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Economic Efficiency and Profitability of Resource Conservation Technologies in the Rice-wheat Cropping System in India's Indo-gangetic Plains: A Review

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ABSTRACT

This review paper aims to thoroughly analyse the economic viability and profitability of resource conservation technologies in the rice-wheat cropping system in India's Indo-Gangetic Plains. A thorough analysis of the body of current research has been considered as part of the manuscript preparation process. The utilization of resource-saving technology is crucial in maintaining and improving the rice-wheat system's productivity while lowering production costs. Zero tillage methods for wheat and DSR and FIRB methods for rice were found to be most commonly used resource conserving technologies in the Indo-Gangetic Plains. Additionally, data suggests that implementing resource conservation methods led to a notable increase in productivity, cost reduction and sustainability in the rice-wheat system. Adoption of resource-conserving technology decreased farmers' costs per ha by 20-22 per cent and raised net income by 25-30 per cent in the wheat-rice system. The high cost of RCTs machinery, the lack of a comprehensive resource conservation agriculture package for different agro climatic regions, the scarcity of suitable varieties for RCT technology and the shortage of skilled agricultural laborers to effectively operate machinery were noted as barriers to technology access. Aside from improving technical efficiency, other important elements that positively impact the adoption of RCTs include financial availability, improved extension services and resource management training. The policies must be developed to promote and facilitate the broader use of these technologies accordingly.

Key words: Conservation, Efficiency, Rcts, Rice-wheat, Zero tillage.

Resource conservation technologies (RCTs) mainly concern conserving resources by minimizing tillage, protecting soil moisture and nutrients by growing cover crops and crop residues and implementing temporal and spatial crop sequencing (Sharma *et al.,* 2021; Kundu, 2022). Farmers have long utilized these pro-sustainable technologies and their associated behaviors, but in recent years, these practices have been undermined. Farming's viability is at serious risk due to declining net returns and growing sustainability risks. Technologies for resource conservation, which are a part of conservation agriculture (CA), can reduce some of these negative externalities while increasing farm profitability (Krishna, 2022). There was a significant push in all the regions of the nation to enhance the acceptance and popularity of RCTs. Yet, the policies and initiatives are insufficient and ineffectual to produce the intended results in this direction due to the lack of precise information. (Singh *et al.,* 2011; Saha *et al.,* 2022).

Since, RCTs make efficient use of the resources at hand and preserve soil fertility, they seem like desirable solutions for attaining sustainable and intensive crop production in a variety of agro-ecological contexts. Though the Resource Conservation Technologies are site-specific, but large adoption of RCT is necessary. Hence, larger scale testing of these new technologies under various production systems is required. The existing cropping patterns exhibit unequal adoption of resource-conserving technology and there is a lack of trustworthy information regarding the overall adoption trend (Ramesh *et al.,* 2016; Swaminathan *et al.*, 2022). Thus, it is essential to support alternative technologies that will contribute to preserving the critically important but progressively diminishing natural resources and, over time, increase productivity growth by maintaining the quality of the soil and the production environment (Singh *et al.,* 2011).

Within this strategy, resource-conserving technologies (RCTs) are essential for maintaining and improving crop output across a range of cropping systems at a reduced cost of production. The rolling out of RCTs is expected to benefit farmers in ways such as decreased soil erosion losses, lower energy and irrigation costs, labor input savings, enhanced productivity and water use efficiency,

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decreased groundwater pumping, enhanced nutrient use efficiency and the adoption of new crop rotations. Planners and policymakers find it challenging to create appropriate policies for the popularization and increasing acceptance of RCTs, even though these concerns are currently the subject of intense debate. Against this background, the current study addresses the following queries:

i. Cost-effectiveness of RCTs vis-ů-vis conventional technologies used in rice-wheat cropping systems and.
ii. Impact of the Resource Conservation Technologies on various economic indicators.

The present reviews' findings will help policymakers understand how effective resource conservation technologies are on different economic indicators. This will enable the design of proper approaches to successfully implement resource conservation techniques along with traditional farming practices for a range of cropping systems.

Scenario of rice-wheat cropping system in the Indo-gangetic plains

A common agricultural pattern in the Indo-Gangetic plains of India is rice-wheat. It is the largest agricultural production system in the world, covering around 12.3 million hectares in India, with the Indo-Gangetic plains accounting for about 85 per cent (Ladha *et al.,* 2003; Timsina and Connor, 2001). India has a prominent pathway of foodgrain production from 87.4 million tons in 1961 to 315.7 MT in 2021-22 (Economic Survey, 2022-23). In India, rice covers around 46.4 hectares, yielding 130.3 metric tons of production and 2,809 kg of productivity per ha. In contrast, wheat occupies 30.5 ha, produces 106.8 metric tons and yields 3,507 kg of productivity per ha (Economic Survey, 2022-23).

According to Ambast *et al.* (2006), groundwater is essential for irrigation in the rice-wheat-producing regions of India, including Punjab, Haryana and Uttar Pradesh. Ramesh *et al.* (2016) and Kumar *et al.* (2021) state that the sustainability of the rice-wheat cropping system is also being threatened by the existing agricultural practices, which are deteriorating the soil and water resources. The region's agricultural sustainability is called into question due to the significant repercussions of the rice-wheat monoculture. The system of rice-wheat cropping has greatly helped to satisfy the growing number of deprived populations, but it has also brought about several sustainability problems, such as dwindling water supplies, deteriorating soil health and environmental degradation, all of which are contributing factors to stagnant or decreased land and water productivity. Therefore, alternative tillage and techniques need to be developed, tested and recommended for the sustainable development of the rice-wheat cropping system. This will improve soil health, water and land productivity and the surrounding environment, all of which will contribute to an overall improvement in the farmers' standard of living (Bhatt, 2016).

Resource conservation technologies used in the rice-wheat cropping system

To maintain and improve the rice-wheat system's productivity at a lower cost of production, resource-conserving technologies, or RCTs, are important. It was reported by Singh (2010) that these were the best short-term and long-term options for maintaining productivity. According to Kumar *et al.* (2021), implementing conservation tillage techniques greatly increased the productivity of the rice-wheat system. Scientists have suggested resource-conserving solutions for this aim, including zero tillage, laser leveling, irrigation based on soil matric potential, bed planting, direct sowing, mechanized rice transplanting and crop diversification (Bhatt *et al.,* 2016; Kumari and Kumar, 2023). In the process of cultivating rice, RCTs included rice intensification, direct aerobic rice, direct seeded rice and cultural techniques such as brown manuring, leaf color charting, stale seedbed management, mulching and crop residue management (Alena *et al.,* 2022). The most effective resource-saving technique in the Indo-Gangetic Plain was zero-tillage for wheat planting following rice, especially tractor-drawn ZT seed drill (Biswas, 2016). In the rice-wheat cropping system, Kumar *et al.* (2018) investigated the adoption trend of multiple RCTs. They reported that the zero-tillage method (88.33%) was the most popular, followed by rotational tillage (38.33%) and laser land leveling (26.67%). According to Krishna *et al.* (2022), there is considerable economic potential for the ZT technology in the IGP's rice-wheat systems.

Economic efficiency of RCTs in the rice-wheat cropping system

The advantages of resource conservation technologies over traditional methods in terms of economic efficiency, including cost savings and effective input use were examined by Singh *et al.* (2011). According to the findings of their investigation, the savings in the cost of cultivation of wheat in several states, including Punjab, Haryana, Uttar Pradesh and Bihar, ranged from 11% to 16%. RCT adoption reduced human and mechanical labour usage by 20-27 percent (Singh *et al.,* 2011) and it was responsible for 3-4% of the overall cost of wheat production. Due to its ability to reduce the need for machinery, labour and seed, RCTs-in particular zero-tillage technology-were found to be more cost-effective than conventional approaches in the rice-wheat cropping system (Gangwar and Singh, 2015; Kumar *et al.,* 2017). Resources were used more efficiently and at a lower cost which saved labour, fuel, time, fertilizers, insecticides and farm energy (Kumar *et al.,* 2021). Zero tillage harvests benefits such as reduced planting time, fuel and water use, increased nutrient efficiency, decreased weed populations, less machinery wear and tear and a reduction in air pollution. Water was conserved and weed pressure was decreased with zero tillage (Jat *et al.,* 2010). According to Rasool (2015), zero tillage saved irrigation water in the wheat crop by 20-35 per cent when compared to conventional tillage, saving roughly 6-8 percent of the total cost. The implementation of a furrow-irrigated raised-bed system (FIRBS) in wheat conserved 25-30 per cent of seed, 40-50 per cent of water and 25-30 per cent of nutrients without compromising yield (Tiwari, 2021). Thus, by using these technologies, there was increased farm profitability and improved sustainability of agriculture in resource-poor countries (Kumar, 2014). In wheat production, the use of resource-conserving technology (zero tillage) hasled to a 20 per cent decrease in farmers' costs per hectare and a 28 per cent increase in net revenue (Reeves *et al.,* 2016).

Profitability of RCTs in the rice-wheat cropping system

Numerous research evaluated the comparative efficiency of RCTs on different economic metrics. Adoption of laser land levelers was found to increase the cultivable area by 2-3 per cent (Kumar, 2017); rice yields were found to be 15 per cent higher than conventional practices (Shanwad *et al.,* 2014); and net return was found to be 80 per cent higher for adopters of RCTs in wheat than for nonadopters (Gangwar and Singh, 2015; Devi *et al.,* 2013). According to Biswas (2016) adoption of ZT was beneficial due to the notable "yield effect," which was resulted in an average 12 per cent increase in productivity and the "cost-saving effect," which reduced the need for conventional fertilizer (104 Rs/ha) phosphate fertilizer (1938 Rs/ha), irrigation (380 Rs/ha), seed (462 Rs/ha), nitrogen (269 Rs/ha) and land preparation (1938 Rs/ha). Farmers' profits were reported to rise by Rs. 2,200-3,000/ha when they were practiced zero tillage (Jat *et al.,* 2010). According to Kumar *et al.* (2021), the use of different resource conservation methods improved soil health, nutrients and water efficiency with higher sustainable yields, resulting in a sustainable improvement of RWCS. Compared to non-adopters, the RCTs improved productivity and decreased technical inefficiency by 28 per cent (Kumar *et al.,* 2022).

Resource conservation technologies did, however, greatly enhance the farm economy. However, RCTs must also be evaluated throughout time from a long-term viewpoint utilizing a temporal analytical framework (Chatarjee *et al.,* 2020). According to Samuel *et al.* (2020) research, the long-term effects of RCTs on farm returns revealed that, although the treatment without conservation yielded better returns in the first three years, the treatment with conservation produced higher returns overall after three years. According to Gupta and Seth (2017), field data also demonstrate that resource-saving technologies increased yields while consuming less water and having a less detrimental influence on the natural environment.

Constraints and problems in adoption of the RCTs

The features of the suggested technology, farmers' assessments of its benefits and necessity and the distribution and accessibility of production inputs (land, labour/time, capital, knowledge, skills, *etc.*) all were influenced the adoption of resource conservation technologies. Additional aspects included the governmental climate, institutional support and knowledge sharing and farmers' attitudes toward risk and trials (Drechsel *et al.,* 2006). The methods used to raise awareness and distribute it were skewed against smallholders. To calculate the impact of social targeting of resource conserving technologies, more investigation is needed (Krishna *et al.,* 2022). We pinpoint the essential elements that could lead to a rise in adoption, such as access to institutional support services, education and legally protected land (Tambo and Jonathan, 2018). Since RCTs solutions are site-specific, extensive testing of these new technologies under various production systems is necessary if they are to see widespread acceptance (Ramesh *et al.,* 2016). Singh and Kaur (2020) examined the growing concerns regarding the state of resource conservation technologies, farmer attitudes and the challenges associated with adopting particular technologies. According to the report, policy formulation is necessary to promote and facilitate the broader usage of these technologies. Furthermore, critical elements that favorably influenced the adoption of RCTs and improved their technical efficiency include credit availability, improved extension services and training in natural resource management (Kumar *et al.,* 2022). The study by Kumari *et al.* (2018) identified three primary constraints related to financial, socio-psychological and extension constraints. These included the higher cost of zero-till machines (70.37%), farmers' lack of cooperation in sharing experiences (67.30%) and farmers' ignorance of minor machine adjustments (80.74%). According to Singh *et al.* (2010), available varieties for resource conservation technology were scarce, the cost of RCT machinery was high, there was a lack of skilled agricultural labourers to operate these machines effectively and there was a lack of a complete package of resource conservation agriculture for all agro-climatic regions. Moreover, the three most important variables impacting farmers' adoption of resource conservation technologies were their propensity for innovation, their attitude toward RCTs and their level of awareness about them.

CONCLUSION

With increased yields, increased profitability, improved soil fertility and improved water-use efficiency, the Indo-Gangetic plains have helped adapt the idea of resource conservation technologies to rice-based cropping systems. This suggests a potential path towards sustainable agricultural production in rice-based systems. However, resource-conserving technology was not always appropriate because there were instances in which the disadvantages outweighed the benefits. However, when numerous resource-conserving technologies are coupled, their benefits can compound and act in unison.

The economic viability of resource-saving technology resulted in lower cultivation costs for the rice-wheat cropping system. Furthermore, it was proved by numerous studies that the RCTs were lucrative because no-till farms generated higher returns than farms that used traditional tillage. However, several limiting constraints must be solved before farms may use resource-saving technologies. Additionally, smallholders were disadvantaged by the procedures used to raise awareness and disseminate information about the RCTs. Education, the protection of land rights and the availability of institutional support services, such as agricultural credits, were the main elements that could encourage greater adoption.

Conflict of Interest

All authors declared that there is no conflict of interest.

REFERENCES

Alena, N. and Mahapatra, A. (2022). Resource conservation technologies in rice cultivation. Indian Journal of Natural Sciences. 13(72): 43209-43214.

Ambast, S.K., Tyagi, N.K. and Raul, S.K. (2006). Management of declining groundwater in the Trans Indo-Gangetic Plain (India): Some options. Agricultural Water Management. 82(3): 279-296.

Bhatt, R., Surinder, S., Kukal, M., Busari, A., Arora, S. and Yadav, M. (2016). Sustainability issues on rice-wheat cropping system. International Soil and Water Conservation Research. http://dx.doi.org/10.1016/j.iswcr.2015.12.001.

Biswas B. (2016). On-farm impact analysis of resource conservation technology on wheat at Tarai-teesta flood plain of eastern indo-gangetic plain (IGP). Journal of Applied and Natural Science. 8(2): 833-839.

Chatarjee, S., Chakraborty, R. and Banerjee H. (2020). Economic impact assessment of conservation agriculture on small and marginal farm households in eastern India. Agricultural Economics Research Review. 33(Conf. No.): 127-138.

Devi, S., Singh, A.K., Bordoloi, R. and Jat, P.C. (2013). Determinants of resource conservation technologies (RCTs) adoption in rice (*Oryza sativa* L.) cultivation under rainfed farming condition. J. Agri. Sci. 4(2): 77-82.

Drechsel, P., Olaleye, A., Adeoti, A., Thiombiano, L., Barry, B. and Vohland, K. (2006). Adoption Driver and Constraints of Resource Conservation Technologies in sub-Saharan Africa. IWMI, West Africa Office, Accra, Ghana.

Economic Survey, 2022-23. Ministry of Finance, Government of India.

Gangwar, A. and Singh, R. (2015). Efficiency of conservation agriculture: Evidences from wheat farms in Eastern Uttar Pradesh. International Journal of Agriculture, Environment and Biotechnology. 8(3): 763-772. doi:10.5958/2230-732X.2015.00084.4.

Gupta, R. and Seth, A. (2017). A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic plains (IGP). Crop Protection. 26(3): 436-447.

Jat, M.L., Singh, R.G., Sidhu, H.S., Singh, U.P, Malik, R.K., Kamboj, B.R., Jat, R.K., Singh, V., Hussain, I., Mazid, M.A., Sherchan, D.P., Khan, A., Singh, V.P., Patil, S.G. and Gupta, R. (2010). Resource Conserving Technologies in South Asia: Frequently Asked Questions. International Maize and Wheat Improvement Centre, New Delhi India. Technical Bulletin. pp 44.

Krishna, V.V., Keil, A., Jain, M., Zhou, W., Jose, M., Surendran, P. S., Barba, E. L., Singh, B., Jat M.L. and Erenstein, O. (2022). Conservation agriculture benefits Indian farmers, but technology targeting needed for greater impacts. Frontiers Agronomy. 4: 1-14. doi: 10.3389/fagro.2022.772732.

Kumar, A., Poswal, R.S., Singh, S., Sendhil, R., Chand, R., Pandey, J.K. (2018). Adoption of resource conservation technologies for sustainable production: Evidence of potential impact from Haryana. Indian Journal of Economics and Development. 14: 77-86. doi:10.5958/2322-0430.2018.00039.2.

Kumar, A., Singh, R., Sendhil, R., Chand, R. and Pandey, J.K. (2017). Impact of resource conservation technologies in Haryana. Journal of Community Mobilization and Sustainable Development. 12(2): 257-264.

Kumar, L., Rajput, D., Venkatesh, D.S., Kumar, A.V., Singh, P.K. and Srinivas, R.A. (2021). Resource conservation technologies (RCTs) in rice-wheat production: An overview. IJARIIE. 7(2): 23-27.

Kumar, R. (2014). Socio-economic assessment of conservation agriculture in India. Conservation Agriculture for Carbon Sequestration and Sustaining Soil Health, India Publishing Agency. New Delhi. pp. 517.

Kumar, S., Singh, D.R., Singh, N.P., Jha, G.K. and Kumar, S. (2022). Impact of natural resource conservation technology on productivity and technical efficiency in rainfed areas of Southern India. Journal of Environmental Planning and Management. doi: 10.1080/09640568.2022.2114320.

Kumar, S., Singh, D., Singh, N., Jha, G. and Kumar, S. (2022). Impact of natural resource conservation technology on productivity and technical efficiency in rainfed areas of Southern India. Journal of Environmental Planning and Management. 67. 1-22. 10.1080/09640568.2022.2114320.

Kumari, A.R., Meena, K., Dubey, S.K., Pundir, A. and Gautam, U.S. (2018). Know-hows of zero tillage technology and the associated constraints experienced by the farmers in rice-wheat cropping system of Eastern Uttar Pradesh. Indian Journal of Extension Education. 54(3): 1-7.

Kundu, D.K. (2022). Conservation Agriculture and Resource Conservation Technologies in Indo-Gangetic Plains: Status and Challenges Ahead. Conservation Agriculture and Climate Change. CRC Press, London.

Kumari, P. and Kumar, R. (2023). Resource conservation technologies in era of climate change: A review. Agricultural Reviews. 44(3): 336-342. doi: 10.18805/ag.R-2365.

Ladha, J.K, Dawe, D., Pathak, H., Padre, A.T., Yadav, R.L., Bijay, S., Singh, Y. *et al.* and Hobbs, P.R. (2003). How extensive are yield declines in long-term rice-wheat experiments in Asia? Field Crops Research. 81:159-180.

Ramesh, Negi, S.C. and Rana, S. (2016). Resource Conservation Technologies (RCTs)-Needs and future prospects: A review. Agricultural Reviews. 37(4): 257-267. doi: 10. 18805/ag.v37i4.6456.

Rasool, R. (2015). Resource conservation technology in rice-wheat cropping system. Journal of Humanities, Arts, Medicine and Sciences. 1: 25-48.

Reeves, T.G., Thomas, G. and Ramsay, G. (2016). Save and grow practices in maize, rice and wheat: A guide to substantial cereal production. FAO, Rome.

Saha, R., Barman, D. and Behera, M. (2022). Conservation Agriculture and Climate Change: Impacts and Adaptations. CRC Press. OXON, U.S.

Samuel, J., Rama Rao, C.A., Chary, G.R., Raju, B.M.K. and Pushpanjali. (2020). Environmental impact of resource conservation technology: The case of soybean in Central India. Multilogic in Science. Conf. IX (XXXII):489-492.

Singh, D. and Kaur, P. (2020). Resource conservation technologies in Punjab: Status and problems. Indian Journal of Economics and Development. 16: 281-287.

Shanwad, U.K., Dabali, S.D., Rajkumar, S., Shivamurthy, D., Patil, S.G. and Jat, M.L. (2014). Resource conservation technologies (RCT) in direct seeded rice (DSR): A tool for climate resilient agriculture in hilly region of Karnataka in South India. Conference: International Symposium New-Dimensions in Agro-meteorology for Sustainable Agriculture. Pantnagar, India.

Sharma, J., Bharti, V., Kumar, D., Menia, M. and Bochalya, R.S. (2021). Resource conservation technology for enhancing the rice productivity in India: A review. The Pharma Innovation Journal. 10(9S): 163-167.

Singh, N.P., Singh, R.P., Kumar, R., Vashist, A.K., Khanb, F. and Varghese, N. (2011). Adoption of resource conservation technologies in Indo-gangetic plains of India: Scouting for profitability and efficiency. Agricultural Economics Research Review. 24: 15-24.

Singh, O.P., Singh, H.P., Badal, P.S., Singh, R. and Pandey, D. (2010). Impact of resource conservation technologies on carbon emission in major wheat growing regions of India. Ind. Jn. of Agri. Econ. 65(3): 399-411.

Singh, J.B., Singh, Y.P. and Kumar, J. (2010). Impact assessment of resource conservation technologies (RCTs) in irrigated areas of Pratapgarh District of Uttar Pradesh. Journal of Community Mobilization and Sustainable Development. 5(2): 60-63.

Swaminathan, C., Sobhana, E., Kannan, P. and Yassin, M.M. (2022). Principles, positives and limitations of conservation agriculture: A review. Agricultural Reviews. 43(4): 410-418. doi: 10.18805/ag.R-2166.

Tambo, J.A. and Jonathan, M. (2018). Differential impacts of conservation agriculture technology options on household income in sub-saharan Africa. Ecological Economics. 151:95-105.

Timsina, J. and Connor, D.J. (2001). Productivity and management of rice-wheat cropping systems, Issues and challenges. Field Crop Research. 69: 93-132.

Tiwari, H. (2021). Cutting edge technologies to enhance productivity and resource use efficiency in rice-wheat cropping system. Ph.D. Diss., SVB Patel Univ. of Agri. and Tech., Meerut, U.P.