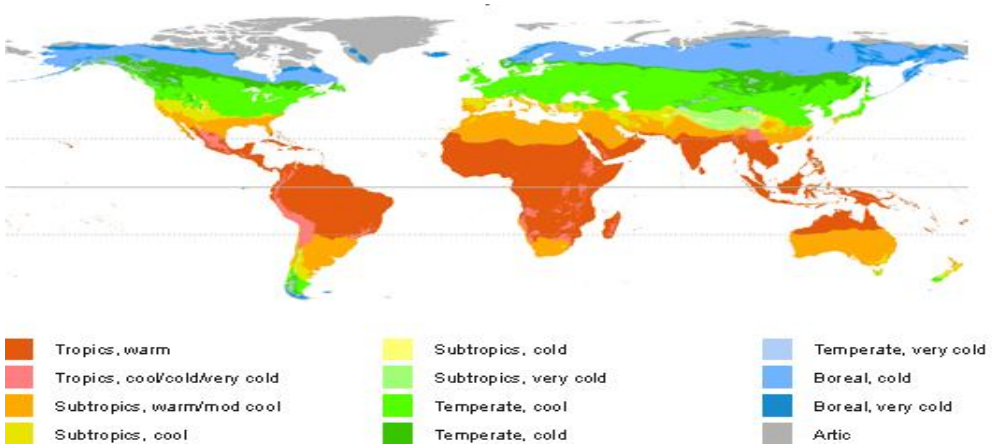
The paper highlighted that three major challenges namely climate change, growing use of food crops as a source of bio-fuel, and soaring food prices make the task of overcoming food insecurity and malnutrition a tough task.

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III. ANALYSIS

The planet is divided into different climatic zones namely temperate, tropical and subtropical which are subdivided into warm, cool, and very cold. Crops are planted according to the climatic conditions in these zones. But the impact of climate change is varying the temperature in the zones.

Figure 1 Climatic zones



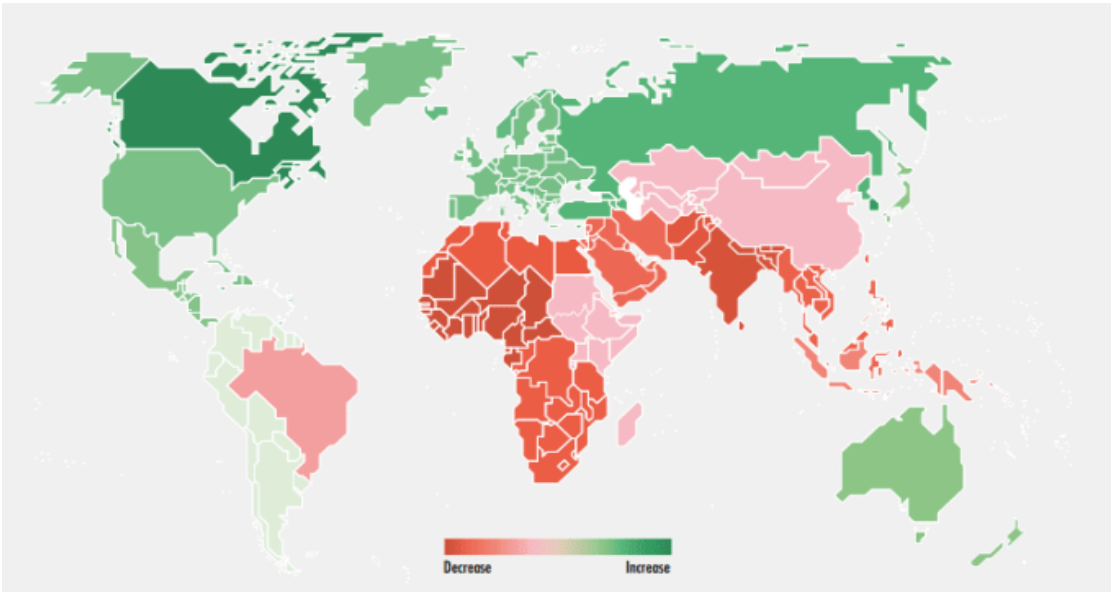
Source: Global Agro-Ecological Zones, FAO

The studies of international bodies like Food and Agricultural Organizations of the United Nations have signified that the effect of climate change will be unequal. While some regions may benefit from the effect, some stand to be the most vulnerable from the effect of climate change.

A. Effect on Agriculture: Study at Global Level

Though some of the regions may emerge as winners as a result of climate change, on a large scale, climate change will harm the agricultural yields which will threaten the food security of the world. FAO (2019) in a jointly prepared report highlighted that 820 million people suffered from the scarcity of food in the year 2018. The number rose from 811 million in the year 2017. This rise in the number of people who are unable to get enough food points towards a major problem that the world would witness in the coming years due to the adverse impact of climate change on agriculture- the **problem of food insecurity.** As the population is set to increase by another 2 billion by the year 2050, production needs to increase to ensure that every person has enough food to eat.

Figure 2 Changes in Agricultural Production by 2050



Source: Food and Agricultural Organization of the United Nation (2018)

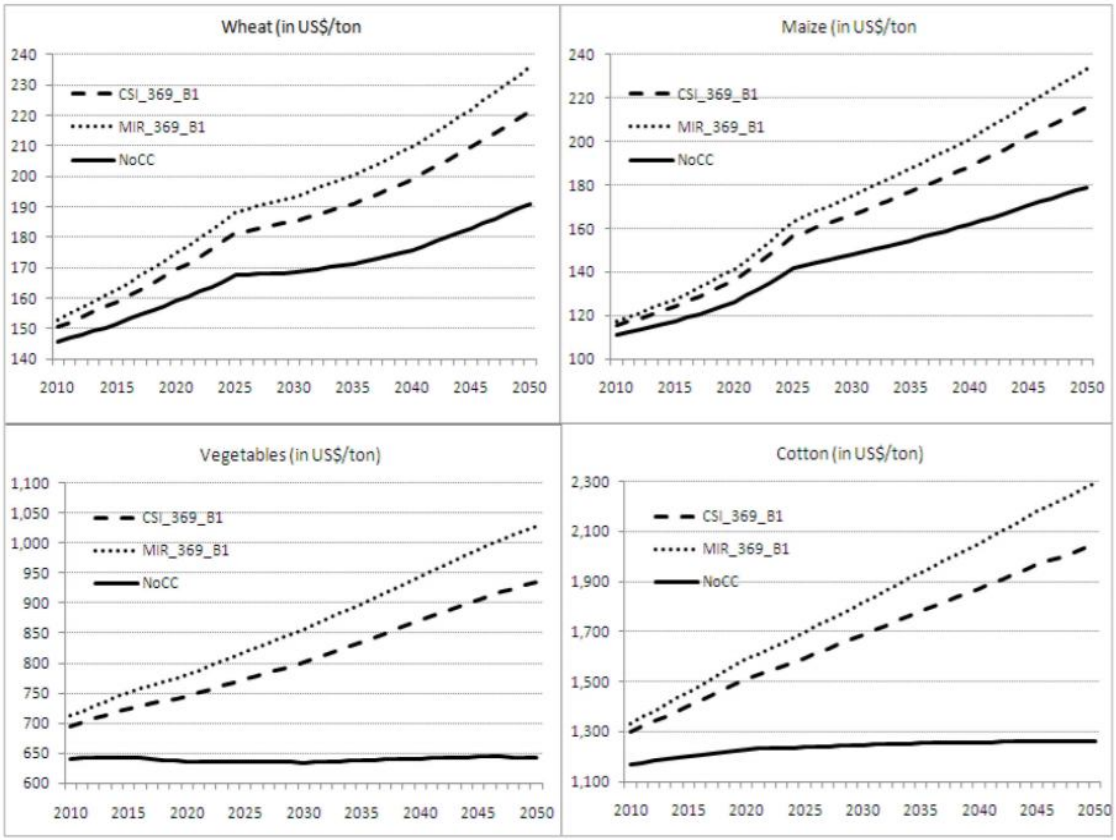
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United Nations in their report identified and mapped the impact of climate change on various regions in the world. From the mapping, it is evident that while some of the regions which are cold climate regions turn out to be winners, most of the regions turn out to be losers due to climate change. The impact is unequal and most of the developing or the poorest countries turn out to be the sufferers who contribute least to the greenhouse gas emission while some of the regions would remain unaffected from the impact of climate change.

The impact will be comparatively lower on higher latitude areas which would witness rather benefit from the effect. Tropical regions will suffer from the impact of climate change. These areas will witness the adverse effect of higher temperature which would lead to a reduction in production yields.

The impact of climate change is said to be much more severe on the developing economies in comparison to the developed ones. The developing or the least developed countries (LDCs) lie in the lower altitudes. Agriculture in these regions has an important contribution to the GDP of the countries. The lack the resources and the ability to recover from the adverse effects of climate change threaten the GDP of these regions. Countries like Yemen, South Sudan are already fighting the problem of famine and food insecurity. The adverse impact of climate change on the yields in such regions will further aggravate this problem of food insecurity.

Figure 3 Estimated Rise in Global Food Price



Source: Robinson et al (2015)

IFPRI's IMPACT model projected the estimated rise in global food prices under mitigation and the impact of climate change. The model predicted that with perfect mitigation strategies, the global food prices would rise between the years 2000 and 2050 but climate change would result in a further increase in the price by 52 percent to 55 percent for maize and 94 percent to 111 percent for wheat. These crops form an important part of the diet of people. An increase in the price of food crops would create a problem of affordability of food by the poor section of the world thus aggravating the problem of hunger and insufficient food available for the people.

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B. Effect on Agriculture in Asia: Study at Continental Level

Table 1 Impact of Projected Climate Change on Global Welfare, GDP & Production, 2080 (percent change)

	GDP	Welfare (EV as % of GDP)	Terms of Trade	Sectoral Output						
				Crop	Agriculture				Livestock	Processed food
					Paddy rice	Wheat	Other grains	Other crops		
World	-1.4	-1.3		-7.4	-9.1	-6.8	-7.8	-7.3	-5.9	-4.6
Australia	-0.3	-0.6	-0.4	-42.9	-12.8	-66.7	-42.5	-40.6	7.1	-0.2
New Zealand	0.2	1.5	2.7	140.6	31.4	38.2	12	156.2	-11	-3.8
Japan	0	-0.2	-0.4	1.9	-4.7	6.8	43.7	3.5	0.5	2.2
PRC	-1.3	-1.1	-0.2	-0.1	-0.5	4.2	-0.5	-0.2	-1.9	-3.6
Korea	-0.2	-0.6	-0.5	-5.1	-4.8	0.4	-10.6	-5.6	-1.4	-0.4
Southeast Asia 6*	-1.4	-1.7	-0.4	-17.3	-16.5	-36.3	-12.6	-17.9	-1.4	-4.5
India	-6.2	-5.2	-1.8	-24	-11.5	-24.7	-36.7	-24.1	-19.1	-29.1
Rest of South Asia	-1.9	-2.7	-4.1	-19.5	-16	-29	-24.6	-19.2	-3.1	-10.8
Central Asia	-1.9	-1.5	1.8	49.7	12.8	66.9	5.1	48.9	-10.9	-0.5
Rest of Asia	-0.4	-0.7	-0.4	-18.4	-20.8	-46.9	-40.5	-14.3	1	-5.2
Canada	-0.2	0.2	0.8	22.1	0.9	17.7	5.1	34.6	-15.3	-1.6
US	-0.1	0	0.4	5.1	21.3	10.5	0.9	6.9	-7	-0.3
EU	-0.2	0	0.4	21.4	12.9	32	17	20.7	-10.1	3.6
Latin America	-1.7	-2.1	-0.8	-24.3	-12.2	-40.5	-23.4	-24.3	-2.7	-5.2
Sub-Sahara Africa	-2.2	-3.2	-1.3	-29.6	-23.6	-61.6	-22.2	-31.3	-0.8	-4.3
Rest of the world	-1	-1.2	-0.5	-10.1	-5	-16.1	-13.1	-7.9	-4.7	-2.1

Source: Zhai et al (2009)

The projected impact of climate change on the agricultural yields of different regions was studied using the simulation model. From the model, it was evident that the impact would remain unequal in the region of Asia. While some may emerge as clear winners, some may have to face a setback in the agricultural yield due to the effects of climate change. The crops in several regions lying in lower latitudes and having hot climates would suffer a decline in their yields due to further warmer atmospheric conditions leading to a dry climate, increased growing time, changed rainfall patterns, dry monsoons, and increased pest attack.

Agriculture form an important aspect of the GDP of some of the Asian countries. South Asian economies would witness the largest setback in their GDP due to a fall in the agricultural productivity followed by Central Asia. The decline in agricultural productivity in Southeast Asia is expected to be at least 17.3 percent by 2080 which is a significant reduction in output while in South Asia, this decline is expected to be more severe due to climate change.

With 1.8 billion people residing in South Asia, the ever-growing population which is expected to increase by a further 40 percent by 2050, feeding every individual sufficiently would be a challenge. Furthermore, reduced productivity due to climate change will make this task even more difficult.

While several regions may experience a completely negative impact due to climate change, it may prove to be ambivalent for a region, that is, the region may experience both positive and negative effects. For example, colder regions like the Russian Arctic may benefit from warmer temperatures due to climate change.

As the temperature increases and the ice melts, more areas would be available for farming in the Russian Arctic, thus more land will be available for farming and hence increased production. While same is not true for the warmer regions of Russia. Warmer conditions will result in decreased production and lengthened growing season by at least 5-10 days.

C. Effect on Agriculture in India: Study at the National level

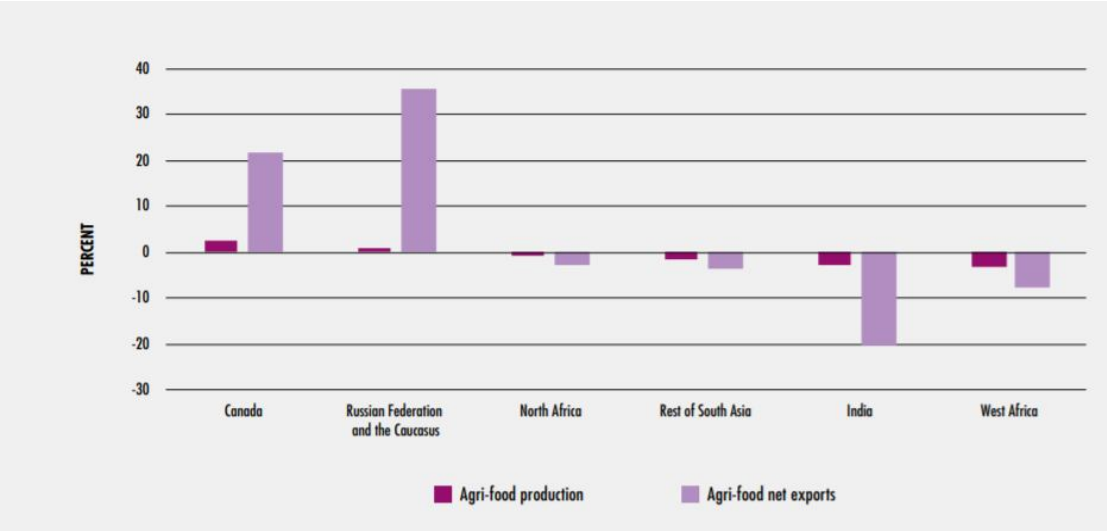
Indian agriculture is primarily dependent on monsoon. . India ranks first in rainfed agriculture, in terms of area and value of products with more than 60% of agricultural land being rainfed. The rainfed areas have a huge contribution to the foodgrain production in India. The rainfed agricultural lands account for 89 % of production in millet, 88 % in pulses, 73 % in cotton, 69 % in oilseed, and 40 % in rice production and also support a large number of livestock.

Along with foodgrain production and supporting the livestock, the rainfed diversity also supports the manufacturing industries which support around 18 % of the GDP of the country by turning the agricultural products into food.

The variation in rainfall also directly affects the yield of Kharif (summer) crops. The prolonged-time period between rainfalls is giving rise to the problem of drought in several parts of the country leading to crop failure. In the year, 42 % of the area in India suffered from drought with the states of Andhra Pradesh, Bihar, Gujarat, Jharkhand, Karnataka, Maharashtra, parts of North-East, Rajasthan, Tamil Nadu, and Telangana being the worst-hit areas from drought. The major reason for drought has been the failed monsoons. The problem of drought has been very prevalent in India since 2015.

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Figure 4 Changes in Agricultural Production & Net Exports in Selected Countries & Regions In 2050



Source: Food and Agricultural Organizations of the United Nations (2018)

Food and Agricultural Organization of the United Nations demonstrated the changes in the agri-food production and agri-food exports that are expected to occur in 2050 due to changes induced by climate change in crop production. The agri-food production would suffer a setback in India and as a result, imports of agri-food products would increase substantially. This tends to enlargen the trade deficit of India. With reduced production, less food will be available to people especially the economically poor people. It tends to aggravate the problem of food insecurity and hunger pushing India's agenda of achieving the SDG 2 of achieving zero hunger by 2030.

IV. CONCLUSION

By simply placing the facts on record and confirming that Climate Change has harmed the entire agricultural scenario, we would have done injustice to the entire case study.

There have been attempts to help the Agriculture sector both organically and through risk-mitigating measures.

Climate-smart agriculture techniques can not only help farmers adapt to and prepare for impacts to preserve but they can even improve their livelihoods.

Rainforest Alliance, a non-profit organization, based out of the United States, has come out with this concept which is not distinct from sustainable agriculture; in fact, it is a way of combining various sustainable methods to tackle the specific climate challenges of a specific farming community. So, what we have here is a specialized solution catering to specific needs and demands.

Rainforest Alliance environment director Martin Noponen explains that "climate-smart agriculture is not a one-size-fits-all approach."

So how does this Climate-smart technique work?

It is a 3-step activity wherein the first step involves improving farmer productivity, and as a result, the livelihoods.

The second step makes farms more resilient to climate impacts that they are facing on an immediate basis, and to those likely to be hit in the future.

And finally, where practical and possible, efforts should be made to curb greenhouse gas emissions normally associated with growing food.

Prisila Mkenda, a researcher from Tanzania has done a lot of work on empowering smallholder farmers through affordable and environmental-friendly pest management options for sustainable crop protection.

She believes that the prevalent " practice in pest management has been the use of synthetic pesticides that is often not affordable to the majority of smallholder farmers. Even when available with subsidies, they are applied at inappropriate rates leading to not only pesticide resistance but also health problems to the farmers, consumers and the non-target organisms in the environment."

There have been concerted efforts by people for the benefit of an affected population due to the impact of climate change on agriculture. A few of such activities, at the cost of repetition, are enumerated below:

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Improved and Efficient Irrigation Management being one of the major efforts in the world primarily because the groundwater level is decreasing. Thus, the conservation of water becomes a primary concern in case of a drought.

Ending our dependence on fossil fuels is crucial because we now have our sights on the Renewable Energy sector helping out, specifically the farming and agricultural sector and in general the common masses.

The approach of the Governments must shift towards more Climate Friendly policies. What is also needed is a shift in the attitude of the urban people, who are one way or the other dependent on the agricultural produce.

As a part of the Sustainable Development Impact Summit, the World Economic Forum has been a strong advocate of solutions to this crisis. They feel that efforts like "reducing tillage, expanding crop rotations, planting cover crops, and reintegrating livestock into crop production systems have proven to reduce agriculture's footprint as well as capture the excess carbon generated by other industries. This captured carbon is then converted into plant material and/or soil organic matter, improving soil health and increasing the ability to produce food on the land in the future."

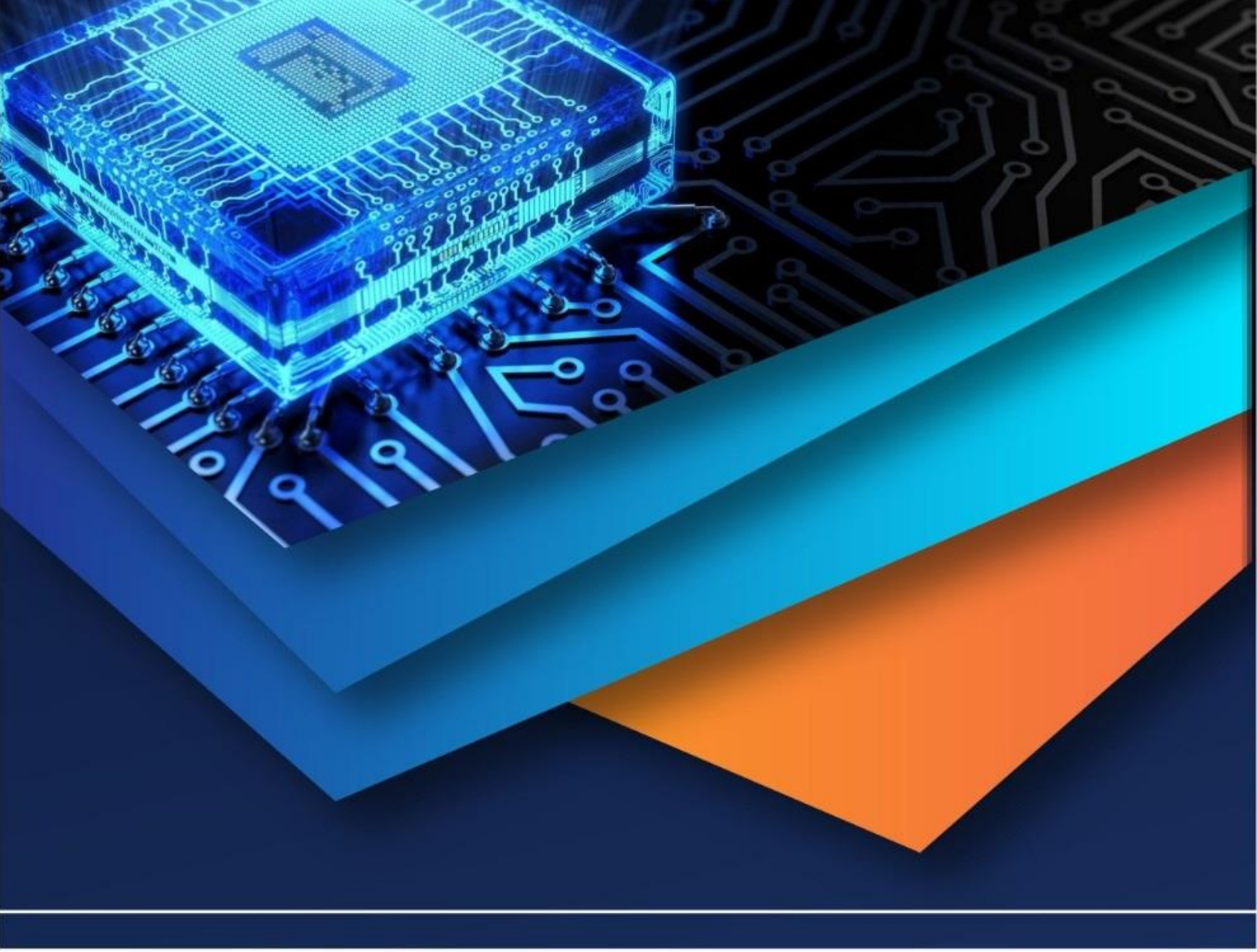
There is yet another challenge that has restricted our efforts in finding correct and relevant solutions to this challenge of Climate Change to agriculture- the lack of correct and sufficient data.

One must appreciate the fact that even though mankind reacted slowly to the above-mentioned challenges, all is not lost. Small areas in the African continent, a single district in Rajasthan, agricultural plains in North America, and many more such efforts have given us hope that we can and we will.

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