Climate-Smart Pathways for Wheat-Rice Farming in the Indo-Gangetic Plains

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Abstract: Climate-smart agriculture (CSA) is an approach designed to transform agricultural systems so that it can respond effectively to climate variability while ensuring long-term food security and sustainable development in Agriculture. The framework emphasizes restructuring of agricultural practices and also institutions to address climate-related risks while maintaining productivity. The three central pillars of CSA include sustainable enhancement of agricultural output and farm income, focusing on the strengthening adaptation and resilience to climate change, and reducing greenhouse gas (GHG) emissions wherever feasible.

CSA focuses on promoting the development of context-specific agricultural strategies that will help in maintaining food security under changing climatic conditions while conserving natural resources. CSA supports informed decision-making across multiple levels like—from farmers to policymakers—by identifying locally appropriate and environmentally sound practices. In the Indo-Gangetic Plains (IGP), the wheat–rice cropping system has been important in national food security but this now faces serious sustainability challenges due to various issues like, declining water resources, degradation of soil, shortages of labour, and rising energy demands. Based on a critical review of existing literature, this paper outlines climate-smart strategies for restructuring the wheat–rice system to improve productivity, resilience, and environmental sustainability in the IGP.

Keywords: Climate-Smart Agriculture, Indo-Gangetic Plains, Sustainability, Greenhouse gas emissions, Food security

INTRODUCTION

Climate change has a lot to do with agriculture. It both causes greenhouse gas emissions and is a sector that is quite sensitive to changes in the weather. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) shows that agriculture and related land-use activities are responsible for about 20–24 percent of all human-made greenhouse gas emissions. Direct agricultural operations are responsible for about 13.5 percent of these emissions. IPCC (2015) says that methane from rice paddies and cattle, nitrogen oxide from fertilised soils, and emissions from heavy input consumption are some of the biggest drivers of pollution.

Climate change is a big danger to food security around the world. Climate-related problems could put about 49 million more people at risk of starvation by 2020 (IFAD, 2016). Higher

temperatures, changes in rainfall patterns, more droughts and floods, and more severe weather events are all starting to hurt agricultural productivity. These effects are especially bad in poor nations, where farming is still the main source of income and people don't have many ways to adjust.

AGRICULTURE UNDER CHANGING CLIMATIC CONDITIONS

Climate change is making it harder for agricultural production systems to work, especially in areas where small and marginal farmers are the main ones. To increase production in these situations, we need to move away from traditional, resource-heavy methods and towards sustainable intensification. Conservation agriculture is a good strategy to cut down on the environmental impact of farming while also making farms more profitable. It focusses on keeping soil disturbance to a minimum, keeping crop residues, diversifying crops, and using resources wisely.

The energy industry is the biggest contributor of greenhouse gas emissions, but agriculture is the second biggest. A large part of these emissions comes from the digestion of cattle and soils that have been treated with fertiliser. Evidence indicates that conservation-oriented techniques can concurrently enhance agricultural yields and diminish emissions, especially in heavily cultivated areas like the Indo-Gangetic Plains.

To offset the emissions that come from using more fertiliser, irrigation, and mechanisation, efforts to boost production through climate-resilient crop types must be paired with sustainable management methods. Emission mitigation is frequently assessed by juxtaposing different scenarios with baseline forecasts. The RCP 2.6 route, for example, wants to keep the amount of CO_2-equivalent in the atmosphere to 450 ppm by 2100. This gives a good chance of keeping the temperature rise below 2°C (van Vuuren et al., 2011).

The Food and Agriculture Organisation (FAO) says that worldwide agricultural production needs to go up by roughly 60% to fulfil future food needs. Getting to this goal is hard because natural resources are already stretched thin and climate change is making things worse. When land use changes, agriculture is responsible for about a quarter of all greenhouse gas emissions. This shows how important it is to find climate-smart solutions.

CLIMATE-SMART AGRICULTURE: CONCEPT AND OBJECTIVES

Climate-smart agriculture is a comprehensive framework that combines efforts to adapt to and reduce climate change with aims for food security. It understands that the best solutions must be made to fit to the agricultural, ecological, socio-economic, and organisational situations. CSA wants farmers, academics, legislators, agribusinesses, and banks to work together to solve the problems that climate change and sustainable agriculture are causing for each other.

The primary objectives of CSA are:

1. **Enhancing agricultural productivity and income** in a sustainable manner to ensure food security and economic stability.
2. **Strengthening resilience and adaptive capacity** of agricultural systems to climate variability and long-term climatic changes.
3. **Reducing greenhouse gas emissions** from crops, livestock, and fisheries while maintaining productivity.

CLIMATE-SMART AGRICULTURE IN THE INDO-GANGETIC PLAINS

Key Challenges

The wheat-rice cultivation system in the region known as the Indo-Gangetic Plains has been very important for India to be able to feed itself. But growing crops continuously using traditional methods has caused groundwater depletion, soil deterioration, difficulty in managing waste, and pollution of the environment. These problems have led to a halt in yield growth and a drop in land and water production.

Some of the biggest problems in the area are less groundwater accessibility soil structural degradation, more extreme weather occurrences, burning crop residue, and higher levels of greenhouse gases. To deal with these problems, we need to move towards climate-smart production systems.

Climate-Smart Strategies

- **Improving Productivity and Farm Income**

Studies done by organisations like CIMMYT have shown that managing the rice-wheat system in a way that protects the environment can make it more productive and profitable. Studies in

Haryana that add green grains to the wheat- rice rotation without tilling and keeping the residue have demonstrated that the soil is healthier, the cost of production is cheaper, and greenhouse gas emissions are lower than with traditional methods.

By planting short-lived legumes during the time between rice and wheat, you can improve nutrient cycling and the long-term health of the system. Direct-sown or aerobic rice can cut methane emissions by a lot when it replaces puddled transplanted rice. Even though emissions of nitrous oxide may go up, the combined impacts of keeping residue and less tillage help the soil store more carbon, which leads to lower net emissions.

Other benefits include less burning of leftover materials, better soil structure, and up to 30% less water use than traditional methods.

- **Building Climate Resilience**

By using crop variety, water-efficient technologies, energy-saving methods, fewer workers, and better soil carbon storage, CSA practices make farms more resilient by lowering the risks of climate change. All of these steps together make farming systems better able to handle climate shocks.

- **Enhancing Water and Land Productivity**

With water becoming more scarce, it's important to change the focus from yield per region to yield per unit of water. Planning irrigation well, using less water, growing crops that can handle stress, and using low-quality water wisely can all help farms use their resources more efficiently and make more money.

- **Mitigating Greenhouse Gas Emissions**

In agriculture, mitigation measures include alternative methods of irrigation and drying in rice farming, making livestock more productive so that emissions for each hectare of production are lower, and not relying too much on synthetic inputs. Policy changes that attempt to cut down on waste and damage to the environment also help to lower emissions.

CONCLUSION

Climate-smart agriculture (CSA) is a scientifically sound and practically useful way to deal with the many problems that agricultural systems within the Indo-Gangetic Plains face. Since a very long period the wheat-rice cropping system has been considered the backbone of India's

food security in this area. However, dwindling groundwater resources, worsening soil quality, growing production costs, and increased susceptibility to climate change are making things harder for farmers. In these conditions, continuing traditional farming methods that use a lot of resources is not good for the environment or the economy in the long run. CSA provides a transformative approach that integrates productivity in agriculture with climate adaptation and environmentalresponsibility.

This review shows that using climate-smart methods like conservation tillage, keeping crop residue, rotating crops more often, adding legumes, and better managing water and nutrients can make the rice–wheat system much more sustainable. These methods make the soil better, add more organic carbon, and help people use energy, water, and nutrients more efficiently. Farmers can now get consistent or higher yields without having to rely on expensive outside inputs. This is especially crucial for marginal and small-scale farmers, those who are most probable to be hurt by changes in the weather and the economy. CSA directly helps people in rural areas by making farms more profitable and lowering the hazards of production.

From an adaptation point of view, CSA makes farming systems more able to deal with the short-term changes in the weather and also with the long-term changes in the climate. Direct-sown rice, aerobic rice culture, raised-bed cultivation, and crop diversification are all ways to make crops less vulnerable to unpredictable rainfall, water constraints, and a lack of workers. Agricultural fields can better handle droughts and floods when the soil is healthier and has more organic content. These adaptation benefits are very important in the Indo-Gangetic Plains, where extreme weather is happening more often and with more force.

At the same time, CSA is important for fighting climate change since it cuts down on the release of greenhouse gases from farming. Practices like alternate drying and wetting in rice farming, better use of fertilisers, more effective handling of crop residues, and better retention of carbon in soils all help minimise methane and nitrogen oxide emissions. Even though farming can't completely stop emissions, CSA lets the industry cut its carbon footprint by a lot while still making food. Because CSA can help people adapt to climate change and also reduce the effects, it is an important part of meeting national along with global climate goals.

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