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Climate Smart Agriculture: An Approach for Sustainable Food Security

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Climate change including extreme weather conditions which are representing challenges to agriculture of developing countries and impact the global food security. Crop production is influenced by long-term trends in precipitation, temperature, inter-annual climate variability, and extreme weather events. The crop plant suffers from different types of stresses at each developmental stage and each plant have different stress tolerating ability (Dwivedi *et al.*, 2018). It is expected that world population will reach about 2.5 billion by 2050, in developing countries of the world. Agriculture is a key source of employment and income for about 65% of the world's poor population residing in the rural areas but at present more than 20% of the population falls on an average, in the category of food- insecurity (Ebert, 2021). Enhancing agricultural productivity and incomes in the small-scale production sector is very important to mitigate poverty and achieve food security, as a key component and driver of economic transformation and development, and within the wider perspective of urbanization and advances in the non-farm sector. It is estimated that globally by 2050, agriculture sector must have to expand by 60% to meet the increasing demand due to continuously increasing human population, and it can only be possible by increasing crop productivity under climate change (Ebert, 2021)

Temperature Shifts under Climate Change

Change in temperature can occur in different forms like fluctuation in overall average temperature, changes in the day and night temperatures, changes in time, duration and intensity of extreme cold or hot weather. Generally, plants have been more vulnerable to the elevated temperature during the reproduction as well as grain filling or ripening stages. Response of plants to increasing temperature is species specific and facilitated by photosynthetic activity for the accumulation of plant biomass which control the plant growth, as well as managed by all changes in plant morphology and physiology that occur during all day. All kind of temperature stresses have their different impacts on harvesting time as well as on productivity of the crops. A different kind of response mechanism is needed to adapt for these effects it is reported that an increase of 1 °C in average temperature can cause the reduction of 5-10% in major food crops (Jarvis *et al*., 2020).

Climate Smart Agriculture (CSA)

Climate Smart Agriculture (CSA) is an approach in which technological, strategic and investment conditions are developed to reach sustainable agricultural development for food security under climate change. The extent to which climate change is affecting agricultural systems necessitates ensuring comprehensive consolidation of these effects into national agricultural planning, investments and programs. CSA is transforming and reorienting sustainable agricultural systems to support food security under the new realities of climate change.

Objectives of Climate Smart Agriculture

CSA is striving to increase agricultural productivity in terms of climate smart crops, food security, and farmers' adaptive capacity and lowering greenhouse gas emissions. The main objectives of CSA are:

1. Sustainable increase of Food Security by agricultural productivity
2. Building resilience and adapting to climate change
3. Developing opportunities for reducing greenhouse gas emissions

Modern Tools of Climate Smart Crop Production

Climate change, which includes high temperatures and drought, is projected to have a detrimental effect on plant agronomic conditions as well as soil nutrients, diseases, and pests. As a result, climate-resilient varieties with broad spectrum and long-term tolerance to both biotic and abiotic stresses are required. The new genetic engineering method for crop enhancement is precise genome editing (Robinson *et al.*, 2018). Climate change has put a pressure on researcher, farmers and scientists working in the field of agriculture to adopt new technologies to cope with the prevailing issues (Figure 1).

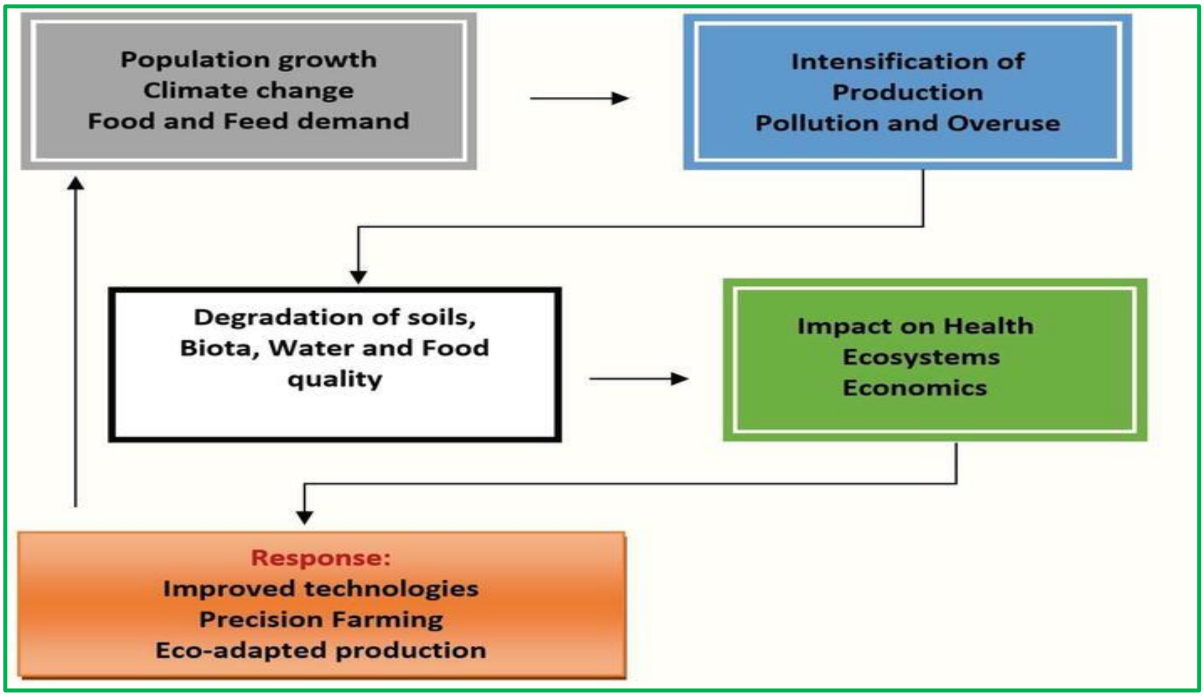

Figure 1: Impact of Climate Change on Agriculture

For targeted genome editing in plants, several techniques have been developed, including zinc finger nucleases (ZFNs), TAL effector proteins (TALENs), RNA directed nucleases (RGENs), and CRISPR (clustered regularly interspaced short palindromic repeats)/Cas9 (CRISPR associated protein 9. Both of these approaches depend on the creation of double stranded breaks at particular loci and the activation of the DNA repair system.

Genome Editing: Crops with higher yields and greater resistance to abiotic stress are needed to meet the demands of a growing global population and the effect of climate change on agriculture. Traditional crop improvement through genetic recombination or random mutagenesis, on the other hand, is a time-consuming process that cannot keep up with rising crop demand (Jarvis *et al.*, 2020). Genome editing techniques including clustered regularly interspaced short palindromic repeat (CRISPR)/CRISPR-associated protein (CRISPR/Cas) allow for selective alteration of almost any crop genome sequence to generate novel variation and speed up breeding efforts. However, the lack of full reference genomes, a lack of awareness of possible modification goals, and the legal status of edited crops restrict current crop genome editing applications. By overcoming the technological and social barriers to genome editing's implementation will allow this technology to produce a new generation of high-yielding, climate-ready crops (Tripathi *et al*., 2019).

Gene Silencing: Gene silencing is a method of down regulating specific genes via the over expression of RNA sequences (RNAi), which prevents a gene's functional expression. It is a method for shutting off specific genes. Future food protection applications may involve shutting off pathogen attack receptors or stress response elements, which could be extremely useful in the face of climate change. Gene editing is a technique for making precise, targeted changes in genomes at a scale of one or a few nucleotides. Using clustered regularly interspaced short palindromic repeats (CRISPR) and the CAS9 nuclease, transcriptional activator-like effectors' nucleases (TALEN), two alternative systems currently provide state-of-the-art protocols for achieving these small-scale genomic adjustments (Wheeler, 2016).

Genetic Resources for Climate Smart Crop

❖ **Climate smart crop production: practices and technologies**

1. Sustainable Crop Production Intensification: Crop production system has continuously been evolving from beginning of domestication of different crop species, almost 10,000 years ago. Crop production has improved and still improving through different means including, varietal selection, improved irrigation and crop planting methods, efficient use of cropping patterns and fertilizers, using the wild plants and wild relatives. Green revolution has been a best and well documented example of improvement in crop production which revolutionized the crop production system almost in all developing countries during 1960s. Planting high-yielding varieties of crop and also using chemical and improved irrigation methods were the main components of green revolution. As a result, production of cereal food crops was increased over 2.2 billion tonnes from 800 million tonnes. However, Intensive cropping for several decades has caused a loss of fertility of agricultural soils, ground water depletion; induce resistance in pests, decreased biodiversity as well as air, soil and water pollution. But now this paradigm should be shifted to a new, as intensive cropping systems has not been sustainable and this is what Save and Grow – i.e. sustainable crop production intensification (Redden, 2021). It means a productive agricultural system not only conserve but also enhances the natural resources using an ecosystem approach which exploits the natural biological processes and inputs. This system not only reduces the negative impact on our environment but also enhances the flow of ecosystem services as well as natural capital. It has been based on the agricultural production systems as well as management practices which include:

a. Maintaining the soil health to increase soil-related ecosystem services as well as crop nutrition.

b. Cultivate a diverse range of species and varieties with associations, rotations, and sequences.

c. Use of quality planting materials and seeds of high-yielding, and well adapted, varieties.

d. Integrated management of pest, diseases, and weeds; and

e. Efficient use of water.

Sustainable crop production systems have assumed to address the vulnerabilities as well as risks caused by the climate changes. CSA has same purpose of achieving food security as the sustainable agriculture, using its own perspective of climate change.

2. Integrated Pest Management: Climate changes have been affecting the spread as well as the formation of different types of disease pests, and weeds. This phenomenon has a large consequence of change in the distribution as well as health of the naturally occurring plants, natural predators, hosts and adaptive variations in agricultural management. With an increase of globalization of trade as well as germplasm exchange, (Robinson *et al*., 2018) following changes present the pest control with new challenges. Integrated pest management (IPM), an ecosystem approach used for crop production as well as crop protection. This technique has based on the considerations of all possible pest control techniques. IPM considers the use of all possible and appropriate means, to prevent the development of pest population ultimately maintaining the levels of pesticide to economically justifiable limit. Thus, decreasing the risks to human health as well as to the environment through minimize agricultural ecosystem disturbance. Making comprehensive decisions at the field level have been essential for effective IPM.

3 Sustainable Soil Management through Conservation Agriculture: Conservative agriculture is technique which involves the covering of maintained land, reduced soil disturbance, and diversifying crop production. Even though conservation agriculture approach was developed to minimize soil erosion as well as to restore the degraded soils, but it also provides strategic initial base point for adaption against climate changes. Conservative agriculture focusses on the reproducing most stable soil ecosystem which can be attain in any agricultural ecosystem to minimize the dependence of producer on the external inputs to full fill the plant nutritional requirements and pest control (Figure 2).

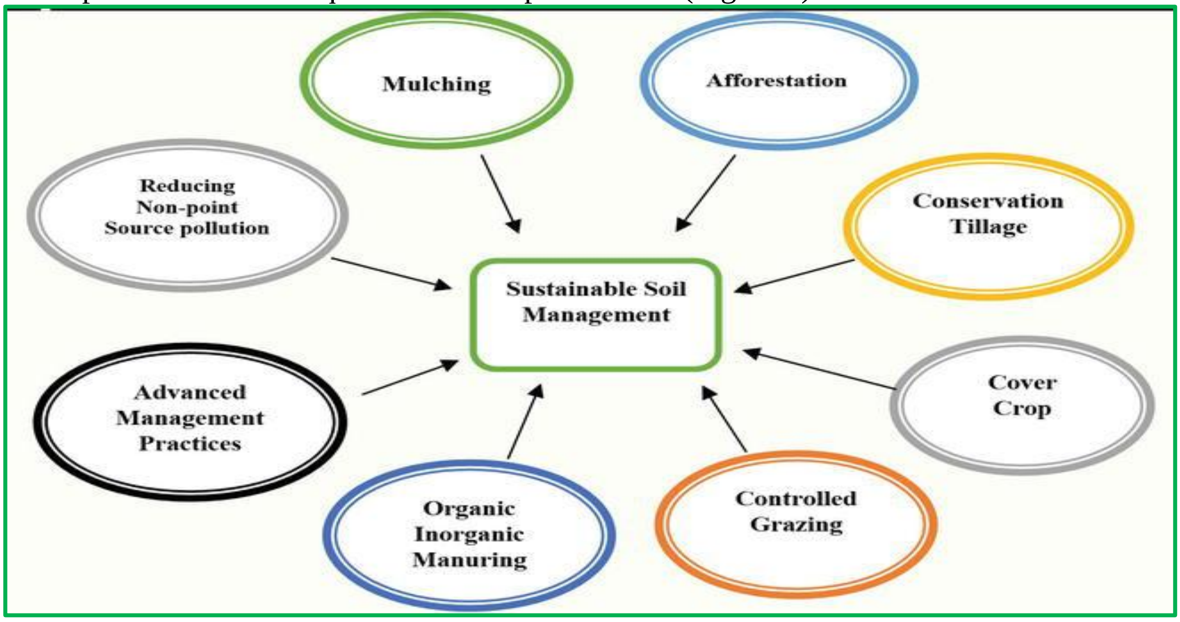

Figure 2: Sustainable Soil Management

By covering the soil, loss of soil moisture can be minimized; soil temperature can be stabilized, low erosion by water and wind, restoration of the soil carbon through plant debris breakdown and also provide the food material for beneficial soil organism. Using crop rotation and diversification technique disease and pest population will be minimized and soil nutritional value increase. Conservation agriculture system has ability to mitigate the climate change as untreated soil can work as carbon sink by storing and sequestering carbon.

4. Sustainable Land Management: Sustainable land management helps to increased productivity, lower costs, better production stability through growing as well as conserving natural capital (like water resources, soil organic matter, and different types of biodiversity). Through SLM practices soil fertility improved by using large quantity of biomass, reducing the soil disruption, conservation of water and soil, an increased activity as well as diversity of soil fauna, and supporting the elemental cycling mechanism (Neufeldt *et al*., 2017). All this led to improved plant nutritional quality, high water retention ability, and improvement in soil structure contributing to increased yields as well as high resilience.

5. Improved Water Management System: Loss of water can be countered and an improved water management can be achieved by the means of water and soil conservation; either by reduce irrigation which helped to maximize the yield per volume of water used; or through using more efficient irrigation technologies that can minimize the unproductive water loss through evaporation. Buy to attain a high irrigation efficiency and addition energy costs also required, because expansion of irrigation should have to be accompanied by the precise energy technologies (e.g. solar pumps). Strategy development and decision making for the water management and control should be accompanied with the water balance analysis, as for understanding of the impact of changes in water usage in agriculture on the water cycle, a precise assessment of water balance is required for both filed as well as catchment levels. But in upstream areas, introduction of rainwater harvesting technique on a large scale could adversely affects the downstream water users by affecting the groundwater recharge and flux.
6. Conservation and Enhancement of Biodiversity: Sustainable farming practices have support both above and below ground cropping systems as well as management of ecosystem services. The nature of associated diversity (plant, microbial animals) can be influenced by the diversity and composition of planned biodiversity (e.g. selected crops) ultimately affecting delivery of ecosystem services. An ecosystem approach means that, to integrate the planned biodiversity that has been maintained through associated diversity e.g. more soil coverage and perennial cultivation, high on-farm plant diversity throughout the agro-ecosystem (e.g. resistance against noxious species).

Conclusion

Crop production plays a vital role under climate change by providing opportunities in adapting and mitigating the effects of climate change, we can get sustainable crop production Climate-smart agriculture approaches provide us more efficient, resilient and sustainable system crop production system which can be utilized by farmers, thus making these systems more efficient, sustainable and productive.

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