

Climate smart agriculture

in cereal systems of Indo-Gangetic plains

H S Jat*, Madhu Choudhary and P C Sharma

ICAR-Central Soil Salinity Research Institute, Karnal, Haryana 132 001

In India, rice-wheat (RW) system has played a significant role in achieving food security of the nation but these achievements were accompanied by problems of resource degradation (soil, water, energy) in Indo-Gangetic plains. The current approaches of RW production are ecologically intrusive, economically and environmentally unsustainable; the problems which seems to be aggravated by the changing climate in the region. Climate Smart Agriculture (CSA)- based sustainable intensification of cereal systems may help in managing the natural resources in the region by improving the adaptive capacity of cereal systems to ensure food security while mitigating the environmental footprints. CSA-based system also improved soil health (SOC- 100% after 5 years with full residue recycling), proved more resilient to climatic risks like temperature stress, water stress and untimely rainfall compared to conventional system. CSA is in accordance with G20 agriculture working group agenda to address the major issues of sustainable development and climate change mitigation in the bread basket of the country.

Keywords: Climate smart agriculture, Rice-wheat system, Sustainable agriculture

THE sustainability of rice-wheat (RW) system in western Indo-Gangetic plains (IGP) of India is crucial to meet out the nation's food security. Sustaining and increasing the production of cereal systems in the Indian states of Punjab, Haryana, and western Uttar Pradesh in the western IGP, popularly known as the "breadbasket" of the country, is essential to meet the food requirement of India's burgeoning population, which is likely to increase 1.6 billion by 2050. The sustainability of this system is at high risk because of resource degradation, declining factor productivity and shrinking farm profitability under current farming practices. Therefore, sustainable intensification (SI) based on system approach following the CSA approach (food security, adaptive capacity and mitigation potential) is felt needed. Looking to the 2nd generation agriculture problems related to energy, resources quality, climate abnormalities in IGP, issues of food security, resource efficiency, soil health, biodiversity and environmental quality is the major concern and might be tackled through the combined efforts under G20. In western IGP, the main focus was on process-oriented research with CSA to design next generation of cropping systems that are highly productive, resource efficient, sustainable, low carbon emitting and adapted to the expected changes in

environmental and socioeconomic drivers.

Continuous cultivation of RW system in western IGP has led to an over-exploitation of fresh ground water reserves, poor soil health, low input response, environmental pollution through residue burning and low farmer's profitability. More than 30 million tonnes of cereal crop residue is burnt in NW India annually. The CSA-based sustainable intensification with systemic and holistic research approach was used to tackle the issues in NW India.

Business as usual/farmer's practices will no longer be able to achieve the targeted growth rate of 4% in cereal production in India while addressing the issues of water, labour, energy and soil health in rice/maize based cropping systems with the current situation of natural resource degradation, residue burning, biotic and abiotic stresses. Projections for the coming decade suggest that average annual yield growth of wheat, rice, and maize must rise by about 1.1%, 1.7% and 2.9% per annum, respectively. It has been estimated that management issues alone contribute to the yield gap of 14–47%, 18–70% and 36–77% in wheat, rice and maize, respectively. Climate change effects could not be buffered with conventional management practices and in this situation India could lose 4–5 million tonnes

of wheat with every 1°C rise in temperature. Unusual terminal heat and untimely rainfall are causing yield declines in wheat, especially in NW India.

Climate Smart Agriculture (CSA)

India has made spectacular progress in foodgrain production and able to exports sizable amount to several other countries after meeting his own food requirement. 'Indian Agriculture is a Gamble with Monsoon' rightly said by our 1st Prime Minister Pd. Jawahar Lal Nehru as our country is witnessing the adverse impacts of climate change on food production in every alternate year in one or other form. Rising temperatures, erratic rainfall, extreme weather conditions (such as prolonged droughts and floods), changing soil fertility, and new pest infestations are major factors contributing to stagnant agricultural growth. CSA is considered a pragmatic approach to ensuring food security in a changing climate conditions. The CSA practices (CSAPs) include site-specific nutrient management (SSNM), conservation agriculture (zero tillage, residue management and efficient crop rotation) and use of stress-tolerant crop varieties. The CSAP encompasses farming practices that sustainably increase productivity, enhance resilience/adaptation, reduce greenhouse gasses (GHG) and help to achieve national food security. The CSA options include water, energy, nutrient, carbon, weather and knowledge-smart practices suitable to cereal systems in the region (Table 1). The CSA practices can also deliver co-benefits in the form of reduced GHG emissions and enhanced soil carbon stock.

Table 1. Climate smart interventions for targeting adaptation and mitigation options in cereal systems

Technology	Adaptation/mitigation potential
Water smart: Laser land leveling, micro-irrigation, furrow irrigation, cover crops, crop residue mulch	Interventions to improve water efficiency and effective control of irrigation and drainage.
Energy smart: Zero/minimum tillage, crop residue management, direct seeded rice, permanent raised beds	Interventions to improve energy use efficiency, e.g. reduced fuel use and chemical fertilizers.
Nutrient smart: SSNM, green manuring, leaf colour chart, optical sensors, fertigation	Interventions to improve nutrient-use efficiency and soil quality.
Carbon smart: Crop residue management, legume integration	Interventions to reduce GHG emissions and improve carbon sequestration
Weather-smart: ICT based weather forecasts and crop advisory, weather index based crop insurance, climate analogues	Interventions to provide services related to income security and weather advice to farmers, crop-specific insurance to compensate income loss due to vagaries of weather.
Knowledge smart: Improved crop varieties, seed banks	Use of a combination of science and local knowledge with smart varieties and technologies

CSA evidences

In CSA-based management system, ZT along with crop residues retention can play an important role in

buffering soil moisture, temperature, replenishing soil nutrients stocks (adaptation to climate risks) and organic matter in addition to reducing the environmental footprints (mitigation of GHGs) by eliminating in-field burning, thus leading to CSA-based sustainable intensification in RW production ecologies. Therefore, new adapted cultivars and technologies were deployed to fit into the changed scenarios with respect to changing climate and natural resource degradation for tackling triple challenges of resource fatigue, decelerating productivity growth in cereal crops and farmers' profitability.



Wheat sowing through Happy Seeder in paddy harvested field

Science based evidences have been collected in the western IGP on cereal based systems for more than 5 years with continued cultivation with CSA on the different parameters from large number of multi-location trials. The results showed that CSA-based rice-wheat-mungbean (RWMb) systems improved the system productivity by 8–12%, profitability by 18–23% using 20–25% less irrigation water and ~20–23% less energy input compared to conventional RW system/farmers practice while reducing the global warming potential (GWP) by ~25% (1.5 Mg CO₂ eq/yr). Whereas, CSA-based maize-wheat-mungbean (MWMb) systems on flats improved productivity by 10–20% and profitability by 40–50% using 70–80% less irrigation water, and 45–50% energy input compared to conventional RW system/farmers, practice while reducing the GWP by 30%. In maize based system, permanent beds doubled the advantage over ZT-flat system. The productivity was improved by ~10 with 10% more saving in irrigation water compared to flat system. CSA-based cereal systems improved the soil organic carbon by 80–100% and available NPK by 30, 30, 50%, respectively compared to conventional RW system. Therefore, 30% and 50% of N and K fertilizers can be saved after 5 years of continuous cultivation. Precise management of N fertilizer through subsurface drip irrigation (SDI) saved 20% of nitrogenous fertilizer in both rice and maize based systems with same or even higher yields. SDI saved 40–50% of irrigation water and increased irrigation water productivity (WP_i) by >100% compared to farmers' practice. However, maize-wheat system recorded 10% higher system productivity (rice equivalents), saved 80% of irrigation water and increased WP_i by many folds compared to conventional RW system. For sustainable intensification, integration

of mungbean in RW and MW system contributes ~15% increase in both system productivity and profitability. CSA-based sustainable intensification helped in mitigating the negative effects of terminal heat stress on wheat and increased the wheat yields by 0.7–0.8 t/ha than conventional till wheat. Crop residue retention reduces the *Phalaris minor* problem considerably (up to 75%) in wheat crop and also reduces environmental pollution by managing the crop residue *insitu* using Happy Seeder. Replacement of PTR with ZT-DSR and ZT-maize in RW system reduced GWP by 30–50 and 40%, respectively. On system basis, CSA based management reduced the GWP by ~25% in both rice and maize based systems.



Mungbean a short-duration crop in paddy harvested field

Impact of CSA technologies

Residue management using Happy Seeder is one of the key elements for no-till planting while retaining



Residue management using Happy Seeder

crop residues on soil surface. Happy Seeder technology provided a yield advantage of 0.10–0.26 t/ha over ZT wheat without residue retention and also reduced production costs by ₹3500–4000/ha and ultimately improved overall farm profitability by ₹5000–6500/ha compared to conventional tillage wheat. The area under Happy Seeders was negligible in the year 2009 and it rose up to ~6,50,000 ha in the year 2019. Direct seeded rice reduces cultivation costs by around ₹5,000/ha and reduces irrigation water use by 25% (30–40 ha-cm). Moreover, when wheat is grown after DSR, wheat productivity has been found to be 8–10% (0.5–0.6 t/ha) higher than when grown after puddled transplanted rice. Around 5 lakh area has been sown through DSR technique in Punjab during COVID time. Zero-tillage wheat has been accepted by farmers in Haryana and Punjab since late 1990's and the areas under zero tillage in NW India reached up to 1.5 M ha without residue retention.

SUMMARY

Climate Smart Agriculture (CSA) based sustainable intensification has a potential to provides safety nets to farmers through reducing the risks of climate change with improving adaptive capacity against climatic risks and hence can potentially save public investments on insurance. Continuous adoption of CSA in intensive cereal systems has significant potential to improve system productivity, farmers' profitability, soil health while reducing the environmental footprints. Continuous cultivation with CSA, 30 and 50% of N and K fertilizers can be curtailed and in-turn saving significant foreign exchange on fertilizer imports and contributing to *Atma Nirbhar Bharat*. The CSA based management practices may help in contributing to Government of India's most of the farmer's welfare schemes of doubling farmers' income; improving soil health; more crop per drop etc. The CSA practices have wider practical applicability and scalability in any region. Its full advantages might be explored through G20 summit as it provides the opportunity to coordinate at the policy level to work towards agriculture stability and sustainability.

*Corresponding author's e-mail: hsjat_agron@yahoo.com

Share your experiences with

Indian Farming

Write to:

Editor

INDIAN FARMING

Directorate of Knowledge Management in Agriculture

Indian Council of Agricultural Research

Krishi Anusandhan Bhavan I,

Pusa, New Delhi 110012

indfarm@icar.org.in