IOSR Journal of Humanities And Social Science (IOSR-JHSS)
Volume 26, Issue 7, Series 6 (July. 2021) 52-62
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Review on the Impact of Climate Change on Indian Agriculture

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ABSTRACT
Over the last 10 years, awareness of the potential of climate change has increased, and with clear evidence of climate change observed in the 20th century, food security and its impact on the region have become increasingly important.More recently, crop simulation models have been widely used to study the impact of climate change on agricultural production and food security.The output provided by the simulation model can be used to make appropriate crop management decisions and provide farmers and others with alternative options for their agricultural systems.As the use of computers increases, the use of simulation models by farmers, experts, and even policymakers and decision makers are expected to increase in the coming decades.In India, considerable work has been done over the past 10 years with the aim of understanding the nature and magnitude of changes in the yield of different crops due to projected climate change.This paper provides an overview of the current state of knowledge about climate change and the possible effects of change on edible grain production in India.

Date of Submission: 06-07-2021 Date of Acceptance: 19-07-2021

I. INTRODUCTION

There is clear evidence that increases in global average temperatures and changes in rainfall were observed in the 20th century (Easterling, 1999 IPCC, 2001, Jung et al.2002, Balling Jr and Cerveny, 2003, Faucheau et al., 2003) All over the world.The most pressing climate change of recent times is an increase in atmospheric temperatures due to elevated levels of greenhouse gases such as carbon dioxide (CO2),(CH4), ozone (O3), nitrous oxide (N2O), and chlorofluorocarbon (CFC).As the concentration of these radioactive or greenhouse gases is increasing, there are many concerns about future changes in climate and their direct or indirect effects on agriculture (Garg et al.2001; IPCC, 2001; Krupa; 2003;Aggarwal, 2003; Bhatia et al. (2004).

In India, studies by several authors have shown that an upward trend in surface temperature was observed during the last century (Hingane et al.1985; Srivastava et al.1992; Rupa Kumar et al.See, 1994; De and Mukhopadhyay, 1998; Pant et al.See, 1999; Singh and Sontakke, 2002; Singh et al. (2001), there is no significant trend in rainfall in all Indian bases (Mooley and Parthasarathy, 1984; Thapliyal and Kulshrestha, 1991; Pant and Rupakumar, 1997; Pant et al. al.Et al., 1999; Stephenson et al. (2001), and trends in decreasing/increasing rainfall on a regional basis.

In recent years, as awareness of the potential of global climate change has increased, the impact on global food security in general, and the region in particular, has been placed at the forefront of the scientific community.The growth, development, water use and yield of crops under normal conditions are mainly determined by the weather during the growing season.Even a slight deviation from normal weather can seriously undermine the efficiency of inputs and food production applied to extremes.Carbon dioxide (CO2) concentrations were steady at 1850 ppm before the Industrial Revolution (280 ppm).Since then, it has risen at a rate of 1.5-1.8 ppm per year. CO2 concentrations are likely to increase by 21 times by the end of the 2nd century(Keeling et al.(1995).Open-top chambers and FACE technology are currently being used to study crop reactions to rising CO2.The results of such studies indicate increased photosynthetic rates and crop yields in plants (Kimball, 1983).Measurements in Delhi showed a similar trend (Uprety, 2003).In an experiment in New Delhi, Uprety et al.In 2003, we observed an increase in rice yield due to an increase in CO2 concentration.Increased net photosynthetic rates and increased sugar accumulation contributed significantly to the acceleration of leaf and brood development and, ultimately, grain yield.Projected climate change due to increased atmospheric CO2 concentrations and global warming can affect future global agricultural production through changes in plant growth rates (Lemon, 1983; Cure and Acock, 1986; Rotter and Van de Geijn, 1999), transpiration rates (Morison, 1987; McNaughton and Jarvis, 1991; Jacobs and DeBruin, 1992).

Agriculture plays an important role in India's overall economic and social well-being.The share of agriculture in both gross domestic product (GDP) and employment has declined over time, but the pace of decline in the share in employment is much slower than that of GDP. The proportion of agriculture in GDP fell from 1983 to 39% in 2000-01 to 24%, but the proportion of total employment declined significantly during the same period from 63% to 57%. The decline in the proportion of agriculture in GDP was not commensurate with the decline in dependence on agriculture.Such trends lead to fragmentation and shrinking of land ownership, leading to inefficiencies in agriculture, rising unemployment and a reduction in the number of marketable surpluses.These factors may contribute to increased vulnerability to global environmental changes (Aggarwal et al. (2004). In India, the current average food consumption is 1 gram per 1 person per day 550, while the corresponding figures for China and the United States are 980 grams and 2850 grams, respectively.The current annual requirement, based on the country's current consumption level (550 gm), is about 21000 million tons (Mt), which is roughly the same as current production.For example, the area under the grain decreased from 1980-81 to 2003-2004 from 126.67 mha to 124.24 mha, while production increased from 129.59 Mt. During that period up to 212 mountains. The production of edible grains in 2003-2004 was very impressive.This is more than 1950-51 times the output of 50.82 Mt in 4 years.

However, the country faces major challenges to increase its food production to the tune of 300 million tons by 2020 in order to feed its ever-growing population, which is likely to reach 1.30 billion by the year 2020. To meet the demand for food from this increased population, the country's farmers need to produce 50% more grain by 2020 (Paroda and Kumar, 2000; DES, 2004). The problem has become acute because urbanization and industrialization have rapidly dwindled the per capita availability of arable land from 0.48 ha in 1950 to 0.15 ha by 2000 and is likely to further reduce to 0.08 ha by 2020. As against the national average of 40% of the total cropped area being irrigated, 60% of the total cropped area is still rainfed and dependent on uncertainties of monsoon. This shows the dependency of Indian agriculture on climate (Figure 1). Moreover, if certain climate change scenarios come to pass, agricultural production in some areas may decrease. How can productivity be increased while ensuring the sustainability of agriculture and the environment for future generations? Decision makers need information supplied by research to make informed choices about new agricultural technologies and to devise and implement policies to enhance food production and sustainability. There is now a great concern about decline in soil fertility, change in water table, rising salinity, resistance to many pesticides and degradation of irrigation water quality in north-western India (Sinha et al., 1998; CGWB, 2002). It is clear that over time more nutrients have been removed than added through the fertilizers, and the farmers have to apply more fertilizers to get the same yield, they were getting with less fertilizers 20–30 years ago. Climate change will further affect soil conditions. Changes in temperature and in precipitation patterns and amount will influence soil water content, run-off and erosion, salinisation, biodiversity, and organic carbon and nitrogen content. The increase in temperature would also leads to increased evapotranspiration. There is need to quantify the specific regional soil-related problems and that affect the global environmental change will have on soil fertility and its functioning for crop growth and production.

However, by 2020 we are facing a major challenge of increasing food production to 13.0 billion tons by 2020 to feed an ever-growing population that could reach 3 billion people.With this population growth, the country's farmers will need to produce 50% more grain by 2020 (Paroda and Kumar, 2000; DES, 2004).With urbanization and industrialization, the problem is getting serious, as the amount of available per capita of arable land will rapidly decline from 1 hectare in 1950 to 0.48 hectares by 2000, and by 2020 to another 0.15 hectares.60% of the total crop area being irrigated is still rainwater, dependent on monsoon uncertainty.This shows that agriculture in India is climate dependent.In addition, if certain climate change scenarios are realized, agricultural production in some areas may be reduced.How can we increase productivity while ensuring agricultural and environmental sustainability for future generations?Decision makers need the information provided by research to make informed choices about new agricultural technologies and to devise and implement policies to enhance food production and sustainability.There are now major concerns in northwestern India about declining soil fertility, changing water tables, rising salinity, resistance to many pesticides, and poor irrigation water quality (Sinha et al., 1998; CGWB, 2002).Over time, more nutrients are removed than are added via fertilizer, and farmers have to apply more fertilizer to get the same yield, and 20-30 years ago they were getting with less fertilizer.Climate change further affects soil conditions.Changes in temperature and precipitation patterns and quantities affect soil moisture content, runoff and erosion, salinization, biodiversity, and organic carbon and nitrogen content.A rise in temperature also leads to an increase in evaporatetranspiration.It is necessary to quantify soil-related problems in certain areas that affect global environmental changes, which affect soil fertility and its function for crop growth and production.

If agriculture is negatively affected, global warming could also threaten India's food security. While the effects of increased CO_2 concentrations increase the net primary productivity of plants, changes in climate change and associated disturbance regimes can lead to an increase or decrease in net ecosystem productivity.In many tropical and subtropical regions, potential yields are projected to decrease with most of the expected temperature increases.Among other things, the effects of rising CO_2 should be considered in the following context:(A) Changes in nighttime temperature due to changes in temperature, in particular increases in CO_2 and other trace gases, changes in moisture availability, and their effects on vegetative and reproductive growth. (B) the need for more agricultural resources (e.g. fertilizers); (C) the survival and distribution of pest populations, thus developing a new equilibrium between crops and pests (Krupa, 2003).Indirectly, there can be considerable impacts on land use due to snowmelt, variations in spatial and temporal rainfall, availability of irrigation, frequency and intensity of drought and flooding between and within seasons, changes in soil organic matter, soil erosion, and pest changes in the profile, reduction of arable land due to submersion of coastal land, and energy availability.All of these can have a significant impact on agricultural production and thus on food security in any region (Aggarwal, 2003).

Rising temperatures and carbon dioxide, and rainfall uncertainty associated with global warming, can and do not have serious direct and indirect consequences for crop production.It is therefore important to assess the direct and indirect effects of global warming on various crops, particularly those that contribute to food security (Gadgilet al. 1995,1999). Currently, mechanical crop growth models are routinely used to assess the effects of climate change.There are several crop models currently available for the same crop that can be used for climate change impact assessment (Mall and Aggarwal, 2002).Crop models generally integrate current knowledge from various disciplines including agrometeorology, soil physics, soil chemistry, crop physiology, plant breeding, and agronomy into a set of formulas to predict crop growth, development, and yield (Aggarwal and Kalra 1994; Hoogenboom, 2000).In most climate change applications, long-term historical weather data is used as input for crop models.In general, historical weather data of at least 30 years is desirable to represent annual weather fluctuations.You can then apply different climate change scenarios to these data records.The simplest approach is to assume a fixed climate change and change the data with a constant number, such as a 1, 2, 3°C increase or decrease in temperature.Similarly, rainfall and insolation can be changed at a fixed rate, such as increasing or decreasing by 10, 20, or 30%. These changes are applied to the daily water data and the crop simulation model is executed using these modified inputs.A more realistic approach is to use the output from the General Circulation Model (GCM) to modify historical weatherdata(Laletal.,1998;Hoogenboom, 2000; Mall et al.(2004).

To study the potential socio-economic effects of climate change, we need to compare 2 future scenarios with and without climate change.The uncertainties contained in such assessments include:(1) The timing, scale and nature of climate change. (2) The ability of an ecosystem to adopt naturally or through controlled interventions into change. (3) Future increases in population and economic activity, and their impact on natural resource systems. (4) How society adapts through the normal response of individuals, businesses, and policy changes.Uncertainty, long-term involvement, and the potential for catastrophic and irreversible impacts on natural resource systems raise questions about how to assess climate impacts, investments, and other policies that affect or are affected by climate change.

In India, considerable work has been done over the past 10 years with the aim of understanding the nature and magnitude of changes in the yield of different crops due to the potential of climate change.The purpose of this review is to: a) investigate the current state of knowledge about the effects of climate change on agricultural production in India, and b) discuss the uncertainties and limitations of these studies in the Indian context and identify future research needs.

1. Climate Variability and Food Production

Climaticalchangeability and occurrence of life-threatening events are major concerns for the Indian subcontinents. There is need to quantify the growth and yield responses of important crops and also identify suitable land use options to sustain agricultural productivity under this large range of climatic variations. In India, the analysis of seasonal and annual surface air temperatures (Pant & Kumar, 1997) has shown a significant warming trend of 0.57◦C per hundred years. The warming is found to be mainly contributed by the post-monsoon and winter seasons. The monsoon temperatures do not show a significant trend in any major part of the country. Similar warming trends have also been noticed in Pakistan, Nepal, Sri Lanka and Bangladesh (Ahmed and Warrick, 1996; Chaudhari, 1994; Rupakumar and Patil, 1996; IPCC, 2001). The rainfall fluctuations in India have been largely random over a Century, with no systematic change detectable in summer monsoon season. However, areas of increasing trend in the seasonal rainfall have been found along the West Coast, North Andhra Pradesh and Northwest India and those of decreasing trend over East Madhya Pradesh, Orissa and Northeast India during recent years (Rupa Kumar et al., 1992).

Extreme weather conditions, such as floods, droughts, heat and cold waves, flash floods, cyclones and hailstorm, are direct hazards to crops. More subtle fluctuation in weather during critical phases of crop development can also have substantial impact on yields. Cultivated areas are subject to a broader range of influences, including changes in commodity prices, costs of inputs and availability of irrigation water. Climate may have indirect and possibly lagged influences on harvested areas.

Mall and Singh (2000) noted that small changes in the temperature of the growing season over the years seemed to be the most important aspect of the weather that affected annual wheat yield fluctuations. Pathak et al. (2003) concluded that negative trends in solar radiation and an increase in minimum temperature resulted in declining trends in potential yields of rice and wheat in the Indo-Gangetic plains of India. In Delhi, the minimum and maximum temperatures are on an upward trend, both in the summer or 'Kharif' growing season (June-October) and in the winter or 'rabi' growing season that starts after the summer monsoon. There was also a slight downward trend in solar radiation during the Rabi and Kharif season after 1980. These changes point to a warming trend. Since solar radiation is closely linked to crop growth, any decrease in this will significantly reduce agricultural productivity. The associated increase in minimum temperatures increases the maintenance breathing needs of the crops and thus further reduces net growth and productivity (Aggarwal, 2003).

The productivity of some of the important pruning systems has either become static or shown a decrease in some places. Recent developments in the decline or stagnation of yields of the rice wheat cultivation system in the Indo-Gangetic Plain and north-west India have given rise to serious concerns in the food supply of the regions (Aggarwal et al,2000; Mall and Srivastava, 2002; Pathak et al., 2003). This trend clearly demonstrates the reduced productivity factor of rice-wheat cultivation systems. These variations in productivity trends show the effects of other biophysical and socio-economic components that need to be removed before assessing the effects of climate change and their variation on crop growth and yields.

2. Projected Climate Change Scenarios over Indian Subcontinent

Climate change is no longer a distant scientific prognosis, but is becoming a reality. Anthropogenic increases in greenhouse gas and aerosol emissions into the atmosphere lead to a change in radiation power and an increase in the Earth's temperature. The conclusion of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) is that the average surface temperature of the world population will increase by 1.4 to 3°C above 1990 levels by 2100 for low-emission scenarios and between 2.5 and 5.8°C for scenarios where greenhouse gas emissions and aerosols into the atmosphere are higher.

The UKMO GCM model (Bhaskaran et al, 1995) forecasts a total rainfall upsurge of roughly 20% and an increase in the temperature of the winter or rabi crop season by 1-4°C with increased CO2 concentration. The specific humidity increases by 19%, suggesting that the increased monsoon rains are largely due to increased moisture content in the atmosphere. The model also predicts a greater number of heavy rain days during the summer monsoon and increased variation. Lonergan (1998) estimates that India's climate could warm in conditions of increased atmospheric carbon dioxide. The average temperature change is expected to be between 2.33 and 4.78°C, double the CO2 concentrations. Relatively speaking, the temperature rise is expected to be more in rabi than in the kharif growing season. Much uncertainty is accompanied by expected rabi precipitation than kharif precipitation in the 2050s.

Rupa Kumar et al. (2003) concluded that in future scenarios of increased greenhouse gas concentrations (GHG), a marked increase in both precipitation and temperature in the 21st century indicates a marked increase in both precipitation and temperature in the 21st century, especially after the 2040s in India. In the area south of 25°N, the maximum temperature will increase by 2-4°C during the 2050s. In the northern region, the increase in the maximum temperature may exceed 4 °C. This study also points to an overall increase in the minimum temperature to 4°C across the country, which may, however, exceed the southern peninsula, northeast India and some parts of Punjab, Haryana and Bihar. Across much of the country, the number of rainy days is generally decreasing. This decrease is more in the western and central part (by more than 15 days), while near the foothills of the Himalayas (the state of Uttaranchal) and in north eastern India, the number of rainy days can increase by 5-10 days. However, an increase in greenhouse gas emissions could lead to an overall increase in the intensity of rainy days by 1-4 mm/day, with the exception of small areas in north-west India where rainfall intensity decreases by 1 mm/day. In general, all reports show changing patterns in precipitation and an increase in temperature in different crop seasons or annual base.

3. Vulnerability of crop production

It is difficult to estimate the effect of climate change on agricultural production in India due to the variety of crop systems and levels of technology used. However, the use of crop growth models is one way to study these effects and is probably the best method we currently have to do so. While many simplification assumptions must necessarily be made, these models provide an understanding of the complex interaction between the main environmental variables that affect crop yields.

Aggarwal and Sinha (1993) reported that at a CO2 concentration of 425 ppm and no temperature increase, the yield of wheat grains at all production levels (i.e. potential, irrigated and rain-fed) increased significantly. In northern India, a 1°C increase in average temperature did not have a significant impact on potential yields, but the managed and rainy yields increased in most places. A temperature increases of 2 °C in most places reduced potential wheat yields. The effect on the inquiry and rainy productivity varied by location. Natural climate variations also had a significant impact on the scale of the response to climate change. Evapotranspiration was reduced in irrigation and rain-fed environments.

Gangadhar Rao and Sinha (1994) studied the impact of climate change on India's wheat performance and showed that wheat yields decreased due to the negative effects of temperature during grain filling and ripening stages of growth. The results of this study show that crop characteristics such as the sensitivity of the duration of grain filling to temperature play an important role in determining the impact of climate change on crop productivity.

Gangadhar Rao et al. (1995) investigated the impact of climate change on the crop productivity of Sorghum in three different growth areas of Sorghum in India, namely Hyderabad, Akola and Solapur. Crop growth was simulated using the CERES sorghum simulation model (Ritchie and Alagarswamy, 1989) with climate scenarios generated by the three CMOs, namely; Goddard Institute of Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL) and United Kingdom Meteorology Office (UKMO). The simulated results indicated a decrease in the yield and biomass of sorghum in the rainy season in Hyderabad and Akola under all scenarios of climate change. After the rainy season, sorghum on Solapur showed a marginal increase in yields on stored soil water. The positive effects of increased CO2, if any, were masked by the negative effects of the expected temperature increase, resulting in shortened harvest seasons. The study also showed that the impact of climate change on the same crop will depend on the season it is grown.

Mohandass et al. (1995) used the ORYZA1 model (Kropff et al., 1994) to simulate rice production in India in the current and future climate. They predicted an increase in rice production under the used GAM scenarios. This was mainly due to an increase in crop yields during the peak season, where the fertilization effect of the increased CO2 value is more than able to compensate for the adverse effects of the increase in temperature. Although many places predicted a big drop in the harvest for the second season due to high temperatures, the relatively small proportion of total rice production this season meant that the overall impact on rice production was small.

Lal et al. (1998) examined the weakness of wheat and rice crops in north western India to change through sensitive experiments with Ceres wheat and Ceres rice models, and found that rice and wheat yields increased well below high CO2 levels (15% and 28% for a CO2 doubt). But an increase of 3.C (2.C) The combined effect of improved CO2 and thermal stress in wheat crops (rice) is 21% (4%) the increased benefits of the irrigation scheme currently underway in the region. Although the side effects of an unlikely water shortage in wheat crops are minimized to some extent below the high CO2 levels, they are largely maintained for rice crops, resulting in a net decrease in rice yields of about 20%.

Sensitivity tests of the CERES rice model for changes in co2 content (Saseendran et al., 1999) showed that the increase in CO2 content in Kerala mode leads to an increase in yield due to the fertilisation effect and also improves the efficiency of water use. Temperature sensitivity tests have shown that in a positive temperature change to 5 °C, the yield is constantly de-depilating. For every 1-degree increase, the decline in yield is about 6%. The second experiment also found that the physiological effect of ambient CO2 at a concentration of 425 ppm compensated for the loss of yield to 2 °C due to the increase in temperature.

Kumar and Parikh, 2001, assessed the functional relationship between net agricultural income and climate variables through linear, quadratic and interaction conditions to understand the climate sensitivity of Indian agriculture. They found that the overall effects of the climate change scenario on a temperature increase of 2°C and an increase of 7% precipitation are negative and about 8.4% of India's total net income at agricultural level. Rising temperatures have significant negative effects, while higher precipitation taken into account in the scenario increases net income. In general, the negative effects due to the temperature change more than compensate for the small positive effect of the change in precipitation. The estimated effects on changes in the buildings revealed that the temperature response function U-shaped is reversed, meaning that as the climate changes more, the greater the loss. The regional distribution of the impact is shown in Figure 6. The northern states of Haryana, Punjab and western Uttar Pradesh, which mainly grow wheat during the winter season, have the most negative effects with coastal areas of Tamil Nadu. On the other hand, the eastern region of West Bengal and parts of Bihar seem to benefit from future changes (Kumar and Parikh, 2001).

Rathore et al. (2001) used the CERES rice model and analysed the impact of climate change on rice production in India. They concluded that by the mid-2000s, an increase in rice in central and southern India will be possible in the expected climate change scenarios of the Lal et al. Act (1995). In north western India, yields may fall under irrigation conditions due to a significant reduction in precipitation during the monsoon season during climate change. The duration of the harvest can also be warmed in all places of the country due to the increase in temperature associated with the accumulation of greenhouse gases in the atmosphere.

These studies have shown that the direct effects of climate change will be small on kharf crops, but that kharf agriculture will become vulnerable due to the increased frequency of extreme weather conditions such as the evolution of rainy days, the intensity of rains, the duration and frequency of droughts and floods, the daily asymmetry of temperatures, the change in humidity, as well as the incidence and infectious strength of parasites. Agricultural production in RABI can become relatively more vulnerable due to higher warming, asymmetry in day and night temperatures, and higher precipitation uncertainty. The impact of climate change on Indian agriculture will be small in the near future, but in the long term, Indian agriculture can be severely affected depending on the season, level of management and magnitude of climate change.

4. Uncertainties due to Scenarios and Crop Models on Impact Assessment

Climate change impact assessments on agricultural production may be biased depending on the uncertainty of climate change scenarios, the research area, crop models used for impact assessment and management level. It is therefore very important to give due weight to these uncertainties when assessing the impact of possible climate change on crop productivity when formulating intervention strategies.

Environmental factors such as cloud cover and solar radiation on the Earth's surface will also change, but GCMs are less consistent in their predictions, especially on a regional basis (Mitchell et al., 1995; IPCC, 2001). Climate models, in general, are subject to various uncertainties, which are particularly pronounced on a regional scale. It is also known that the models are insufficient in the representation of natural processes associated with rainfall. It should be noted here that projected changes in climate components by the end of the 21st century is sensitive to assumptions about future concentrations of greenhouse gases and aerosols. Given that there is still considerable uncertainty in our understanding of how the climate system naturally varies and responds to greenhouse gas and aerosol emissions, current estimates of the magnitude of future warming are subject to future adjustments.

The study shows that the direct impact of climate change on irrigated and well-managed rice crops will always be positive in various agroclimatic regions in India despite various uncertainties. Southern and western India, which are currently relatively colder during the rice age than in northern and eastern regions, are likely to be more sensitive to climate change. As a result, current yield differences in irrigated rice crops in areas are likely to disappear after climate change.

Agarwal & Mall (2002) concluded that several studies are developing a coordinated assessment of the impact of climate change on regional and global food supply and demand. Some of them can also be applied to food policy. These studies use specific GCM-based scenarios and a specific crop model. While there is a great need for a coordinated assessment of climate change in food availability, conclusions based on average simulated grain yields and average changes in climate parameters should be carefully implemented.

5. Mitigation and Adaptation Strategies

A relatively recent weather survey of the last century in many parts of the country shows trends in warming, although statistically they may not be important, but there are many indicators that there is a sign of a moderate rise in CO2 and temperature. Despite uncertainty about the exact size of climate change on a regional scale due to crop scenarios and models in assessing the impact, assessing the potential impact of climate change on India's agricultural production under various socio-economic conditions is crucial for formulating response strategies that are practical for farmers Should be accessible and acceptable. Sustainable agriculture requires identification of appropriate response strategies. The strategies for mitigation and adaptation needed to deal with the expected effects of climate change include adapting to the date of sowing, increasing more resistant plants to climate change, and improving agricultural practices (Attri and Rathore, 2003).

Atari and Arthur (2003) proposed adaptive strategies for sustainable wheat production and ensuring food security. Adaptive measures to mitigate the potential effects of climate change included possible changes in data seeding and the selection of genotypes. Increasing seeding by 10 days in late seeding strains and delaying seeding by 10 days in normally seeded species resulted in higher yields under a changing climate, while observed

The results obtained by Mall et al (2004) on shaman option to reduce the negative effects of temperature rise suggest that postponing planting dates will be beneficial for increasing soybean yields in all places in India. Planting in the second period will also reduce the adverse effects of future surface temperature increases due to global warming in some places. However, soybean production may need a change in additional planning and management practices for the proposed change from the current major season to the second season.

However, it should be noted that changing the sowing dates is a cost-free decision which can be taken at the farmers' level; A major change in the sowing dates will probably affect the agricultural technical management of other crops grown during the rest of the year. Changes in crop sequencing, irrigation and agricultural land use may be additional options for adaptation of agriculture. Kumar and Parikh (1998 a, b) showed that even with farmers adjusting their agricultural standards and inputs in response to climate change, the loss would be significant. The loss of net operating income is estimated to be between 9% and 25% for rise in temperature of 2o C-3.5o C.

It is necessary to identify agroclimatic regions or areas vulnerable to climate change and to identify the appropriate adaptation practices to be followed in order to maintain the productivity of these regions to some extent. These adaptation strategies may include crops and cultivation systems modified to maintain soil fertility in a sustainable way and better management practices. Modern technologies in agriculture could also be beneficial with or without climate change; the government should encourage farmers to switch to newer technologies. The government should also encourage research into the development of climate-resistant crop varieties.

While the assessment of the impact of climate change in the future is very important, most of India's crops, even in irrigated environments, are very sensitive to climate difference. We had a record 75.5 MT wheat crop in 1999-2000, up from 5 MT in 1998-99. The change was largely due to the coldest weather during January to March 2000, which was conducive to grain formation and filling. Apart from policy and management, the glut and deficiency of onions and potatoes these days is an expression of the effects of climate difference. Such a difference in food production is large in rice, pulses and oilseeds, where most of the crop area is rainfed. Any change in climate in the short term will have a huge impact on low-season crops such as vegetables available to adapt for short term and adapt compared to long-term crops. Thus, the effects of climate difference in the short term are likely to be much larger than the expected impact of global climate change. So, if we can develop strategies to manage climate variation in agricultural production, the adjustable share required for climate change will probably be taken care of automatically (Agarwal, 2003).

II. LIMITATION OF STUDIES

The results given in the various studies depend on the numerous assumptions that are integrated into the simulation models of the cultures. Most of the relationships associated with the effect of temperature and CO2 on plant processes come from experiments in which the environment of the culture has changed only during part of the season. The acclimatization of the culture to changes in its environment is not taken into account in the model. Studies have shown that in some crops that grow in an improved CO2 state, there is initially a great response, but over time this response decreases and approaches the response to cultures growing below current CO2 levels. The effects of fibres, diseases and insect pests on the growth of crops, the growth and formation of the final yield are to be controlled. Which needs to be included in future studies for a better assessment of final performance.

Regarding climate change scenarios arising from theme, uncertainty relates to the difference between knowledge of natural processes and/or partial representation, simplification and assumptions in limitations, models and/or approaches due to the statistical approach of model equations, differences in the internal model and the method of simulating climate response on models or subject. Reducing the wide range of uncertainties in global and regional climate change forecasts will require significant progress in our scientific understanding of this issue in the coming years. The probability, frequency and intensity of extreme weather events should be carefully assessed. The current GCM has limited ability to predict changes in weather differences annually and in cycles, or a frequency of catastrophic events such as storms, floods or monsoon intensity, which may be equally or more important in determining crops as a tool of climate data. However, despite these limitations, these studies show significant progress in our understanding of how the future climate is.

However, the impact studies discussed in this paper do not examine, due to uncertainties in the projection of climate change, what types of technological change and adaptation measures will be carried out in the future. Projected future long-term scenarios of climate change could indicate the impact after more than 50 years, while in the meantime, several changes in Indian agriculture, such as new heat tolerance crop varieties, farm-level adaptation, changing demand, the market and changes in agricultural technologies are expected to significantly transform agricultural production in India. India's entire agricultural system could change in the coming decades due to the rapid technological changes, which are expected. Those missing from current studies need to be integrated into future studies aimed at better comprehensively assessing the impact of climate change on Indian agriculture for sustainable development, mitigation and other policy planning. Greater attention must also be paid to the effects of future extreme weather events and the impact of pests and virulence on agriculture in future research.

III. DISCUSSION AND CONCLUSION

The current simulation results from GCM are still considered uncertain. The present capacity of GCM is still not promising to predict the effects of climate change on rainfall. Moreover, the uncertainty involved in predicting extreme flood and drought events from models is great. There are significant uncertainties for India about temperature changes and the projected magnitude of rainfall. While climate models predict a change in rainfall in India by the end of the century by −24 to 15% (Red et al, 2001), regional change may be different (Rupa Kumar et al,2003). Studies on cross-field and long-term monsoon variability and annual rainfall have found that rainfall variation for the subcontinent is within the statistical range (Thapliyal and Kulshrestha, 1991; Srivastava etc., 1992). However, the analysis of last season's data actually shows a change in the warming trend in many parts of India and the rainfall pattern (not statistically significant) in different parts of the country. Therefore, it is very difficult to convince planning and development bodies to include the effects of climate change in their projects and agricultural system at present. However, 60 per cent of the total cultivated area is still raining in India and depends on the uncertainties of the monsoon. The country's food grain production during the period 2002-03 had fallen from a record level of 212.02 MT in 2001-02 to 174.19 MT due to widespread drought. Which reflects the dependence of Indian agriculture on climate despite recent technological developments. Therefore, given the potential adverse effects of climate change on agriculture, it is worth studying and analysing more in depth to assess the problems the country may face in future. We need to focus on how possible climate change will affect the intensity of rainfall, spatial and temporal variability, availability of surface and ground water for irrigation, evaporation rate and temperature in various agronomic areas. For this purpose, more studies are required on direct or indirect effects of climate change on crop development, uncertainties of onset of rainfall, spatial and temporal variability of rainfall, duration and frequency of drought and floods, availability of irrigation, change in ground water level, soil changes, coastal soil sinking due to interaction of crops and pests and rising sea levels.

Rupakumar et al. (1994) showed that there was irregularity in temperature trends related to day and night over India; The observed warming was mainly due to an increase in maximum temperatures, while the minimum temperatures remained almost constant over the past century. Rupakumar et al. (2003) also predicted that due to the increase in greenhouse gas concentrations throughout the country, a significant increase in extreme maximum and minimal temperatures is expected. This is a very important find for agriculture, since the lunchtime temperature increases the saturation deficit of the plants. It accelerates photosynthesis and fruit ripening (Papadakis, 1970). The maximum production of dry material occurs when the temperature is between 20 and 30 ◦ C, provided that humidity is not a limiting factor. When high temperatures occur in combination with high humidity, it favors the development of many herbal diseases. High temperatures also affect the metabolism of the plant. However, a high night temperature increases breathing. It favors the growth of shoot and pests at the expense of roots, stolons, kambium and fruits. It regulates the distribution of photosynthesis between the different organs of plants for the benefit of those that are usually not useful. Therefore, it is possible to include the asymmetry of temperature trends relative to day and night temperature in future studies to better evaluate crop production due to global warming. Extreme climate events, unusual temperatures at some point of development, warn us to identify suitable management options without regretting it to deal with the situation. The interaction between plants and harmful weather and socioeconomic components is relatively weak and must be strengthened.

The increase in food grain production over the past three decades has made India self-sufficient and has made a significant contribution to their food security. The later one, however, is now at risk due to increased demand from ever-increasing populations. The situation is also grim because the decline in soil fertility, the reduction in groundwater levels, increasing salinity, resistance to many pesticides, the deterioration of the quality of irrigated water and the genetic diversity of popular varieties in the agricultural sector have been rapidly reduced. However, it is of the utmost importance to preserve the natural resource. Improving the soil's organic content will ensure better soil fertility, irrigation prices in the western Indo-Ganges will ensure efforts to increase the efficiency of water use and improve other related environmental impacts. However, since this has a negative impact on revenue from the rice grain system, there is considerable socio-political resistance to its implementation. In recent years, the prospect of climate change has generated considerable research interest in trying to predict how plant production will be affected. The aim of this assessment was to provide an overview of the potential impacts of climate change on food production in India.

In future studies, considering the uncertainties discussed above and crop simulations and climate change modelling scenarios at borders, climate change assessment in Indian agriculture may be more accurate and provide a strong basis for regional policy planning . However, climate and crop models are expected to improve rapidly globally and regionally in recent decades. This is not a distant future; These models must achieve reliable regional results on the nature of climate change in response to a number of factors.

Based on various reports at this stage, it can be concluded that the agricultural effects of climate change in India are uncertain. The overall average effect can be positive or negative based on climate scenarios. The effects are quantitatively and qualitatively different depending on the level of crop, agricultural management, region and weather. In terms of seasonal impact, "Rabi" (winter season) agriculture will be more dangerous in central and southern India. However, most scenarios show that climate change will have an overall positive impact or not have a significant impact on Indian agriculture by 2050. By 2080, when the temperature rise is very big, Indian agriculture will suffer the most. In other words, it can be said that food production is not at risk before 2050 and there is no need to import food, but food production is at stake by 2080.

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*Evin Varghese. "Overview of the Impact of Climate Change on Indian Agriculture."*IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, 26(07), 2021, pp. 52-62.