Article

Investigating the Impact of Sustainable Rice Cultivation Processes (Alternative Wetting and Drying and Direct Seeded Rice) on the Indian Agrarian Economy and its Contribution to the UN's Sustainable Development Goals

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Abstract

Sustainability has become an integral part of the United Nations' development goals to ensure that the usage of resources in the present does not deplete the quality or quantity of resources available for future generations. The importance of sustainable agricultural practices has increased by manifolds when combating environmental and food security challenges. Rice cultivation in India alone comprises 26% of global rice production hence alternative rice farming methods are being explored for their potential contribution to fulfilling the Sustainable Development Goals (SDGs) and ensuring that the agrarian economy in India is growing at a sustainable rate.[i] This study aims to analyse the extent to which alternative sustainable rice cultivation methods (Alternative Wetting and Drying [AWD] and Direct Seeded Rice [DSR]) align with Social Development goals and impact the Indian economy. The research employs a qualitative analysis of secondary data from academic journals, government reports, and industry publications to evaluate the environmental and economic impacts of sustainable rice

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farming methods. The findings indicate that practices such as DSR and AWD significantly reduce water usage, lower greenhouse gas emissions, and improve soil health aligning with the SDGs (specifically SDG 12 [Responsible Consumption and Production] SDG 13 [Climate Change] and SDG 15 [Life on Earth]). Additionally, these practices are shown to offer long-term economic benefits for farmers through increased yields and reduced input costs and provide an external benefit to society by reducing the harmful impact of the wastage of water and greenhouse gas emissions on the environment. This study also discusses various government policies and private-sector projects that have incentivised farmers to adopt these sustainable rice cultivation practices. This research contributes to a deeper understanding of how sustainable agricultural practices can be leveraged to achieve global sustainability goals, offering a model for integrating environmental and economic objectives in agricultural policy.

Keywords

Economics, rice farming, sustainable development goals, sustainable growth

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Introduction

Ecological economist Herman Dally uses his theory of the 'steady-state economy' to highlight the importance of considering natural resources in the circular flow of the economy. This concept allows for the analysis of economic activity in terms of the flow of biophysical resources and social outcomes from using the finite resources present in the biosphere. The 'steady-state economy' is one where material and energy use are stabilised and kept within its limits.[ii]

In the recent context, the concept of sustainability is deeply intertwined with Daly's steady-state economy. Sustainability emphasises meeting the needs of the present without compromising the ability of future generations to meet their own needs, which requires stabilisation and responsible management of resources. During the United Nations Conference on Sustainable Development in Rio de Janeiro in 2012, the process of developing a set of Sustainable Development Goals (SDGs) combating extreme poverty and ensuring more equitable development and environmental sustainability commenced. These 17 goals provide a comprehensive framework for achieving sustainability on a global scale.

The SDGs aim to create a balanced approach that integrates economic growth, social inclusion, and environmental protection. In particular, SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Earth) resonate strongly with Daly's steady state economy and are influential to the current state of the natural world. With the amount of greenhouse gas emissions crossing 36 billion tonnes worldwide, SDG 12 encourages companies and farmers to adopt sustainable production practices and efficient usage of natural resources. SDG 13 (Climate Action) focuses on combating climate change and its impacts. Sustainable agricultural processes such as alternative farming methods can help reduce greenhouse gas emissions and foster resilience to climate change.

SDG 15 aims to protect, restore, and promote the sustainable use of terrestrial ecosystems ensuring the long-term availability of agricultural landscapes.[iii]

With the world's population increasing at a steady of 1.1% per year, there is a required increase in food production by at least one-third. The Food and Agriculture Organisation has stated that 'rice is the staple food for over half of the world's population'.[iv] India is the second-largest producer of rice and is the largest exporter of rice in the world. The production of rice has doubled in the past four decades from 56.3 million tonnes in FY 1980 to 120 million tonnes in FY 21-22. However, traditional rice farming methods often involve intensive water usage and flooding practices result in greenhouse gas emissions. By adopting sustainable alternatives to rice farming practices such as alternative wetting and drying (AWD) and direct seeded rice (DSR), farmers can improve their resource allocation by reducing water usage, decreasing methane emissions, and improving yields. These methods not only support environmental sustainability but also offer economic benefits by lowering input costs and enhancing crop resilience to climate variability.

This study is guided by the following question:

- How do sustainable agricultural practices, specifically alternative rice farming methods (AWD and DSR) in India, align with SDGs and impact the economy?

By adopting practices that align with the principles of the steady-state economy, farmers can reduce resource consumption, lower emissions, and support ecosystem health. This study examines these practices' economic and environmental benefits and their role in promoting India's sustainable and resilient agricultural sector.

Alternative Wetting and Drying

Rice cultivation requires the greatest amount of water. Rice occupies 30% of the world's irrigated cropland but, because it is normally flooded for most of the crop season, irrigated rice receives about 40% of the water diverted for irrigation (Dawe et al., 2005). The AWD rice cultivation method is a water-saving technique that reduces the traditional continuous flooding of water on paddy fields and instead periodically allows for the paddy fields to dry before being re-flooded. The farmers use a field water tube to monitor the water level in the soil. It is embedded in the paddy field to a depth of 15 cm, to reveal the perched water-table level (Lampayan et al., 2015). During AWD implementation, the field is irrigated to a depth of around 5 cm whenever the ponded water level has dropped to about 15 cm below the surface.[v]

Climate change has led to the worldwide problem of water scarcity, particularly in India where only 4% of the world's freshwater despite having a population of 1.4 billion people. AWD is a technique that can make rice cultivation more resilient to water scarcity. Using AWD cultivation can save 15%–30% of irrigation methods in comparison to traditional rice farming methods since there is no continuous flooding of the fields and the water used for cultivation is first evaporated and is seeped into the soil before flooding the fields.

Flooded rice produces about 20–40 megatonnes of CO_2 per year which is 12%–15% of the anthropogenic emissions from the agricultural sector globally. The AWD process allows the drain which reduces the possibility of anaerobic conditions in the soil, reducing the CH4 emissions during the rice cultivation seasons. Therefore, farm experiments with AWD have shown a reduction in CH4 emissions by 20%–70%.[vi] Despite the large reductions in methane emissions, AWD does not significantly affect rice grain yields compared to continuous flooding. In the 2-year study, yields differed by only ±2% between AWD and continuously flooded fields.[vii]

The 'adoption and economics of AWD water management for irrigated lowland rice' study[viii] states that 'the investment to develop and disseminate the AWD technology has a high rate of return, with benefit-cost ratio of 7:1'. This means that for every unit invested in AWD, there are seven units of economic return. This strong return on investment highlights the financial incentives for farmers to adopt AWD, making it an attractive option for enhancing farm profitability.

The drying periods in AWD create unfavourable conditions for certain pests and diseases reducing the need for chemical pesticides. Chemical pesticides and fertilisers accumulating in the soil can also result in greenhouse gas emissions. Therefore, the drying periods during the AWD cultivation periods allow for the reduction in harmful emissions and also result in healthier crops. Further, since a constant water supply is not required for AWD, farmers can adapt to any climate and are not threatened by water scarcity. With the increase in extreme climates, farmers need to ensure that their crops are resilient to the impacts of climate change to result in long-term profitability.[ix]

However, if AWD methods are not correctly implemented by farmers, moisture stress can be induced in the rice fields which can result in the reduced yield of rice production. Therefore, farmers must be well-educated and well-versed with the AWD techniques to ensure they are producing at their optimal yield. Meticulous monitoring and timely re-irrigation is crucial to avoid yield losses which restricts farmers from focusing on other crops.

Direct Seeded Rice

The DSR farming method eliminates the need for transplanting seedlings from a nursery to the field which is a labour-intensive and time-consuming process in traditional rice farming. Instead, the seeds are sown directly into the field. 'Direct seeded rice is seen to be one of the most efficient, sustainable, and economically viable rice production systems used today'.[x]

DSR offers several specific benefits over conventional rice planting methods, specifically puddle transplanting. In conventional paddy methods, water is needed almost constantly to ensure that the rice seeds are in completely submerged conditions within the first three weeks of sowing. However, by using DSR the first irrigation process is only required 21 days after sowing the seeds, thus leading to water savings which are crucial in water-scarce regions.[xi]

The TPR (Transplanted Rice) cultivation method involves continuous water flooding which creates anaerobic conditions in the soil resulting in the

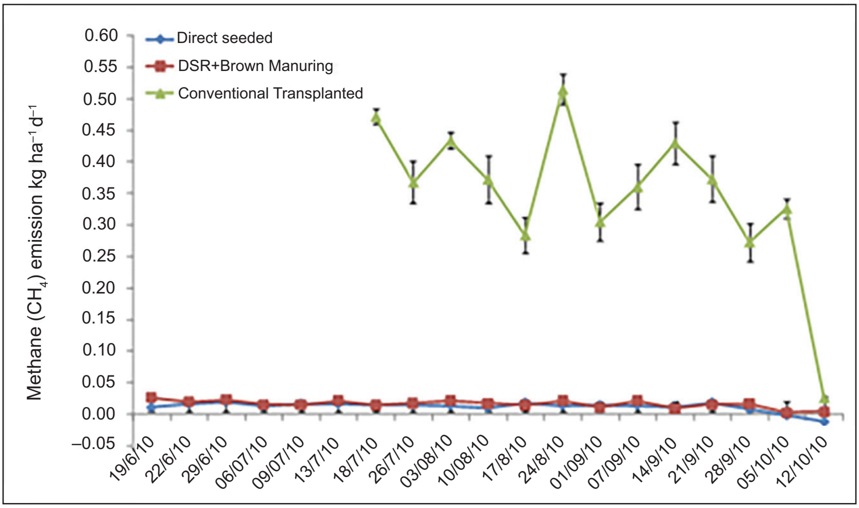

Figure 1. Temporal Methane Emissions from Soil in Direct Seeded Rice and Conventional Transplanted Rice.[xiv]

decomposition of organic matter hence releasing methane emissions. However, since the DSR process eliminates the requirement of stagnant water for cultivation, it promotes aerobic soil conditions inhibiting methane emissions.[xii] Research indicates that cumulative methane emissions from DSR are substantially lower than those from TPR. For instance, cumulative methane emissions were measured at 1.49 kg ha^{-1} in DSR compared to 30.72 kg ha^{-1} in TPR, highlighting a drastic reduction in methane production when using DSR methods.[xiii]

This graph, taken from the study of methane and nitrous oxide emissions from soils under DSR by Bhatia et al. (2013)[xv], underscores how the global warming potential (GPW) was the greatest when rice was grown through conventional transplanting processes since the methane emissions peaked at 0.5 kg per hectare. However, the methane emissions were reduced remarkably to an average of about 0.03 kgs per hectare when using the DSR cultivation approach (Figure 1).

DSR also influences the carbon-efficiency ratio in rice cultivation which is defined as the amount of carbon fixed in the rice grain relative to the carbon equivalent emissions produced during cultivation. It is calculated using the following formula:

$$CER = \frac{Carbon\ fixed\ \ in\ grain\, kgCha}{Carbon\ equivalent\ \ emissions\, kg\, CO2eq\ \ ha}$$

Studies have shown that methane emissions in DSR can be reduced by up to 47% compared to TPR. The increased CER ratio indicates that DSR is a more efficient and sustainable process in terms of carbon emissions relative to the yield produced.[xvi]

However, it is more difficult to control weeds through the DSR process due to the lack of a standing water layer when the rice is emerging from the soil. Through the TPR method, the rice is grown in a nursery in optimum conditions protected from weeds and then the stagnant water in the flooding conditions of the rice protects the rice crops from weeds. The presence of weeds can reduce the quality and quantity of rice produced through the DSR method, making it a huge disadvantage.

Additionally, while DSR significantly reduces methane emissions, it may lead to marginal increases in nitrous oxide (N_2O) emissions. For example, emissions of N_2O were observed to be higher under DSR (up to 1008 g N_2O ha^{-1}) compared to TPR (which had emissions of around 670 g N_2O ha^{-1}) in some studies. This trade-off between methane and nitrous oxide emissions poses challenges for overall greenhouse gas management in rice cultivation.[xvii]

Economic Impacts of Sustainable Practices

1. Resource allocation

Since there is a finite number of resources present in the economy, making the most optimal use of these resources will reduce the problem of scarcity. Hence governments and firms have to allocate resources in such a way that they are not depleted so that there are enough resources for the next generation to use. AWD and DSR optimise the allocation of water resources in rice farming. By reducing water input by 10%–40%, AWD allows farmers to use water more efficiently, which is critical given the increasing scarcity of water resources in India. This efficient allocation can lead to better overall productivity in the agricultural sector, as water saved can be redirected to other crops or uses, enhancing the total output of the agricultural economy. Further, since DSR eliminates the process of transplanting rice from nurseries to the paddy fields, the labour required decreases hence allowing them to cultivate other crops, optimising the usage of these resources.

2. Externalities and the environmental impact

Negative externalities occur when the actions of producers or consumers give rise to negative side effects on other people who are not a part of these actions. Traditional rice farming methods give rise to negative externalities of production as the production of rice through these methods results in excess water usage, soil degradation, and methane emissions which cause an external cost to society. To reduce the welfare lost to society, farmers must switch to farming practices, like AWD and DSR which reduce these external costs. AWD can reduce methane emissions by 48%–55% compared to continuous flooding, mitigating greenhouse gas externalities.[xviii] Further, DSR reduces methane emissions by 10%–90% while also improving soil health and reducing erosion.[xix] These practices generate positive externalities of production by reducing pollution and resource degradation. This aligns with the economic concept of sustainability, where the long-term viability of agricultural practices is essential for future generations.

3. Producer surplus

Producer surplus is the difference between the price at which producers are willing to sell their products and the price at which they sell them. When alternative rice farming methods like DSR and AWD are used, the cost of irrigation is reduced since farmers incur lower energy costs related to pumping water specifically in regions where electricity and fuel costs are high. Furthermore, AWD reduces the need for constant water management and monitoring which in turn reduces the labour costs to farmers. The surplus that they gain by switching to alternative farming methods incentivises them to use sustainable practices for more crops as well. Moreover, carbon credits provide an additional revenue stream for producers who adopt sustainable practices that reduce greenhouse gas emissions. When producers sell carbon credits, they effectively increase their total revenue, which can enhance their producer surplus. This can lead to higher overall production efficiency and sustainability, which can increase the long-term viability of their operations and enhance producer surplus.

4. Market failures

Common pool resources are those that are not owned by anyone, do not have a price, and are available for anyone to use without payment or any other restrictions. Often since these products are rivalrous, the consumption of the good by one person reduces its availability for someone else, and non-excludable, since there is no price no one can be excluded from using it, there is often an overuse of these common pool resources. By releasing greenhouse gases into the atmosphere through rice farming practices, farmers overuse a proportion of natural resources leading to ecosystem degradation and depletion. Hence, governments must correct this market failure by subsidising sustainable rice farming practices and creating regulations and awareness of the benefits of these systems.

Policy and Institutional Support

1. National policies and incentives:

- National Mission on Sustainable Agriculture (NMSA): The NMSA was launched in 2014 as part of India's broader National Action Plan on Climate Change (NAPCC). Its primary objective is to promote sustainable agricultural practices that can withstand the challenges posed by climate change while ensuring food security. In the context of rice farming, NMSA has significantly impacted water conservation and productivity through the promotion of techniques like AWD and DSR.

  NMSA's emphasis on these practices has also contributed to lower greenhouse gas emissions, aligning with India's climate change mitigation goals. It works towards achieving SDG 13 (Climate Action) taking urgent action to combat climate change as it Integrate climate change measures into national policies, strategies and planning.[xx] Overall, since its inception, NMSA has played a crucial role in making rice farming more sustainable and resilient to climate variability, thereby supporting the livelihoods of millions of farmers in India.
- Pradhan Mantri Krishi Sinchai Yojana (PMKSY): The PMKSY, launched in 2015, aims to enhance irrigation coverage and water use efficiency in agriculture. The scheme's focus on 'Har Khet Ko Pani' (Water for Every Field) and 'Per Drop More Crop' has helped reduce the dependency on

traditional, water-intensive irrigation methods. The implementation of PMKSY has led to increased irrigation efficiency, reduced water wastage, and enhanced crop productivity, which is vital for ensuring food security in the face of climate change. By improving access to irrigation and promoting sustainable water management, PMKSY has contributed to the resilience and sustainability of rice farming in India, benefiting millions of farmers across the country.

2. Institutional support:

Bayer CropScience: The Bayer Rice Carbon Project represents a significant step by the private sector to advance sustainability in rice farming. This initiative focuses on reducing the carbon footprint created by rice cultivation by incentivising farmers to use alternative cultivation practices that lower greenhouse gas emissions and enhance water efficiency.[xxi] The project promotes AWD and DSR to use water more efficiently and reduce methane emissions, a greenhouse gas that is 28 times more harmful than carbon dioxide and inevitably emitted in traditional rice cultivation methods.

By incentivising farmers to adopt these climate-smart practices, Bayer is not only contributing to environmental sustainability but also enhancing the economic resilience of farmers. Yatham Joshi, a rice cultivator in Telegnana's Nalgonda district has been cultivating rice on 6 acres of land for the past 20 years. As summers got hotter, and the rain in the monsoons got more scarce, agricultural production got more difficult and more labour intensive said Yatham.[xxii] Through the Bayer Rice Carbon Initiative, Yatham and her family started using the DSR technique on one acre of land and have now expanded her practice to all six acres. She says this transition helped her save ₹ 60,000 per year just in labour costs.

Bayer's initiative started in 2021, has introduced AWD in 38,000 hectares and DSR in over 7,000 hectares of land, helping over 17,000 farmers.[xxiii] The project reflects a broader movement among private firms to take active roles in addressing global challenges like climate change. Private sector firms who are leveraging their resources and expertise to drive innovation in sustainable agriculture contribute greatly to the achievements of SDG 12 and SDG 13.

Future Directions and Innovations

Innovation in rice cultivation is imperative in our quest for a sustainable future. As we confront the dual challenges of a changing climate and a burgeoning global population, rice innovation emerges as a beacon of hope. To combat climate change, scientists have been developing climate-resistant rice varieties that can grow in any weather condition be it droughts, floods, or even changes in temperature. For example, scientists have discovered 'scuba rice' which can grow underwater for two weeks, aiding those farmers who cultivate rice in flooded regions prone to heavy rain. Furthermore, through the use of advanced technologies like GPS, drones, and sensors farmers can monitor their fields ensuring efficiency and profitability. Nutrient-enhanced vice varieties contain higher levels of essential nutrients that can improve food security and nutritional outcomes.[xxiv] This innovation not only addresses malnutrition but also enhances the market value of rice, benefiting farmers economically. Financial incentives through carbon credits for reducing greenhouse gas emissions can provide additional income for farmers adopting sustainable practices. This economic benefit can motivate more farmers to transition to environmentally friendly methods.[xxv]

Conclusion

This research aimed to analyse the extent to which alternative sustainable rice cultivation methods (AWD and DSR) align with the Social Development goals and impact the Indian economy. The study found that sustainable rice farming practices, AWD, and DSR contribute significantly to water conservation, reduction in greenhouse gas emissions, and preservation of soil health. It is crucial to note that these farming techniques have significant disadvantages like the emission of nitrogen oxides and increased pest infestation. However, the positive externality of production creates an external benefit to society benefiting more than individual farmers but society as a whole. Additionally, the cost-benefit analysis indicates that while the initial investment in sustainable practices may be higher, the long-term economic gains in terms of increased yields, reduced input costs, and enhanced market competitiveness are substantial. These practices closely align with the three specific SDGs (12, 13, and 15) as they promote environmental sustainability and reach the targets set by the United Nations. While this research provides valuable insights into the potential of sustainable rice farming practices, it is limited by its reliance on secondary data and the focus on a specific geographical region. Future research could benefit from primary data collection and a broader examination of diverse farming contexts. In conclusion, by aligning economic incentives with environmental sustainability, these practices offer a viable pathway towards a more resilient and sustainable future for both farmers and the planet.

Declaration of Conflicting Interests

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Notes

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