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7. Potential of Agriculture in Mitigating Climate Change

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7.1 Introduction:

Climate change is misunderstood as the changes in the weather. There is little consensus on the definition of adapting to climate change in existing debates or on the criteria by which adaptation actions can be deemed successful or sustainable. Intergovernmental Panel on Climate Change defines climate change broadly as “any change in climate over time whether due to natural variability or as a result of human activity”. NASA’s version of climate change is, “a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth’s atmosphere”.

There are four major key climate change indicators – greenhouse gas concentrations, sea-level rise, ocean heat, and ocean acidification that set new records in 2021. This is yet another clear sign that human activities are causing planetary-scale changes on land, in the ocean, and the atmosphere, with harmful and long-lasting ramifications for sustainable development and ecosystems, according to the World Meteorological Organization’s new report.

7.2 Causes of Climate Change:

Both anthropogenic and natural activities are the causes of climate change. Anthropogenic emissions of greenhouse gases are partially responsible for the observed increase in global temperature since the mid-20th century (Kaufmann et al., 2011). The solar energy is absorbed by the earth’s surface and then reflected into the atmosphere as heat. As the heat goes out to space, greenhouse gases absorb a part of the heat. They radiate the heat back to the earth’s surface, to another greenhouse gas molecule, or space (The Greenhouse Effect).

The concentration of greenhouse gases such as methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) has increased by 150%, 40%, and 20%, respectively since 1750 (IPCC, 2014).

The biggest concern scientists have is about the emission of CO_2 since it is about 75% of the total global emission of greenhouse gases. Before 1750, CO_2 emissions from fossil fuels were negligible, but they increased rapidly with industrialization (IPCC, 2001). The agriculture sector also contributes 15% of total emissions, primarily methane and nitrous oxide (Malhi et al., 2021). Aerosols play a crucial role in terms of climate change. It has a direct impact on the climate by absorbing and reflecting sunlight or indirectly through cloud modification (Mitchell *et al.*, 1995). The primary anthropogenic sources of aerosols are Sulphur dioxide emitted by the burning of vegetation and the combustion of fossil fuel (Kiehl and Briegleb, 1993).

Natural activities such as volcanic eruptions, El Nino-Southern Oscillation (ENSO) cycle, albedo, and many others are the possible natural cause of weather and global climate change on many timescales.

- Explosive volcanic eruptions discharge large amounts of gases, ash, and fine explosive grained debris into the sky, which influence climatic patterns for years. The Sulphur gases convert to Sulphate aerosols, sub-micron droplets containing about 75% sulfuric acid (Bethke *et al.*, 2017).
- ENSO is a significant climatic event that occurs on Earth and can alter global air circulations, resulting in temperature and precipitation variations. It is divided into three phases: "El Nino" and "La Nina," as well as "Neutral." The warm phase of ENSO is El Nino, and the cold phase is La Nina. Between the continuums is neutral (Gergis and Fowler, 2009). The "Southern Oscillations," a large-scale variation in atmospheric pressure across Indonesia and the tropical Pacific Ocean, were identified by Sir Gilbert Walker in the 1930s (Trenberth and Hoar, 1997). This ENSO brings severe climatic changes.
- Albedo is the measurement of the reflectivity of sunlight by any object (Hall and Qu, 2006). It is measured from 0 to 1 on a scale or in percentage. A higher value of albedo means higher reflectivity while a lower value means lower reflectivity of sunlight. The albedo of forests varies from 5% to 15%, and that of water ranged between 2 to > 99% (Bonfils et al., 2001; Ridgwell *et al.*, 2009). The overall albedo is 0.30. But the greenhouse effect results in variations in albedo or earth's equilibrium temperature and causes climate change.

7.3 Effects of Climate Change:

7.3.1 Food Security:

The world's population grew at a faster pace than in the previous century. The present human population is 7.6 billion, with 8.6 billion estimated by 2030 and 9.2 billion by 2050 (Foresight, 2011). Climate change harms soil, water, and crops, all of which are linked to food security. The depletion of the soil organic carbon pool, as well as the available water capacity, are all effects of climate change on soil quality. The changing climate has an impact on the soil through crusting and compacting. Erosion and salinization are two issues that need to be addressed (Gillis, 2013). The degradation of soil ultimately leads to a lower yield of crops and also poor quality of food. Due to this, many people will start suffering from major health issues.

7.3.2 Ozone Depletion:

Ozone (O_3) is a trioxygen substance identified by C.F. Schonbein (1839) of Germany (Rubin, 2001). First, the GHGs like CFC, HCFC, and SF6 are the GHGs and are directly involved in ozone depletion. Secondly, climate change is expected to cause a 0.6 to 4-degree Celsius increase by 2050. It has led to rapid cooling of the stratosphere and ozone depletion in the lower polar stratospheric region (Hartmann et al., 2000). Chlorine can destroy the atomic structure of $O_{3,}$ and at the same time, human-made chlorofluorocarbons (CFCs) have a long atmospheric residential period and it could be the possible reason for the stratospheric O_3 destruction (Molina and Rowland, 1974). The depletion of O_3 has led to increasing pressure differences at mid- and high-latitudes, as well as a shortening of the easterlies toward Antarctica, resulting in alterations in atmospheric and oceanic circulations, as well as changes in surface temperature, wind, and precipitation patterns (Solomon et al., 2016). Flooding and protracted droughts, forest fires, and oscillations of inaccessible water have all resulted from these changes (Wu and Polvani, 2017; Bai et al., 2016; Mariani and Fletcher, 2016; Holz and Veblen, 2011).

7.3.3 Extreme Weather Events:

The changing climate resulted in the warming of the ocean, melting of polar ice and glaciers, change in sea level, strong hurricanes with intense rainfall, and ocean acidification. The warming of the ocean leads to surplus water vapour that further encourages the formation of powerful hurricanes with heavy rainfall. In addition, the melting of the glaciers raises the amount of seawater in the ocean. The coastal storm wreaked havoc on the increased seawater levels combined with simultaneous rainfall resulting in the emergence of devastating floods and storms. The ocean has absorbed about a third of the CO_2 released by anthropogenic activities. The constant rise in CO_2 absorption caused by humans causes a drop in ocean pH and disrupts the normal chemical equilibrium in saltwater. It also lowers the calcium carbonate level (Doney et al., 2009; Feely *et al*., 2004). The lower value of pH of marine water is very harmful to the survival of aquatic animals.

7.3.4 Insect Pest and Disease Development:

Temperature variations have had a significant impact on insect activity, distribution, and disease transmission, while moisture content, temperature, and precipitation have all had a significant impact on plant illness induced by the specific carrier (Coakley et al., 1999). Every 2°C increase in temperature has the potential to hasten the end of the pest's life cycle (Yamamura and Kiritani, 1998). Insects and pests respond to climate change in a variety of ways, including geographic distribution.

Temperature variations lead to the evolution of species with increased virulence, and pest shifts due to changes in food availability, which result in phenology changes that influence community composition and dynamics (Moore and Allard, 2008). The increased CO_2 levels are responsible for the emergence of serious threats of polyphagous pest Spodoptera litura (Kranthi et al. 2009). Various fluctuations in temperature, moisture regimes, and day lengths might have interrupted diapause activities in some insect species (Parmesan, 2006; Tripathi et al., 2016).

7.3.5 Agriculture Sector:

According to an old report by the World Health Organization (WHO), climate change has significantly affected the present agricultural systems, and in the future, the impact can be even more threatening. A temperature rise of 1°C will reduce the wheat yield by 5% to 10% or more (Asseng et al., 2015). Barley yields will decrease significantly between 25% and 80% in the future, as per the climate projections model (Cammarano *et al.*, 2019). Agricultural productivity in Africa's tropical and subtropical regions is more vulnerable to global warming and at risk than in temperate regions. In India, for example, climate change could result in a 40% reduction in agricultural productivity by the 2080s (IPCC, 2007a, b). Climate change impacts, such as rising temperatures, droughts, floods, plant diseases, pests, and other factors, may have a detrimental impact on net crop production. Variability in interannual monsoon rainfall causes droughts and floods on a massive scale in India, wreaking havoc on the country's agricultural production and economy (Parthasarathy *et al.*, 1992; Selvaraju, 2003). Due to India's fast-rising population, current infrastructure, methodologies, crop selection, and cropping systems must be altered to address these climate change barriers.

We need more than words to defend Earth since climate change is destined to have an alarming impact on our ecosystem and our way of life as we know it. Bold climate action is required. This strategy calls for comprehensive climate laws to cut greenhouse gas emissions and slow global warming, as well as extraordinary adjustments in how we think about our consumption and a worldwide movement headed by climate activists. Climate change has affected all aspects of human societal development as a global problem, especially agriculture, which is closely related to human survival (Dong et al., 2015). Agricultural production is facing an unprecedented threat that is becoming more serious as climate change develops. Agriculture is responsible for around 10.5% of total GHGs in the United States, but it also provides the potential to cut emissions and extract carbon dioxide from the environment.

7.4 Agriculture Strategies in Mitigating Climate Change:

Agriculture is both a victim and an abettor of climate change. Serious attention is thus required, not only to enhance its adaptation capacity but also to exploit its mitigation potential as a carbon sink (Kang and Banga, 2013). Smart agriculture practices are the main component of climate change mitigation strategies (Doria *et al.*, 2009). Smart agricultural practices that control the rate of land degradation and soil fertility loss due to drought, salinity, waterlogging, and soil erosion are discussed in the chapter.

7.4.1 Conservation Agriculture:

The basic concepts of conservation agriculture are minimal soil disturbance, crop rotation, and soil cover lay the way for sustainable agriculture approaches. Conservation agriculture can reverse the years of soil degradation caused by conventional tillage by minimizing soil traffic, increasing crop diversity, and maintaining soil cover. Furthermore, conservation agriculture reduces GHG emissions, fertilizer consumption, and increases carbon absorption in the soil (Pisante *et al.*, 2014). No-till methods have also been promoted as a carbon-sequestering alternative to traditional tillage. However, the influence of no-till cultivation on climate change mitigation is exaggerated, as the additional organic carbon in no-till agriculture is relatively minor (Powlson *et al.,* 2014).

7.4.2 Micro-Irrigation Technology:

The use of micro-irrigation technology to cultivate aerobic rice is a viable option for long-term rice production. It also contributes to the reduction of methane emissions from rice fields. Aerobic rice also has a big role to play in future climate change mitigation, as it saves 73% of irrigation water needed in field preparation and 56% of water utilized during crop growth (Parthasarathi *et al*., 2012). A limitation of freshwater accessible for irrigation in the western United States, China, and south, west, and central Asia might result in the conversion of 20-60 million ha of irrigation land to rained land, resulting in a loss of 600-2900 kcal in food output (Elliott *et al*., 2014). But micro-irrigation technology such as sprinkler irrigation and drip irrigation can help mitigate and adapt to climate change, and provide sustained economic benefits.

7.4.3 Leaf Colour Chart (LCC):

Farmers' improper fertilizer management has resulted in reduced nitrogen use efficiency in north-western India. To increase fertilizer efficiency, a leaf colour chart (LCC) was shown to be highly useful. The resulting rice yield was on par with the recommended blanket dose of 120 kg N/ha after fertilizer treatment when the LCC showed less than 4 shades (Singh *et al*., 2007). Fertilizer application at LCC 4 reduced methane and nitrous oxide emissions by 11% and 16% in rice and 18% fewer nitrous oxide emissions in wheat as compared to standard N fertilizer application (Bhatia *et al.*, 2012).

7.4.4 New Varieties of Plants:

Plant breeding to create new varieties is one technique to cope with environmental pressures. This will necessitate germplasm selection, breeding cycle shortening, and multi-location trials to determine a variety's fitness for the target environment (Atlin *et al*., 2017; Chhogyell *et al.,* 2016). As the frequency and intensity of abiotic stress are expected to rise as a result of climate change, developing stress-tolerant cultivars is critical as a mitigation approach. The ability to incorporate the SUB 1A gene into multiple high-yield rice varieties marketed in South Asian countries has been facilitated by the cloning of the gene in rice plants. After being submerged for 18 days, these submergence-tolerant types provide a better yield than the original variety (Gregorio *et al.*, 2013).

7.4.5 Climate-Smart Agriculture Technology (CSAT):

Laser land leveling (LLL), weather-advisory services, and crop insurance are the most-preferred climate-smart agriculture technologies of the eastern Indo-Gangetic plains (IGP), while the farmers of the western IGP mainly prefer direct seeding, LLL, zero tillage, crop insurance, and irrigation scheduling (Taneja *et al.*, 2019). In Pakistan's Punjab region, climate-smart agriculture methods were studied, and increased cotton productivity was observed, as well as higher returns and resource efficiency (Imran *et al.*, 2018). Climate-smart solutions that either give nutrients or water or support soil structure are the most efficient. Some technologies, such as half-moons, stone bunds, and zai, as well as nutrient application, are suitable for maintaining food production and securing smallholder farmers in semi-arid West Africa (Zougmore *et al.,* 2014). These mitigation measures offer a lot of promise for mitigation and adaptation. They are, however, dependent on a technology's fit for the region, people's perceptions, economic viability, and technical intricacy. Furthermore, these tactics function well when a variety of interventions are utilized in tandem with one another.

7.4.6 Agroforestry System:

Agroforestry systems are mostly preferred diversified systems of tropical small farmers that combine the production of livestock or food crops with the growth of trees for timber, fuel, or other tree products. Agroforestry appears to have a lot of potential for boosting above-ground and soil carbon stocks, reducing soil erosion, degradation, and GHG emissions (Mutuo *et al.,* 2005). Agroforestry systems have a greater capacity for carbon sequestration than pastures or field crops. This is because planting trees in croplands and pastures usually results in more net above- and below-ground carbon sequestration (Albrecht and Kandji, 2003). It provides litter for organic material and soil nutrients, reducing the need for synthetic fertilizer (Montagnini and Nair, 2004). It was estimated that the C sequestration potential of agroforestry was 2.6, 3.9, 6.1, and 10 Mg C/ha/yr for the semi-arid, temperate, sub-humid, and humid regions respectively (Nair *et al.,* 2009). In comparison to annual cropping systems, agroforestry methods in the humid tropics were able to decrease N_2O and CO_2 emissions from the soils while simultaneously increasing the methane sink strength.

7.4.7 Traditional Farming:

Soil carbon sequestration is enhanced through traditional farming such as increased application of organic manures, use of intercrops and green manures, incorporation of trees within farms or in hedges, etc. (Stigter *et al.*, 2005). Estimates of 3.5-4.8 Gt CO_2 reductions by carbon sequestration (approximately 55-80% of total GHG emissions from agriculture) and a reduction of N_2O by two-thirds are noticed through organic agriculture (Niggli *et al.*, 2008). Traditional systems also may reduce significant GHG emissions and therefore, may contribute to mitigating global warming (Tscharntke *et al.,* 2005).

7.4.8 Shifting Crop Sowing Date:

Changing the sowing time minimized the negative effects of high temperatures on the inflorescence stage and seed shed, and is recommended as an adaptation technique to address such difficulties (Singh *et al.*, 2013). The optimum sowing dates for wheat have been identified as October 22-28 in the north-eastern part, October 24-30 in the central region, and October 21-27 in the south-western region of Punjab, India (Sandhu *et al.*, 2019). In some parts of Brazil, modifying the sowing date proved a viable strategy for reducing the detrimental effects of warming on soybean yields, but only when planting was delayed relative to the suggested time (do Rio et al., 2016). Due to financial repercussions and a lack of management measures, African farmers are extremely sensitive to climate change (Biber-Freudenberger *et al.,* 2016). Farmers in Sub-Saharan Africa who use sequential cropping methods and alter planting dates according to climate had the lowest crop yield loss (Verchot *et al.*, 2007). These simple adaptation strategies like changing planting times have the potential to decrease the impact of climate change (Aggarwal, 2008).

7.5 Conclusion:

Climate change is expected to result in significant economic losses on both the micro- and macro-levels. As the world's population rises, so does the strain on agriculture to maintain food and nutritional security, which is exacerbated by climate change. The future of climate change and its consequences are very uncertain, which makes planning for mitigation complex. This necessitates the development of climate-resilient technology based on a regional multidisciplinary approach. Suitable cultivars that can respond to environmental fluctuations, as well as planned agronomic management and crop pest control, must be created. Farmers must be educated about various climate-smart technology and trained to make their adoption possible. These solutions considerably mitigate the negative effects of climate change on crops and the environment.

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