CHAPTER-4

CLIMATE CHANGE AND RESILIENCE

Vimal Dakhane
Dr. Ambedkar College of Arts, Commerce and Science,
Chandrapur (MS) - 442403 India
Email: vimaldakhane@gmail.com

Summary

Climate change adversely affects agricultural productivity. Climate Resilient Agriculture integrates adaptation and mitigation strategies to enhance the resilience of agricultural systems against climate-related disturbances. Achieving climate-resilient agriculture is critical for food security and environmental sustainability. It requires a multifaceted approach that combines innovative technologies, traditional practices, and robust policy frameworks to address the challenges posed by climate change. Successful implementation of these strategies can contribute to meeting global sustainable development goals and ensuring the resilience of agricultural systems in the face of ongoing climate challenges. Global cooperation is essential for transferring climate-smart technologies and implementing strategies that address both economic and environmental challenges.

Keyword: Climate Change, Agricultural Productivity, Climate Resilient Agriculture (CRA), Sustainable Agriculture, Agroforestry

Introduction

Climate change has affected and still affecting the globe with vulnerable impacts on agriculture productivity. Agricultural productivity depends mainly on temperature and rainfall which gets affected by long term weather pattern shifting. High and low temperature regimes, increased rainfall variability, and rising sea levels due to global warming are weakening the freshwater and costal ecosystem leading to increased risk of flooding. Climate change and global warming essentially impacting all walks of human life. India alone has 17.5

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percent of total world population however, only 2.4 percent land is available for agriculture. Thereby, ensuring food and environmental security has become a daunting task for the policy makers in India as well as in the world.

Destroying natural resources due to climate change and global warming further advances the extreme weather conditions. For nations like India wherein maximum capital is earned by agriculture and related industries challenge is formidable to have less land and more produce with reduced carbon and water footprints. To achieve climate smart agriculture several measures required to be taken in terms of policy making and its implementations, awareness among farmers regarding newly assisted technologies and empowering with necessary resources.

In 2013, National Academy of Agriculture Sciences defined Climate resilience agriculture (CRA) as: "the incorporation of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and recovering quickly. Such perturbations and disturbances can include events such as drought, flooding, heat/cold wave, erratic rainfall pattern, long dry spells, insect or pest population explosions and other perceived threats caused by changing climate. In short, it is the ability of the system to bounce back. Climate resilient agriculture includes an in-built property in the system for the recognition of a threat that needs to be responded to, and also the degree of effectiveness of the response. CRA will essentially involve judicious and improved management of natural resources viz., land, water, soil and genetic resources through adoption of best practices"(NAAS-2013, 2013).

The mitigation strategies in agriculture focuses on management of Green House Gas (GHGs) emissions, reduced carbon and water footprints and sustainable farming practices. Adaptation means the ability of the communities to adapt to climate change and related impacts (Grigorieva, Livenets, & Stelmakh, 2023). However, for resilient agriculture, adaptation strategies needed to be integrated along with mitigation.

The impact of climate change has seen on productivity of the crops which is directly linked with agricultural practices like water use and application of fertilizers, insecticides, and herbicides etc. Along with the negative impacts there are certain positive influences of climate change such as CO_2 fertilization due to increase in CO_2 levels leading to increased crop yield by enhancing photosynthesis. New economic and market zone is created due to shift in the area of cultivation, specially, in some horticulture crops. These positive impacts can boost the climate resilient architecture if assisted with technologies.

Adaptation Strategies

Factors like economic status of the country, different stakeholders in the agriculture sector from farmers to policy makers and influence due to physical, environmental, technological, economic, political, institutional, psychological, or socio-cultural activities affect the designing of adaptation strategies. The adaptation strategies in agriculture can be categorized in local, regional and national level.

Local Scale Actions

Using different crops, plant breeding and new crop variety development according to changing climate by farmers are the well-known local scale initiatives of adaptation strategies. Also, crop rotation to improve soil quality and fertility, changing the planting and harvest dates to match with changing climate, sustainable irrigation practices and wastewater reuse for increasing the soil capacity to hold the moisture are other adaptation strategies used by farmers on daily basis around the globe. These practices help in improving farm management of different farm types. Thereby increasing the diversity in the farm types to mitigate the climate change at regional level.

Regional Level Actions

The actions of local scale are employed at regional levels by various institutions to create awareness among the farmers of different areas. Here, agriculture scientists, experimentalists, NGO workers and public private sectors work together to pursue the adaptation strategies. Capacity building of various stakeholders of agriculture sector have a huge impact on mitigating and adaptation plans govern by the nation. Following are some strategies used at regional level for adapting to changing climate:

1. Farmer's education on new technologies and methods of adaptation
2. Early warning weather systems for better planning
3. Integrating digital platforms with weather systems
4. Improving agriculture consultancy, insurance and credit systems
5. Reduction in chemical fertilizer use
6. Modern irrigation systems
7. Alternative agriculture techniques like agroforestry.
8. Green corridor creation for improving carbon support biodiversity

National Level Actions

National Action Plans for Adaptation or National Strategic Plans and National Agricultural Policies are currently employed support mechanisms of various countries around the world. Government should invest in R&D for developing new technologies and agriculture methods at national scale: for development of early warning systems to prevent loss from natural disasters, formulating new crop varieties having drought or heat resistance, developing agroforestry systems, efficient methods of irrigation, using renewable energy sources in modern agricultural systems etc. Nations adaptation actions also include implementing farming systems and agro-technologies for supporting biodiversity through green corridor creation and developing international agriculture market.

Along with all these action strategies certain other approaches become a stepping stones to make agriculture systems more resilient to climate change. E.g. Conservation agriculture, scientific agroforestry, sound policy framework by governments etc.

Resilient Farming Practices

Climate resilient farming system practices ensures maximizing yield by changing farming practices according to weather and creating pest or disease resistance varieties. Tolerant Crops, Tolerant Breeds in Livestock, Feed Management, Water Management, Agro-advisory, and Soil Organic Carbon basin are some of the strategies for climate change adaptation or resilience. Tolerant crops can either bred or genetically engineered according to the environmental conditions and thus technological advancements are needed to produce tolerant crops. Indigenous livestock breeds are tolerant to drought, able to walk long distances, able to digest low quality feed and can easily get adapted to the ecosystem. These characters make indigenous livestock breeds appropriate for climate change resilience. Feed management is also required for improved livestock production. Water smart technologies are now becoming essential given the climate crisis on all the water resources on earth. Systematized efforts of governments, NGOs, researchers, and other private agencies are now focusing on design and development of cost-effective and environmentally friendly water-conserving devices. Agro-advisory depends on response farming allowing dissipation of knowledge about location and time specific technologies to the farmers. Improving organic matter in the cultivating soil is another strategy through which soil's fertility can be maintained. This can be done using conservation agriculture technologies, soil conservation practices (contour farming) and nutrient recharge strategies (Srinivasarao, 2021).

UNDP suggests that the sustainability of global food production will be dependent on our ability to innovate and become much more climate-resilient. The *Cultiv@te* initiative has selected about 31 technologies and innovations in the area of urban agriculture, rainfed agriculture and livestock farming and aquaculture to combine the global leading innovations with local knowledge (Agorize, 2022).

Carbon Footprint reduction in Agriculture

Carbon footprint is "a measurement of the total GHG emissions caused directly or indirectly by an individual, an organization, even a product, and is expressed as a carbon dioxide equivalent (CO2e)". One of the largest source of GHGs is agriculture. Tillage, inorganic fertilization, harvesting, pesticides, composting, biochar addition, and crop photosynthesis capacity are among the main practices leading to increased GHGs (Gao, Liu, & Wang, 2014). Some of the best practices to reduce agriculture carbon footprint includes:

1. Crop rotations for soil health improvement
2. Nutrient management by right time, right rate, right source, and right place i.e. 4R strategies
3. Avoiding bare fallow practice wherein land is left uncropped and free of vegetation for a season which leads to soil erosion.
4. Manage tillage by traditional practices
5. Manage manure and fertilizer amounts

Use data-driven support systems as a part of agro-advisory wherein growers understand multiple alternatives, processes, and identify sources of unpredictability (Terrones, 2023).

Technology and Innovations in Sustainable Agriculture

Technological and innovative advancements which are paving the sustainable agriculture approaches are:

1. Using AI and Machine learning tools for sustainable agriculture to enhance efficiency, resource utilization and minimize waste by automation e.g. automatic weeding robots.
2. Enabling Precision farming by Drone surveillance. This enables the farmers for early detection of crop issues and efficiently apply resources throughout the field e.g. intelligent spraying by UAV sprayers.
3. GPS and Data analytics has major role to play in management of crop fields and improving precision farming e.g. Aerial survey and imaging

4. Vertical Farming is another sustainable solution which minimizes land use and transportation, enable farmers to meet food demands in future e.g. Hydophonics.
5. Some technologies include combination of all the given tools.

Climate Smart Technologies

- Seawater Rice in China: Increased sea levels and decreased groundwater poses challenge in irrigation of crop fields in China. Yuan Longping known as "father of hybrid rice" developed salt tolerant hybrid rice varieties through advances in traditional breeding techniques by overexpressing a gene from chosen wild rice more tolerant to salinity. And planting this variety in saline soil lead to high yields.
- Insect resistance cotton in India: Genetically-modified insect-resistant Bt-cotton is the first GMO to be released in India in 2002. Bacteria *Bacillus thuringiensis* has certain toxin producing genes products toxic to insects/pests. These genes were isolated and inserted in cotton plant genome to make Bt-cotton which is a resistance plant against pests.
- Push-pull technology and intercropping in Kenya: Incorporating multiple plant species in crop field for improving the soil quality, pest management and livestock management proven to be an innovative project undertaken by Kenya's International Centre of Insect Physiology and Ecology (ICIPE) and the United Kingdom's Rothamsted Research. E.g. *Desmodium uncinatum* planted with maize, Napier and Sudan grass.
- Selecting typhoon-resistant crops: Cassava and sweet potato by CGIAR Research Program on Roots, Tubers and Bananas (RTB)
- Marker-assisted breeding of climate-resilient rice by International Rice Research Institute (IRRI)
- Polytunnels for extended growing seasons and crop protection by Haygrove.
- Polytunnels provide a regulated environment to the sensitive crops against the climate change or weather impacts. Bigger polytunnes able to regulate the temperature because of the packed air and the tunnel fabric passes light and act as thermal heat barrier that creates a more stable, stress-reduced growing environment for plants.
- Agroforestry and integrated farming systems for increased resilience by ICRAF

- Integrating trees with crops is the main function of agroforestry which leads to production of timber, fodder, Fuel and shelter along with food. It can restore degraded forest and protect ecosystem.
- Crop diversification and intercropping by Covers & Co.
- Bioinsecticide for pest control in crops by Seipasa
- Improved drought tolerance through seaweed priming by BioAtlantis
- Pest control through release of self-limiting insects by Oxitec
- Photo-selectivity mesh for crops by Hortomallas
- Crop gene-editing using CRISPR-based technology by Pairwise
- Robotized identification of crop characteristics by Alphabet (WIPO, 2022)

These technologies although provided by certain locations or companies but have potential to be implemented worldwide. To do so all the countries associated to WIPO (World Intellectual Property Organization) should pact to transfer such technologies for environmental as well as economic gain.

The climate smart technologies have integrate both adaptation strategies with resilient farming practices. Like intercropping systems developed by Covers & Co or innovative way of intercropping developed in Kenya can be implemented across globe as local, regional and national level adaptation strategies. Similarly, Polytunnels or photo-selectivity mesh can be promising innovation and technologies for future of resilient farming. Using advance molecular gene editing techniques and genetically modified organisms' studies economic and environmental crisis can be substituted. However, these technologies need to be well researched for their long term impact on climate.

Climate resilient agriculture is a need of an hour in this climate crisis. To achieve CRA, adaptation and mitigation strategies involving smart technologies, innovations and traditional practices needed to be implemented globally such that sustainable development goal of clean water, Good health and wellbeing, Zero Hunger, Life below water and life on land and lastly the climate action goals can be achieved.

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