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Climate Resilient Agriculture: A Pathway to Sustainable Food Security and Climate Change Mitigation

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Nature and human beings have both contributed to climate change, whereas human beings are the major culprit, as for the past five decades, human actions that release greenhouse gases (GHGs) into the atmosphere have been the primary cause of global warming. This includes excessive fossil fuel usage (coal, oil, and gas), by far the largest contributor, and agricultural activities like altered land use patterns, deforestation, and faulty livestock and paddy management. The Intergovernmental Panel on Climate Change (IPCC) reports that warming due to human interference increased at a rate of 0.2ºC every decade, reaching around 1ºC over pre-industrial levels in 2017.

To date, 70% of the population of India relies on agriculture, which encompasses the cultivation of both short- and long-duration crops, perennial fruit trees, and livestock farming, as well as aquaculture. These practices require a stable, unchanging optimum climate, according to which present land use and management practices are tailored. A total of 60.5% of the land area is under agriculture and generates around 16% of the Gross Domestic Product (GDP). However, this contribution has shown a decline of approximately 1.5% of GDP per year due to the negative effects of climate change on production. But still, it stands in its importance economically through generating significant employment, providing food security, and escaping poverty. The decline in production as a result of climate change may be due to higher pest incidence, changes in temperature and rainfall, and other climate uncertainties. In 2022, world agrifood systems emitted 16.2 billion tonnes of carbon dioxide equivalent, with a rise of 10 percent since 2000, and contributed about <30 percent of total emissions. Crop and livestock practices accounted for 48 percent, with a 15 percent increment from 2000. By 2050, it is projected that emissions will rise by approximately 30% if appropriate measures are not considered to reduce them.

Conclusively, there is a sudden need to restructure and develop climate-resilient strategic approaches that are environmentally sound and economically viable and can reduce GHG emissions while maintaining crop production to sustain our future generations' food supply. These practices will ensure food availability, assist in raising production and productivity, and sustain ecosystems, as well as enhance their ability to face climate change, unfavourable weather conditions, and climate-related disaster risks in agriculture. Climate Resilient Agriculture (CRA) has huge potential to lessen the effects of climate change on agriculture, either alone or by integrating resource-efficient technologies and sustainable nutrient and water management practices.

Climate-resilient agriculture can be defined as agriculture that reduces poverty and hunger in the face of climate change, improving the resources it depends on for future generations (Christian Aid, Time for Climate Justice, 2015). CRA, as a subset of the climate-smart agriculture (CSA) paradigm, lowers the risks associated with climate change by creating more resilient social and agricultural systems, climate-smart pest control, and

advanced weather-based advisory systems, boosting productivity and resilience at various levels. A scientific assessment of the available literature was conducted to examine the significance of practices and technology to guarantee food supply and socioeconomic well-being under CRA and thoroughly record the effectively implemented current adaptations.

Major programs for climate-resilient agriculture

National Innovations on Climate Resilient Agriculture (NICRA): Indian Council of Agricultural Research (ICAR), with the Ministry of Agriculture, Government of India, initiated NICRA in February 2011 to get all areas of agriculture on a single platform. ICAR-Central Research Institute for Dryland Agriculture, Hyderabad (CRIDA), is the pivotal institute seeking to fulfil resilience. This has three fundamental objectives: strategic research, technology demonstrations, and capacity building.

Village Climate Risk Management Committee: It works at the village-level to settle a plan of action considering interventions, farmers' participation, and concord with ongoing government schemes related to climate change adaptation. Out of the chosen hundred villages, this project was carried out in one village, which is highly sensitive to the extreme environment.

New technological methods for climate resilient agriculture

Water and energy management technologies

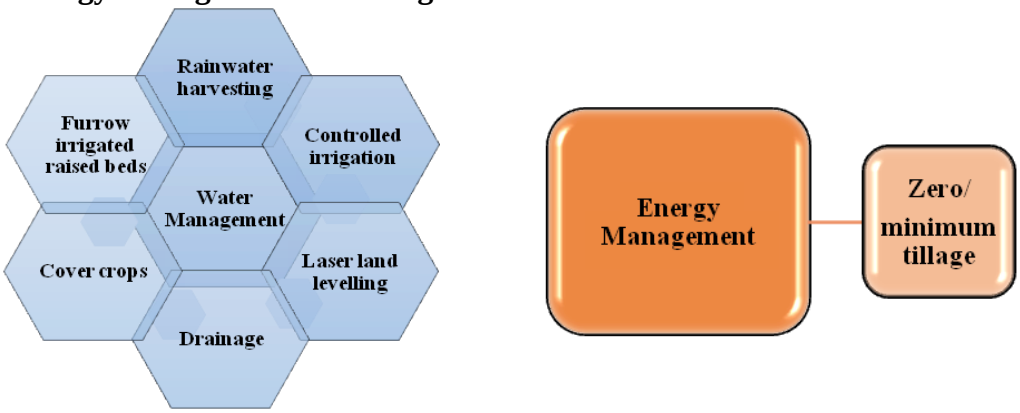

Fig. 1. Water and energy management techniques for CRA

These methods improve water use efficiency by applying water directly to the root zone and reducing water loss from evaporation and runoff. This method also offers effective drainage and rainwater management during the monsoon season while improving nutrient use efficiency. By lowering the energy required for land preparation, this improves energy use efficiency. In the long term, it also enhances water infiltration and organic matter content in soil.

Nutrient management and carbon smart agro forestry

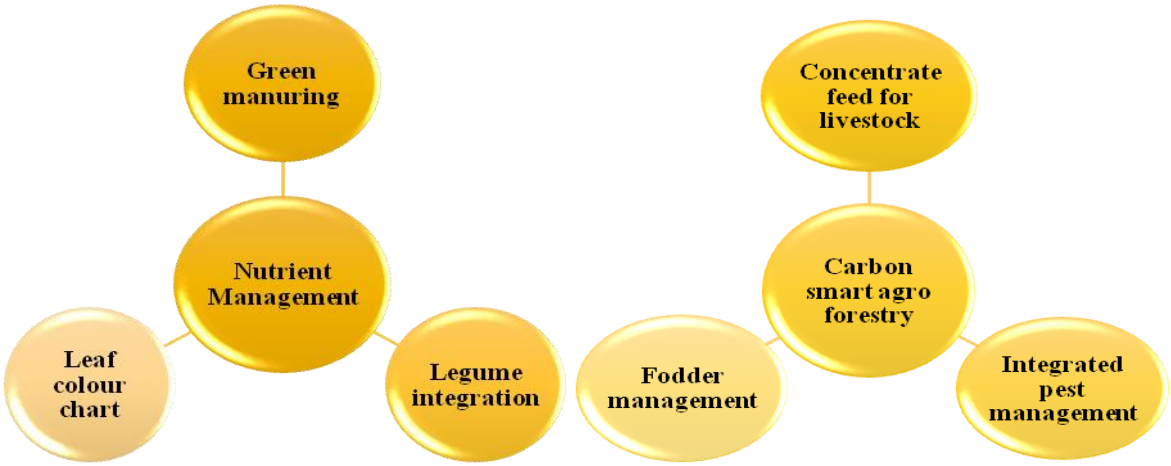

Fig. 2. Nutrient management and carbon smart agro forestry techniques for CRA

These practices ensure an optimum supply of nutrients to the plant by following the 4 R principles as right source, time, place, and rate. Including legumes in a system leads to improved nitrogen supply and overall soil health. Additionally, site-specific nutrient management reduces losses while increasing nutrient use efficiency. These interventions also help to reduce greenhouse gas emissions while enhancing carbon sequestration. Additionally, they reduce chemical use and nutrient losses.

Pest and risk management

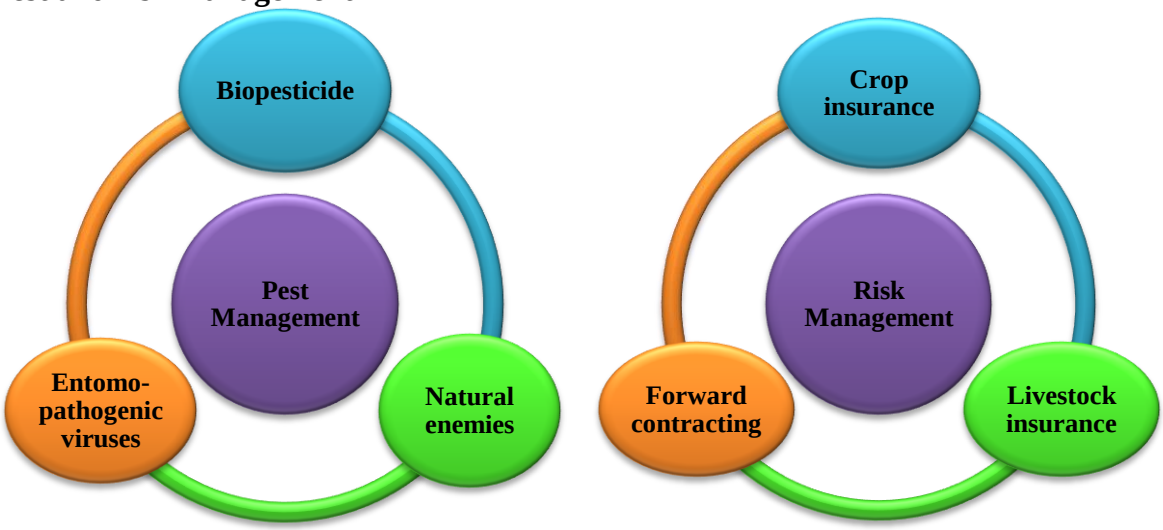

Fig. 3. Pest and risk management for CRA

These practices serve as critical tools for sustainable farming by mitigating risks. While insurance schemes provide financial safety against crop failure and climate uncertainty, biopesticides offer eco-friendly pest management without harmful residues. Together, they aim to stabilize farmer income and protect environmental health through biological control and financial risk management.

Weather and knowledge smart technology

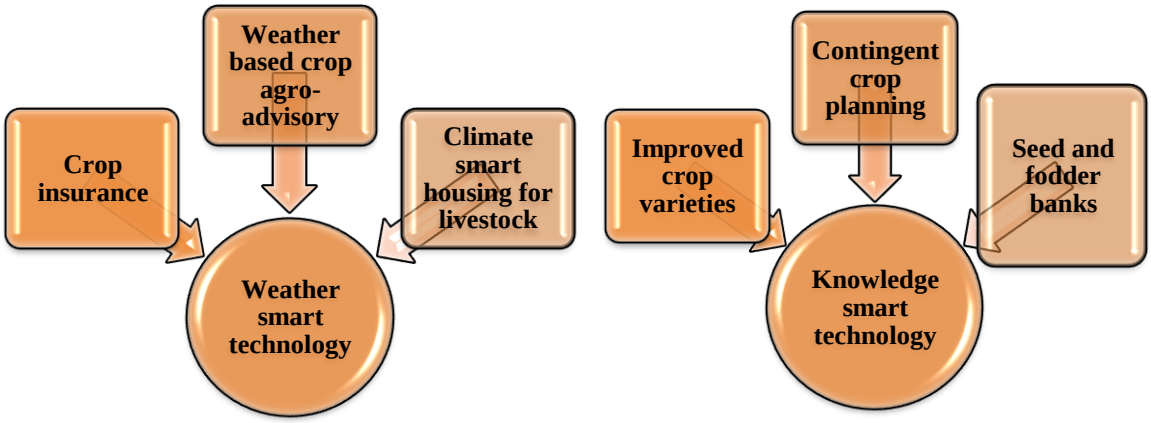

Fig.4. Weather and knowledge smart techniques for CRA

Weather-smart practices deployment provides services to farmers related to income security and weather advisories. Furthermore, climate-based data gives farmers additional agro-advisories and shields livestock from severe weather. Drought, floods, and heat/cold stress are examples of major weather-related emergencies that can be managed by combining science and local knowledge. Stress can be reduced by creating cultivars that can withstand harsh weather.

Conclusions

Climate change poses a profound and growing threat to global agriculture, particularly in a country like India, where a large proportion of the population depends on farming for its

livelihood. Rising temperatures, erratic rainfall patterns, and increasing frequency of extreme weather events are already affecting crop productivity, soil health, and overall agricultural sustainability. Therefore, the need for adaptive and resilient agricultural systems is no longer optional but essential for ensuring food security and economic stability. Climate Resilient Agriculture (CRA) emerges as a practical and forward-looking approach to address these challenges by enhancing the capacity of farming systems to withstand climate change. Moreover, the CRA not only focuses on adaptation but also contributes to mitigation by reducing greenhouse gas emissions and enhancing carbon sequestration. However, the widespread adoption of these practices requires strong policy support, farmer awareness, capacity building, and continuous research to tailor solutions to diverse agro-ecological conditions. Hence, transitioning towards climate-resilient agricultural systems is crucial for safeguarding future food systems, improving farmer livelihoods, and protecting natural resources. A coordinated effort involving government agencies, researchers, farmers, and stakeholders is essential to scale up these practices and build a resilient agricultural future capable of sustaining generations to come.

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