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CLIMATE CHANGE AND AGRICULTURAL SUSTAINABILITY: ISSUES AND CHALLENGES IN INDIA

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Abstract: *In the present paper an attempt has been made to examine different issues related to climate change and its implications for agricultural sustainability and food security with special reference to India. The onset of industrial revolution in Europe can be said to be the starting point of environmental degradation and climate change. In post independence era India has also witnessed faster economic growth in terms of industrial output and food production (post-green revolution). The excessive CO_2 emission and release of other gases have an adverse impact on climatic conditions of India putting a serious question mark on agricultural sustainability. The doubt about agricultural sustainability has many implications for us including food security. The changing climatic conditions affect agricultural system at three levels: the crop (or livestock) level, the farm (or cropping system) level and at the food system level. Negative impacts of climate change include more frequent droughts and floods, heat stress, increased outbreaks of diseases and pests, shortening of crop growing periods etc. The adverse impact of climatic variability on agriculture production at farm level gets aggravated to the level of food shortages and rising prices which can affect food security especially for the poor and downtrodden.*

Key Words: *Climate Change, Carbon Emission, Agricultural Sustainability, Food Security.*

I. INTRODUCTION

Ecological imbalances, Environmental degradation and Climate change are many facets of the same problem and these phenomena have emerged to pose perhaps, the biggest challenge confronting the world today, and the future existence of man, animals and plants would depend on the fact as to how effectively this challenge is tackled. This is mainly because of the fact that this problem has many implications for food production, natural ecosystems, freshwater supply and health, etc. According to the latest scientific assessment, the earth's climate system has significantly changed on both global and regional scales since the preindustrial era. It is an established fact that global temperatures are rising, glaciers are melting, sea levels are rising and established climate patterns are dramatically changing, threatening many species of both flora and fauna. There is clear-cut evidence that atmospheric temperature is gradually increasing since the beginning of the industrial revolution in the 1850's. Since the onset of the industrial revolution European economy as a whole was dominated by large factories, many of them employed thousands of workers. Most of the manufacturing and transportation works relied

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heavily on steam power, and gasoline and electric motors resulting into increased pollution of all kinds and disturbed eco-system. Along with changes in production methods in different sectors, there are evidences which suggest that most of the environmental problems and the resultant global warming (of 0.1°C per decade) observed over the last 50 years are attributable to human activities. In 2013, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report concluded that "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century." The largest human influence has been emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide. The IPCC projects that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius (C) by 2100. This unprecedented increase is expected to have severe impacts on the global hydrological system, ecosystems, sea level, crop production and related processes. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India (Sathaye *et al.*, 2006).

Climate change has been defined by many in many ways. While some define it as an offshoot of Earth's natural processes, others define it as a result of human activities. Striking a balance between these two varying perspectives, climate change is defined by The United Nations framework Convention on Climate Change (UNFCCC) as "a change which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The Occasional Paper Series (3) on climate change published by Research unit of Rajya Sabha Secretariate (2008) has defined climate change as the variation in the Earth's global climate or in regional climates over time. It refers to changes in the state of the atmosphere over time scales ranging from decades to millions of years. Truly, the present changes in the Earth's climate cannot be explained alone by the natural processes that explain Earth's previous warm periods. There is a broad scientific consensus that most of the warming in the recent decades can be attributed to human activities [Intergovernmental Panel on Climate Change (IPCC), Third Assessment Report, 2001]. If humanity is, in large part, responsible for this change, then whatever choices we make today as regards production and consumption, will have a significant bearing on the climate of the future and ultimately the sustenance of lives. Although the concept of climate change has been defined in different ways; there is no denying the fact that climate change is very broad and highly complex phenomenon which embraces in its ambit many things like changes in atmosphere, temperature, sea level and ocean acidification. *Atmosphere change* denotes change in the proportion of Carbon dioxide (CO_2), Methane (CH_4), Nitric Oxide (N_20), Ozone (O_3), Cholorofloure Carbon (CFCs) and other green house gases like fluorinated gases, black carbon etc. *Temperature change* refers to changes in surface temperature, troposphere and stratospheric temperatures. *Sea level change* is related to natural phenomenon like rising sea level, flooding the coastal areas, cyclones, Tsunamis, etc. *Ocean acidification* affects Calcium carbonate ($CaCO_{3)}$ saturation which has adverse impacts on marine organism, crabs, marine mammals and changes in the ocean chemistry resulting into the loss of livelihoods of nearly 30 millions of world's poorest people who directly depend on coral reef eco system. All these phenomena associated with climate change have adverse effects living being via producing a retarding effect on food security and public health.

In the light of the above introductory paragraphs, an attempt has been made in this paper to examine the challenges of climate change for agricultural sustainability, food security and human health.

II. CLIMATE CHANGE AND SUSTAINABLE AGRICULTURE

Agriculture sector is supposed to be the backbone of the Indian economy. The agriculture sector employs nearly half of the workforce in the country. However, it contributes to about 16 per cent of the GDP and 10 per cent of the total exports. According to PRS Legislative Research Report, 2017 on State of Indian agriculture, India's production of food grains has been increasing every year, and India is among the top producers of several crops such as wheat, rice, pulses, sugarcane and cotton. It is the highest producer of milk and second highest producer of fruits and vegetables. In 2013, India contributed 25 per cent to the world's pulses production, the highest for any one country, 22 per cent to the rice production and 13 per cent to the wheat production. It also accounted for about 25 per cent of the total quantity of cotton produced, besides being the second highest exporter of cotton for the past several years. However, agricultural growth has been fairly volatile over the past decade, ranging from 5.8 per cent in 2005-06 to 0.4 per cent in 2009-10 and -0.2 per cent in 2014-15 which has substantially to do with the vagaries of monsoon. There is a big question mark as to how far the growth of Indian agriculture is sustainable owing to the fact that Indian agriculture is fundamentally dependent on weather conditions for its productivity. Moreover, the agricultural practices adopted since the onset of green revolution has also put in danger the sustainability of Indian agriculture. As a result of adopting various measures for agricultural development including green revolution the crop production has increased manifold in India but it has also resulted into various forms of land and water degradation. Large scale ecological losses were reported in crop land, grass land and forest land, such as soil erosion, soil alkalinity and salinity, micronutrient deficiency, water logging and fast depletion and contamination of ground water (Singh, 2015).

Sustainable agriculture is the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species. Sustainable agriculture seeks to provide more profitable farm income, promote environmental stewardship, and enhance quality of life for farm, families and communities. The frequent climate changes associated with low rainfall and increased warming have posed serious threat to sustainable agriculture. Low rainfall has resulted in ground water depletion because of draining of water for irrigation and other purposes and increased warming has negatively affected the yield of rice and wheat (Pattanaik, 2010). According to Sinha and Swaminathan (1991) an increase of 2 degree centigrade temperature could decrease the rice yield by about 0.75 ton/ha in the high yielding areas and a 0.5 degree centigrade increase in winter temperature would reduce wheat yield by 0.45 ton/ha. Sinha and Swaminathan (1991) have further observed that wheat and rice are the most important crops from the point of view of maintaining a sustainable nutrition security system for India. The implications of climate change deriving from tropical deforestation, particularly as concerns temperature and precipitation, with reference to the yield of wheat and rice in different parts of India should hence be studied carefully. Any possible positive gain arising from increased CO_2 concentration

is likely to be offset by the yield decline induced by higher temperature and shorter growing period. The Indian Council of Agricultural Research (ICAR) has estimated that annual wheat output may decline by four to five million tons with every 1°C rise in temperature. According to A. K. Singh, Deputy Director-General (Natural Resource Management) of the Indian Council of Agricultural Research (ICAR), medium-term climate change predictions have projected the likely reduction in annual crop yields due to climate change between 4.5 per cent and 9 per cent by 2039. A 1°C rise in temperature may reduce yields of major food crops by 3-7 per cent. Studies done at the Indian Agricultural Research Institute indicate that for every 1°C rise in the temperature in the growing season, there is possibility of loss of 4 – 5 million tons of wheat. It was also revealed that showed that a 2°C increase in temperature would decrease wheat yields in most places in India (Agarwal and Sinha, 1993). According to Rao and Sinha (1994) wheat yields could decrease between 28-68 per cent due to climate change without taking into account the CO_2 fertilization effects. Saseendran *et al.* (2000) have stated that an increase of 1°C in the mean annual temperature tends to decrease rice yield by about 6 per cent. Horticultural crops are more vulnerable to changing climatic conditions than cultivable crops. Temperature changes will specifically affect field vegetables with more gravity. Water deficits owing to climate change will have a direct effect on the productivity of fruits and vegetables (Zarin, 2007). Impact of climate change on agricultural productivity is very location specific which includes soil types, crops and even the socio-economic conditions of the farmers. The scientists, policy makers and the governments are unanimous on the view that as these changes take place, agriculture is getting affected adversely, and the threat of decrease in food production is becoming very real. Many developing countries including India would be hit hardest in the process. It has already been witnessed that the pattern of monsoon in India has become unpredictable, uncertain and erratic. Scientists attribute these changes to climate change. Agriculture is highly sensitive to climate variability and weather extremes, such as droughts, floods and severe storms. Therefore, agriculture production in many countries, including India will be impacted by climate variability and ultimately the sustainability of agriculture itself has come into question. It is estimated that greater loss is expected in Rabi as compared to Kharif crops. By 2020 in some African and Asian countries, yield from rainfed agriculture could be reduced by up to 50 per cent. The worst affected would be millions of small and marginal farmers and people who are already the most vulnerable. Rising sea levels due to climate change would force communities in low-lying coastal areas and river deltas to move to higher ground levels. Similarly, increase in frequency of droughts due to climate change would force farmers and pastorals, who rely on rainfall to raise their crops and livestock, to migrate to other areas in search of land and water. Climate Change is likely to lead to some irreversible impact on biodiversity. Approximately 20 to 30 per cent of the species assessed so far are likely face the threat of extinction. Several other studies (Babu and Bhalachandran, 2009) have also produced evidence that climate change will not only depress agricultural productivity but it will also add several conflicting pressures on agricultural production. It will affect agricultural sector in the Indian sub-continent in many other ways. Impacts on agriculture due to climate change have received considerable attention in India as they are closely linked to the food security and poverty status of a vast majority of the population (Kumar, 2009). It will affect agriculture productivity directly through higher temperatures, greater crop water demand, more variable rainfall, cold spells and extreme climate events such as floods and draughts.

II (i) Status of CO_2 Emission in the Major Countries

In the light of the observation made by Sinha and Swamnathan (1991) and others researchers regarding CO_2 emission, global warming and its impact for agricultural sustainability, it is appropriate to have a look at Table 1 depicting the trend in per capita CO_2 emissions in different countries. The figure of USA and Japan show declining trends but other countries like China, Russia and India are seen to be emitting more in terms of per capita CO_2 emission. USA per capita CO_2 emissions was 23.3 MT in 2004 which was reduced to 16.5 MT in 2014. Similar situation was observed in case of Japan also. However, per capita CO_2 emissions in case of China, Russia and India have depicted a rising trend.

Table 1
Emission of CO_2 in the Major Countries

Countries	*CO_2 Emission in per capita (in metric ton)*									*CO_2 Emission in 2014 (Metric ton)*	*Change in 1990 to 2014*
	1990	*2000*	*2004*	*2006*	*2008*	*2010*	*2011*	*2012*	*2014*		
USA	19.6	20.6	23.3	18.67	18.5	17.6	17.3	16.3	16.5	5,330	-3.1
EU	9.2	8.4	8.3	8.3	8.1	7.7	7.1	7.1	6.7	3,420	-2.5
CHINA	2.1	2.8	3.6	4.18	5.7	6.2	7.2	7.2	7.6	10,590	5.5
JAPAN	9.5	10.2	13.0	10.14	9.91	8.9	9.8	10.8	10.1	1,280	0.56
RUSSIA	16.5	11.3	10.0	11.03	11.9	11.8	12.8	12.7	12.4	1,770	-3.7
INDIA	0.8	1.0	1.0	1.29	1.4	1.7	1.6	1.6	1.8	2,340	1.1

Sources: Population Data, UNPD, 2013 (United Nations Population Divisions) and Trends in Global CO_2 Emissions: 2015 Report © PBL Netherlands Environmental Assessment Agency, The Hague, 2015.

The above data shows China's CO_2 emissions to be twice as high as those in the United States. China's CO_2 emissions have grown extraordinarily since it started its industrialisation process and after it joined the World Trade Organization in 2003. In 2008 China produced over 1.38 billion metric tons of hydraulic cement, almost half of the world's production. Emissions from cement production account for 9.8 per cent of China's 2008 total industrial CO_2 emissions. India experienced dramatic growth in fossil-fuel CO_2 emissions averaging 5.7 per cent per year and becoming the world's third largest fossil-fuel CO_2-emitting country. India's CO_2 emissions in 2014 continued to increase by 7.8 per cent to about 2.3 Gt CO_2. This increase, about 170 million tons, made India the largest contributor to global emissions growth in 2014. India is the fourth largest CO_2 emitting country, following closely behind the European Union, and ahead of the Russian Federation. Similarly, the quantity of methane gas in the atmosphere has increased by 145% since the mid 19th century. This increase is a result of gas produced by livestock and paddy fields. The increase in quantity of these gases leads to what is known as the green house effect. The potential for soils to support agriculture and distribution of land use will be adversely affected by changes in temperature and climate and the soil water balance. The effect of increased temperature and CO_2 levels on arable crops will be broadly moderate but more severe for horticultural crops. Field vegetables will be adversely

affected by temperature changes as water deficits will directly affect fruit and vegetable production. Further, Poultry and pigs could be exposed to higher incidences of heat stress influencing productivity. It will also result in increase in disease transmission by faster growth rates of pathogens in the environment.

III. INDICATORS OF AGRICULTURE SUSTAINABILITY

Sustainability of agriculture is a complex phenomenon. A large number of indicators have been developed but they do not cover all dimensions and levels. Some argue that the concept of sustainability is a "social construct" (David 1989; Webster 1999) and is yet to be made operational (Webster 1997). Beus and Dunlop (1994) considered agricultural practices such as the use of pesticides and inorganic fertilizers, and maintenance of diversity as measures of sustainability. Gowda and Jayaramaiah (1998) used nine indicators, namely integrated nutrient management, land productivity, integrated water management, integrated pest management, input self-sufficiency, crop yield security, input productivity, information self-reliance and family food sufficiency, to evaluate the sustainability of rice production in India Reijntjes *et al.* (1992) identified a set of criteria under ecological, economic and social aspects of agricultural sustainability. Ecological criteria comprises the use of nutrients and organic materials, water, energy, and environmental effects, while economic criteria includes farmers' livelihood systems, competition, factor productivity, and relative value of external inputs. Food security, building indigenous knowledge, and contribution to employment generation are social criteria (Rasul and Thapa 2003). The concept of sustainability centre on the need to develop agricultural technologies and practices that: (i) Do not have adverse effects on the environment; ii) Are accessible to and effective for farmers; and (iii) Lead to both improvements in food productivity and have positive side effects on environmental conditions. The main goal of Agricultural sustainability centre on the following factors: Increase grain yield, ensure food security and eliminate famine; increase peasants' income, eliminate poverty and stimulate comprehensive agricultural development; Protect and enhance the environment and natural resources; Control the negative effects of climate change; Improvement in the welfare and quality and Quantity of Human, wildlife and farm animals; Minimize use of non-renewable resources and use green energy

The key principles for sustainability may be:

i) To integrate biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes,

ii) To minimise the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers,

iii) To make productive use of the knowledge and skills of farmers, thus improving their self-reliance and substituting human capital for costly external inputs, and

iv) To make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

IV. CLIMATE CHANGE AND WATER MANAGEMENT

Drought is expected to increase in frequency and severity in the future as a result of climate change. It can be caused by not receiving rain or snow over a period of time mainly due to global warming. **A drought is a long period of dry weather, when no rain falls for weeks, months or even years.** Drought can have serious health, social, and economic impacts**.** Drought often creates a lack of clean water for drinking, public sanitation and personal hygiene. Where temperatures are higher, losses of water from soil and reservoirs due to evaporation are likewise higher than they would otherwise be. **Many parts of the world expect drought every year.** A shortage of water makes water management a crucial part of protecting both the environment and the economy in India. Watersheds heavily influenced by groundwater, rates of surface water and groundwater exchange can also change along a river reach The process of watershed development consists in harvesting rainwater wherever it falls, regenerating the environment, increasing green cover and adopting sustainable land and husbandry practices in the watershed. It implies making bunds, digging trenches, building gullies etc in a way that will arrest the rapid water runoff from hill slopes to the ground. This is necessary because during the days of rainfall, the tendency of water is to gush down the slopes and also take the top soil cover along with it. This means that there is no water conservation and precious fertile soil is lost due to erosion. When this flow is reduced or made to go through steps, water percolates into the ground at various spots and increases the underground water table. At the bottom of the hills, it collects to form water reservoirs. And while flowing down slowly it helps turn patches of land green. Watershed provides safe drinking water, provides food, enables us to adapt to the impacts of climate change more easily by cooling the air and absorbing greenhouse gas emissions, and provides natural areas for people to keep active and recharge our batteries. Watershed produces energy and supplies water for agriculture, industry and households. Forests and wetlands help to prevent or reduce costly climate change and flooding impacts, manages drought, contributes to tourism, fisheries, forestry, agriculture and mining industries and introducing sustainable agricultural practices for hilly and plan areas.

V. CLIMATE CHANGE AND FOOD SECURITY

It has already been stated above that agriculture is the largest source of livelihood to Indian people. Besides providing the source of livelihood to farmers and labourers, the agricultural sector also addresses food security for the nation. The Food and Agricultural Organisation (FAO) of the United Nations defines food security as a situation where all people have, at all times, physical and economic access to sufficient, safe and nutritious food that meets the dietary needs and food preferences for a healthy and active life. Despite high levels of production in the country, 15 per cent of the population continues to be under-nourished, as per 2014 estimates (FAO, 2015). India enacted the National Food Security Act in 2013 which aims to provide food and nutritional security to people by ensuring access to adequate amount of quality food at affordable prices. Under the 2013 Act, persons belonging to certain categories are provided with food grains (wheat, rice and coarse cereals) at subsidised prices. As of 2015, 68 per cent of the population, i.e. 81 crore persons (of which 77 per cent are in rural areas and 23 per cent in urban areas) are covered under the Act. Over the past few decades, with increasing per capita income and access to a variety of food groups, the consumption pattern of food in the country

has been changing. Dependence on cereals for nutrition has decreased and the consumption of protein has increased. Sources of protein include pulses, meat, seafood, and eggs, among others. According to a Finance Ministry report on incentivising the production of pulses in the country, poor levels of nutrition suggest that increasing the consumption of proteins should be the policy priority for the government. The report estimates that the cost of pulses as a source of protein is lower than other sources. Under the current domestic scenario, India is facing a shortage of pulses which is being plugged by imports. Food Security issues depend on availability, accessibility and affordability of food to all the people round the year. Food availability must be improved by providing the irrigational facilities. Accessibility and affordability will improve by the policies for enhancing minimum agricultural wages, absorption of food by the better health facility and better transport and marketing networks (Deshpande, 2017). Past year to year variations in climate and agricultural outcomes, yields of major crops in India are projected to decline by 4.5 to 9 per cent within the next three decades. (Guiteras, 2007). Climate Change reduces quantity and quality of crop produced; Crop and fodder productivity, livestock health and fish catch; increasing susceptibility to pests. Direct crop damages due to water logging results into nutrient loss, frost, hail storm, salinity and water stress, crop acreage and diseases, shift in cropping patterns. This also directly affects the livelihoods and food security of millions of people due to impacts on agricultural productivity. The impacts of climate change will include changing agricultural productivity and livelihood patterns, economic losses, and impacts on infrastructure, markets and food security. Diseases affecting livestock or crops can have devastating effects on food availability. In totality, climate change affects all three components of food security-Availability, Accessibility and Affordability.

VI. ACTIONS REQUIRED FOR POLICY IMPLICATIONS

For sustainable environment and improvement of deteriorating climatic condition, developed, under developed or developing Countries must join hands and make genuine, relentless and collective efforts to reduce the carbon emissions. Developed countries are more responsible, so they must play more active and judicious role to protect the environment. There is need of concerted efforts by all countries according to the principle of proportionate share. World Bank should establish the climate fund and ask for proportionate share by the countries or may fix as per GNP. Every country should formulate Forest Management Policies. Every country has fix emission target every five years and it should be monitored by World Bank. For sustainability of agricultural production is required to Nutrient or fertilizer balancing. Proper fertilization is an essential condition for high productivity and crop quality. Cultivation of crop requires Rotation pattern, fuel efficient technology and clean sources of energy. For this there is need to promote organic farming, which has the potential to reduce the emission of Green House Gases and improve the soil fertility by retaining crop residues and reducing soil erosion. It has the potential of reducing the use of irrigation water and sequencing CO_2. Organic farming has a stabilizing effect on the soil structure, improving moisture retention capacity and protecting soil against erosion. For food security there is need to establish of a water security system, and improve the traditional water harvesting. Improved agriculture and Irrigation practices achieve 'more crop per drop'. India needs Income Security not Food Security, needs empowerments not entitlement. Public Distribution System should be governed properly and

there is need to maintain Rainbow Revolution. But sustainable agriculture, especially organic agriculture, itself cannot meet India's food demands, primarily because of low yields and insufficient organic fertilizer but in the long run organic agriculture will be better, because of being environmentally, socially and economically sustainable in the long run. The government can encourage farmers by providing some financial assistance in initial year and need to promote and establish the market for organic products. Several countries (USA, Europe, and Germany) have proved that organic farming increases the crop productivity, better and nutritious food with sustaining the eco-system.

VII. SUMMARY AND CONCLUSION

Climate change has emerged to pose perhaps, the biggest challenge confronting the world today, and the future existence of man, animals and plants would depend on the fact as to how effectively this challenge is tackled. The problem of climate change has many implications for food production, natural ecosystems, freshwater supply and health, etc. According to the latest scientific assessment, the earth's climate system has significantly changed on both global and regional scales since the preindustrial era. It is an established fact that global temperatures are rising, glaciers are melting, sea levels are rising and established climate patterns are dramatically changing, threatening many species of both flora and fauna. There is a big question mark as to how far the growth of Indian agriculture is sustainable owing to the fact that Indian agriculture is fundamentally dependent on weather conditions for its productivity. Moreover, the agricultural practices adopted since the onset of green revolution has also put in danger the sustainability of Indian agriculture. As a result of adopting various measures for agricultural development including green revolution the crop production has increased manifold in India but it has also resulted into various forms of land and water degradation. Large scale ecological losses were reported in crop land, grass land and forest land, such as soil erosion, soil alkalinity and salinity, micronutrient deficiency, water logging and fast depletion and contamination of ground water. The frequent climate changes associated with low rainfall and increased warming have posed serious threat to sustainable agriculture. Low rainfall has resulted in ground water depletion because of draining of water for irrigation and other purposes and increased warming has negatively affected the yield of rice and wheat. In totality, climate change affects all three components of food security-Availability, Accessibility and Affordability. For sustainable environment and improvement of deteriorating climatic condition, developed, under developed or developing Countries must join hands and make genuine, relentless and collective efforts to reduce the carbon emissions. Developed countries are more responsible, so they must play more active and judicious role to protect the environment. There is need of concerted efforts by all countries according to the principle of proportionate share. Sustainable agriculture and food security are two important aspects of ensuring "Food for All" and "Food Guarantee for All".

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