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Climate Smart Agriculture: Approach and Perspectives for the Rice-Wheat Crop Rotation System in IGP (Indo-Gangetic Plains)

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Authors' contributions

This work was carried out in collaboration between all authors. Author YK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RS and AK managed the analyses of the study. Authors VS and AG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Climate-smart agriculture (CSA) is an approach that helps to guide the actions required to change and devise agriculture management techniques to effectively support growth and ensure food security in a changing climate scenario. The objectives of CSA are sustainably increase agricultural yield and incomes; adapt and build resilience to climate change like climate resilient agriculture practices; and reducing greenhouse gases (GHG) emission. CSA is a way of developing agricultural strategies for the sustaining food security in IGP under climate change. The CSA would help small and marginal farmers in IGP, to find out agricultural practices that are suitable for local conditions and to overcome the negative impact of climate change. A thoroughly literature review on CSA, this study managed to devise strategies for the reorienting of rice-wheat cropping system in IGP, for the conditions of declining natural resources and productivity, water, labour and energy shortages of Indo-Gangetic Plains.

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1. INTRODUCTION

Agriculture is a major driver of climate change. According to 5th FAR (IPCC fifth assessment report), Agriculture and its allied sciences contribute 20-24% of human induced GHGs emission and IPCC estimates that agricultural contributes about 13.5% of GHGs emission. These emissions are largely from the results of synthetic fertilizers use; methane from large scale animal operation and some methane are released from rice paddies [1]. It is projected that climate change affects around 49 million people at risk of hunger by 2020 [2].

1.1 Agriculture and Climate Change

Agriculture and changing climatic conditions would impose complex challenges to researchers and scientists trying to improve crop yield on marginal farmers in developing countries. Sustainable and conservation agriculture intensification that includes minimal soil disturbance, permanent soil cover, economical and diversified intercropping system. It is an important technique to overcome the negative impact of agricultural on the climate and improve the income of smallholder farmers. The agriculture sector is the second largest emitter of GHGs gases after the energy sector. About 65% emission come from the farm related operation that is mainly cattle belching and soil treated with natural or synthetic fertilizers. Conservation agriculture techniques can help boost yields and profits by smallholder farmers in an intensively cultivated region of India while helping reduce the impact on agriculture on global warming. Hardy, high-yielding crop varieties can be more resilient to erratic weather patterns caused by climate change, but agricultural strengthening must be balanced with sustainable techniques to counterbalance the effects of emissions caused by greenhouse gases. We identified the mitigation needed by comparing this reduced budget for the scenario's baseline, business-as-usual emissions. The RCP 2.6 scenario represents condition expected to limit emissions from 450 ppm of CO_2e in 2100, which results in a 66% or 'likely' chance of staying below the 2°C warming limit [3]. The united nation food and agriculture organization (FAO) estimates that nurturing the world population would require a 60% increase in total agriculture production.

Moreover, climate change is already impacting negative productivity locally and globally. The various climatic risks of cropping, livestock and fisheries are expected to increase in coming decades, particularly in developing countries where adaptive capacity is weaker. Impacts on agriculture threaten both food security and agriculture's pivotal role in rural livelihoods and agricultural sector.

1.2 Climate Smart Agriculture (CSA)

CSA is an integrated way that considers the social, economic and environmental context specific to the location. It is practiced through a strong linkage of agricultural and business sectors, policy makers, institution and financial in its integrated combined way of addressing the interlinked challenges of food security and climate change.

Its three objectives are;

I. To sustain increase agriculture production and support equitable increases in farm incomes, food security and development;
II. To adapt and build resilience of agricultural for food security in changing climatic conditions;
III. To deploy measures for the reduction of greenhouse gas (GHGs) emissions from agriculture, that is mainly from crops, livestock and fisheries.

2. CSA FOR THE INDO-GANGETIC PLAINS (IGP)

2.1 Challenges

Rice wheat cropping pattern of IGP is contributed a lot in mitigation of food shortage but also causing many sustainability issues like the declining of water resources, soil degradation and in health and environment, which further negative impact on yield, land and water productivity [3]. Hence, CSA and other approaches are adopted by the farmers to improve soil health and environment for overall lifting of the livelihoods of the farmers of IGP, but encountering challenges, are:

- **In the sustainability of production and productivity**

  Era of Green revolution that is started in early 1970s with mainly two staple crops like wheat and rice in the Indo-Gangetic Plains (IGP). IGP has played a significant role in the food security of this region. However, recent years we faced a significant slowdown in the yield of both crop and sustainability of both important cropping system is at risk due to second-generation technology problems and put more stress on natural resources. Traditional cultivars and conventional technique would not be able to maintain the increase in productivity achieved during the past few decades. Due to increased population and urbanization, demand for food is also increasing rapidly.

The rice-wheat cropping system is less profitable as these resources like water, energy and labor intensive and the resources become limited. These problems are increasing from deterioration of soil health, the emergence of new weed flora and emerging challenges to climate change. Therefore, a paradigm shift like CSA is required for enhancing the system's productivity and sustainability.

- **The declining underground water, degrading soil structure and salinity problems in eastern IGP**

Faulty management practices and excessive use of Insecticides and pesticides in IGP pollute the underground water quality. Use of poor quality water in agricultural sector leads to emergence of several diseases in living beings and decreased the grain quality which ultimately affects overall production of crops and human health.

Day to day soil health is declining down from an alarming rate resulting in deficiency of macro and micro-nutrient deficiencies in soils of IGP [4]. Rice is conventionally established through tillage under wet conditions with an objective of reducing percolation losses and reduced weed growth. However, intensive tillage resulting in breaking of large aggregate further coupled with poor contact with seed, thereby reducing potential yields like puddling operations are water, capital and energy intensive which finally deteriorates the soil structures. Intensive cropping system of Rice-Rice-Rice and Rice-Wheat leads to water saturation in eastern IGP and there are more chances to stand water in crops for many days and it causes salinity problems in these areas.

- **In the crop residues management and emission of GHGs concentration**

Rice-wheat cropping system produces huge crop residues which generally burnt into the field for the timely sowing of the wheat crop. Burning of farm residues generates ample amount of greenhouse gases and aerosols and other hydrocarbons to the atmosphere affecting the atmospheric composition. For example, 70%, 7%, 0.66% of C and 2.09% of N evolved as CO_2, CO, CH_4 and N_2O upon burning of rice straw. This change might have direct and indirect effect on the radiation balance. These gases may lead to a regional increase in the levels of aerosols, acid deposition, increase in tropospheric ozone and depletion of Ozone layer which protects us from direct sunlight. Hence, various techniques must be developed and adopted at a large scale in IGP which could be beneficial for reducing the concentration of GHGs like direct drilling of wheat seed in standing rice stubbles using Happy Seeder or direct seeding [5]. Carbon sequestration and carbon credit type of technique are useful for decreasing greenhouse concentration in these changing climatic conditions, which is an integral part of CSA.

- **The increase of extreme weather events and abnormalities**

IGP dominated by the largest seasonal mode of precipitation in the world, due to monsoon circulation. Mainly temperature and precipitation variability have predominant inter annual and intra seasonal components, giving rise to extremes in seasonal anomalies resulting in large scale droughts and floods, also cloudburst and prolonged break in the monsoon. Further, IGP climate is marked by severe cold waves during winter and heat waves in summer. Besides natural threats, IGP is also over stressed due to exploitation of the land and water resources. It can be concluded that IGP is under the twin threat of increasing population and climate change [4].

2.2 Strategies

2.2.1 To sustainably increased agricultural income and its production

As part of efforts to maintain agriculture equilibrium, scientists at the international maize and wheat improvement Centre (CIMMYT) studied basmati (scented) rice-wheat rotation system in North-western part of Indo-Gangetic Plains. For example for the seeking of optimum plant population to lower impact of global warming while increasing profit in farming.

An experiment in green gram growing carried out in the taraori village of Haryana concluded that two ways of managing crop rotation system like zero tillage rice and wheat planted in crop residues, zero tillage wheat and green gram planted in crop residues of the rice-wheat system of this region of India are agronomicallly sustainable and economically viable and beneficial in terms of improving soil health and reduced greenhouse emission [6]. The experiment evaluated six different combinations of tillage, residues management and green gram (*Vigna radiata*) incorporation into rice-wheat rotation and it compared to conventional tillage techniques with conservation agriculture technique in a village of northern state of Haryana, known as major basmati grown area of India. Aim was to identify a cropping system which produce greater yield at minimum cost of cultivation that leads to be higher profitability while minimum soil and environment disturbances.

Scientists and researchers are trying to increase production by making use of the normally fallow season from May to July, which makes an interval in between growing rice (July to November) and wheat (November to April). Rather than extending the wheat and rice growing season, it helps to keep the soil healthy in such an intensive cereal-cereal rotation, it also included green gram (mung beans). By planting basmati rice using a direct seeded rice and aerobic rice cultivation in its place of the conventional tillage (Puddling) and transplanting method, it reduced methane emission by about 50 %. However this reduces methane emission in a rice-wheat system is counter balanced by increasing the concentration of nitrous oxides emission. In context of emission, the research concluded that if we used combining zero tillage and residues retention in the crop growing system then we sequestered carbon that is present in the soil and it helping to prevent the greenhouse gas emission.

Other environmental benefits included viz., improvement in soil health, help in eliminating residues burning and efficient water use in fields that is planted with rice-wheat rotation, where sustainable agriculture were used. The water is saved about 30% in comparison with farms using conventionally till system.

2.2.2 To adapt and build resilience to climate change

- Reduced climatic risk- Maize on raised bed for diversification
- Water saving- Direct seeded rice and Aerobic rice cultivation
- Energy saving- Zero tillage
- Labour saving- Direct seeded rice
- Early harvest, and
- Increased soil carbon like carbon sequestration

2.2.3 To improve water and land productivity

The benefits are:

- ➢ Yield per unit of area is the traditional measure of productivity in agriculture. Water is the most limiting resource and with the challenge to produce more with less consumption of water, production per unit of water has emerged as an important concept like "Per drop more crop" means every drop of water is efficiently utilized for the production of crop.
- ➢ For a farmer, strategies to increase the productivity of water may lead to more income and enhance their livelihoods.

i. Allocation of less water to more stress tolerant crops.
ii. Planning for irrigation of crops during critical growth stages.
iii. Irrigations at lower adequacy.
iv. Allowing more depletion of available soil moisture.
v. Judicious use of poor quality water like use of mixed water of the canal and saline water.

2.2.4 Climate-smart agriculture strategies to improve crop productivity

- About 75% of the world's population lives in rural areas and major occupation is agriculture. Growth in the agricultural sector is highly effective in reducing poverty and increasing food security in countries with a high percentage of the population dependent on agriculture [7].

- Increasing productivity as well as reducing costs through increased resource-use efficiency is important means of attaining agricultural growth. Yield gaps indicating the difference between the yields farmers obtains on farms and the technically feasible maximum yield, are quite substantial for marginal farmer in developing countries [8].
- Similarly, livestock production is often much lower than it could be reducing these gaps by enhancing the productivity of agro-ecosystems and increasing the efficiency of soil, water, fertilizer, livestock feed and other agricultural inputs gets higher return to agricultural producers, reducing poverty and increasing food availability and access.

2.2.5 To reduce GHGs emissions

2.2.5.1 Reducing emissions

According to FAO, to achieve future food security and agriculture intensification goals by 2030, adaptation towards climate change and lowering the greenhouse gases emission will be necessary. Around 41% of GHGs come from agriculture, CGIAR (Consultative group of International Agriculture Research) says. Adaptation is fundamentally about risk management and mitigation options are helpful for reducing and managing the risks of climate change [9].

It includes various ways to reduce emissions of GHGs from agriculture like:

- Alternate drying and wetting of paddy field; by reducing the number of irrigation means letting the paddy field drained alternatively, it leads to half of methane emission from flood rice production as the CGIAR expert said. The management way is originally developed as a way to conserve water, so it has potential to be adaptive to climate change also.
- Increasing the production of milk and meat production, it increased the contribution of anthropogenic induced GHGs, about 14.5% in the livestock sector in which much of the methane is produced by ruminant digestion like enteric fermentation. As the number of animals are increased then its productivity of herds are also increasing which means that fewer animals are required to produce the same amount of milk and meat, it also reduces the emission of GHGs into producing that food [10].
- Now a day, to raising more production, farmers adopted intensive farming system but it is a culprit for sustainable agriculture because it involves mechanization and more uses of synthetic fertilizers. The researchers found that a change in economic policies to stop wastage of natural resources, it helps to prevent water contamination and land degradation.

3. CONCLUSION

CSA is an innovative, multi-disciplinarians and sustainable approach in which identifies efficient ways of maintaining suitable cropping system in IGP. It uses, sound agriculture management practices which is helpful to improved nutrient content and productivity of the different crop in a sustained way. CSA will help to produce more yields with lower production costs and therefore, higher economic profitability for small and marginal farmers. CSA is provides a better way to reduce GHGs emission from the field using various resources conservation technique (RCT).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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