Knowledge Partner

Direct Seeded Rice for Sustainable & Profitable Rice Cultivation

"Transforming the rice value chain for a greener and prosperous future"

Disclaimer

Sathguru and FSII have prepared this white paper on the basis of information gathered from various sources and discussions, and Sathguru or FSII has not independently verified it. Neither Sathguru, FSII, nor any person associated with either makes any expressed or implied representation or warranty with respect to the sufficiency, accuracy, completeness or reasonableness of information set forth in this report, nor do they owe any duty of care to any recipient of this publication. This publication does not in any way constitute the provision of professional advice. Sathguru or FSII is not liable for any loss or damage, howsoever caused, by relying on the information provided in this document. This report has been prepared without prejudice. All the images are used only for representational purposes, and copyrights rest with their respective owners.

This publication was authored by the Sathguru Management Consultants team for FSII by:
K. Vijayaraghavan
G Radhakrishnan
K V Satyanarayana
Anand Singh
Rituparna Majumder
Poornima Gade

The authors extend gratitude to all members from FSII who contributed to this report and public and private sector stakeholders.

Sathguru has a wealth of experience and knowledge in life sciences and allied segments across strategy, M&A and innovation partnerships. For any comments or discussions, please reach out to the authors at vijay@sathguru.com or agribusiness@sathguru.com

March 2024

To download a copy of the publication, please visit www.sathguru.com.

Table of Contents

List of Abbreviations

AICRPR	All India Coordinated Research Project on Rice
BAP	Best Agronomic Practices
DSR	Direct Seeded Rice
DSRC	Direct Seeded Rice Consortium
FPO	Farmer Producer Organizations
GHG	Green House Gases
ICAR	Indian Council of Agricultural Research
ICFRE	The Indian Council of Forestry Research and Education
IIRR	Indian Institute of Rice Research
IRRI	International Rice Research Institute
mDSR	Mechanized DSR
NDC	Nationally Determined Contributions
NRRI	The National Rice Research Institute
QTL	Qualitative Trait Locus
SAUs	State Agricultural Universities
TPR	Transplanted Puddled Rice

Introduction

Rice, a widely consumed staple crop worldwide, holds immense importance as a strategic crop for ensuring food security among the most vulnerable and food-insecure populations, particularly in low- and middle-income nations. Its significance in providing sustenance to millions of people across the globe cannot be overstated. It is estimated that rice accounts for approximately 21% of the total caloric intake worldwide. However, in certain regions, such as parts of Southeast Asia, rice can make up as much as 76% of the daily caloric intake.

Transplanted puddled rice (TPR) is a traditional method of growing rice in Asia and Southeast Asia. This method involves preparing the field by flooding it with water and then tilling the soil to create a puddled layer to transplant seedlings. However, this method is becoming increasingly unsustainable due to several factors. The TPR system is used by over 80% of global farmers, and it causes 1.5 percent of total global greenhouse gas (GHG) emissions and 10 - 12% of methane emissions. It consumes up to 43 percent of the world's total irrigation water. On average, producing 1 kg of rice requires between 4,000 to 5,000 liters of water, which puts an enormous strain on water resources. In areas where water is scarce, this method is not feasible. Secondly, there is a growing shortage of labor in many rice-growing regions. As more people migrate to urban areas in search of better job opportunities, the number of available workers for rice cultivation decreases. This shortage of labor is particularly acute during the peak planting and harvesting seasons, which can result in delayed planting or harvesting, leading to lower yields.

While TPR has been the predominant method of rice cultivation in Asia and Southeast Asia for many years, it is becoming increasingly unsustainable. There is a need to explore alternative methods that require less water and labor without any adverse impact on yields. Furthermore, TPR also leads to high methane emissions – rice production is the cause of approximately 10 - 12% of global methane emissions. Though TPR has advantages like weed suppression and high yield potential, disadvantages like high labor and water requirements, soil degradation, and methane emissions outweigh the benefits.

In the pursuit of sustainable agriculture, researchers, government bodies, and industry have been actively working towards implementing innovative rice production techniques that can effectively conserve water while addressing the persistent issue of labor scarcity. These concerted efforts aim to streamline the production process and enhance the overall efficiency of rice cultivation, thereby fostering an eco-friendly and economically feasible approach to agriculture. ***Direct-seeded rice (DSR) is*** an alternative method of rice cultivation that involves sowing rice seeds directly into fields instead of transplanting them from a nursery. This technique reduces water and labor requirements, increases efficiency, and minimizes emissions compared to traditional rice farming. DSR has the potential to become a sustainable and profitable solution in the long run, making it an attractive option for farmers seeking to increase their yields and incomes while reducing their environmental impact.

The Direct Seeded Rice (DSR) cultivation system not only helps in increasing crop productivity but also offers a range of additional benefits, including reduced greenhouse gas (GHG) emissions. It is also an eco-friendly agricultural practice that contributes to mitigating the impact of climate change. DSR has been reported to reduce CH_4 emission by 30-98% and global warming potentials by 20-44%[1]. If DSR adoption in India reaches a significant acreage, a substantial reduction in CH_4 emissions can be achieved at the national level. This will also help India in meeting its NDC goals, specifically GHG emissions from agriculture. Additionally, when the Carbon Credit market achieves a significant penetration, smallholder farmers can earn additional income per acre by marketing them.

In this knowledge paper, we discuss the benefits and challenges of the DSR cultivation method, including the role of key stakeholders across the value chain to increase its adoption.

[1] Direct Seeding of rice. IRRI Farming Technologies

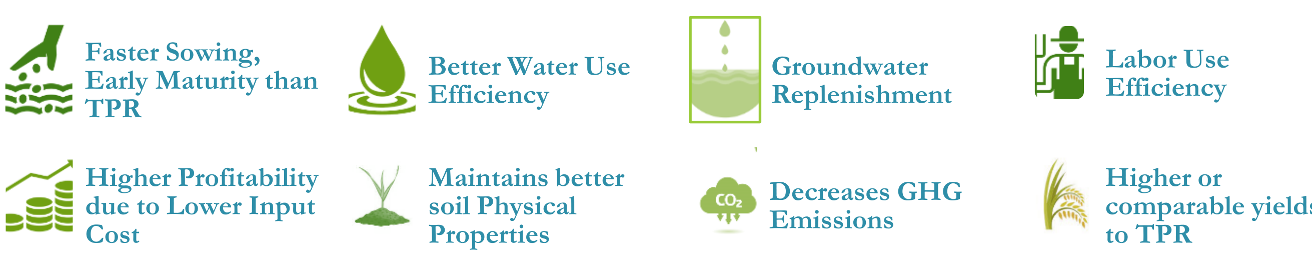
DSR: A sustainable approach to rice production

Direct Seeded Rice (DSR) is a modern rice cultivation technique that has the potential to reduce the environmental impact of rice cultivation significantly. By efficiently minimizing labor, water, energy, and agrochemical inputs, DSR ensures that rice cultivation is sustainable and eco-friendly. This innovative technique not only enhances the productivity of rice farms but also reduces the negative environmental impact of traditional rice cultivation practices. The International Rice Research Institute (IRRI) has projected that there is a need to increase rice production by 25% in the next 25 years to meet the demand of the increasing global population.

Advantages of DSR Technology:

Direct seeding of rice (DSR) is a modern technique that involves sowing rice seeds directly into the soil without any need to raise the seedlings in the nursery and then transplanting them into the main field flooded with water[2].

Some advantages of DSR technology are as follows (Figure 1).



[2] Chaudhary, A., Venkatramanan, V., Mishra, A. K., Sharma, S. 2022. Agronomic and Environmental Determinants of Direct Seeded Rice in South Asia. Circular Economy and Sustainability (2023) 3:253–290. https://doi.org/10.1007/s43615-022-00173-x

Water savings	DSR can help farmers reduce water usage by up to 40% compared to the transplantation method, as it requires fewer irrigation cycles. This makes it a better cultivation method during weak monsoons and in water-scarce areas.
Reduced Labor Requirement:	The increasing labor cost and lack of labor availability at the right time are major constraints in various operations in rice cultivation. DSR technology can reduce the need for labor by up to 50% as most of the farming operations can be mechanized, leading to a significant reduction in input costs. DSR avoids raising seedlings in the nursery, thereby saving time (~15 days), labor, and water.
Avoiding health risks for farm workers	The DSR system can be beneficial in improving the health of farm workers in the long run. The TPR system negatively impacts the health of farm workers due to physical strain and health risks such as back problems and other hazards associated with working long hours in wet and muddy field conditions while transplanting.
Groundwater replenishment	Unlike the TPR system, DSR does not form a hard crust beneath the plough layer, allowing better water percolation and helping replenish groundwater.
Energy Savings	DSR saves up to 20-25% energy as less energy for water pumping is required for field preparation and irrigation.
Reduced GHG emissions	DSR doesn't require flooding the paddy field before planting. This helps reduce greenhouse gas (GHG) emissions, especially methane (CH_4). DSR has the potential to reduce GHG emissions from rice by up to 45%.
Soil Conservation	DSR technology can be used in unploughed or minimally tilled soil, leading to reduced soil disturbance and improvement in soil quality. DSR allows farmers to conserve soil moisture while maintaining the integrity of the soil and promoting healthy plant growth.

Figure 1: Benefits of Direct Seeded Rice (DSR)

The use of DSR technology can reduce the input costs for the farmers by 15-20%. Efforts of various stakeholders, including several state governments, **have helped to bring approximately 4.5 million ha of rice under the DSR system in India**[3].

[3] Achievements of Indian rice research and IRRI partnership showcased at IRC 2023

Economics of DSR cultivation vis-a-vis TPR

The farmers who have cultivated rice using the DSR method have reaped better yields, which may be because of good weed management practices. Several factors contribute to the yield variations in DSR. Some of them are-

i. ***Agronomic Management Practices:*** The yield gap of DSR relative to TPR is highly variable depending on management practices such as inappropriate weed and water management, leading to a loss from 10 to 15%[4].

ii. ***Soil Type:*** The yield gap can be significantly reduced by planting in areas with high organic carbon content, such as clay and acidic soils[4].

In addition to the above reasons, the choice of crop varieties/hybrids, biotic and abiotic stresses, and individual farming practices can significantly impact farmers' actual benefits. The yield penalty in DSR has been observed to be in the range of 10-15%. Another study mentions only a 5% reduction in grain yield (5%) with DSR. Various studies have observed lower production costs in the range of 10-35%, compensating the yield penalty and leading to significantly higher net returns[5].

A comparative assessment of economic impact through DSR over TPR cultivation systems in rice[6] has been indicated n Figure 2 and 3

- **25%** Incremental return obtained through DSR systems over TPR
- Benefit-cost ratio: **03 -0.4** through DSR as against **0.2** through TPR

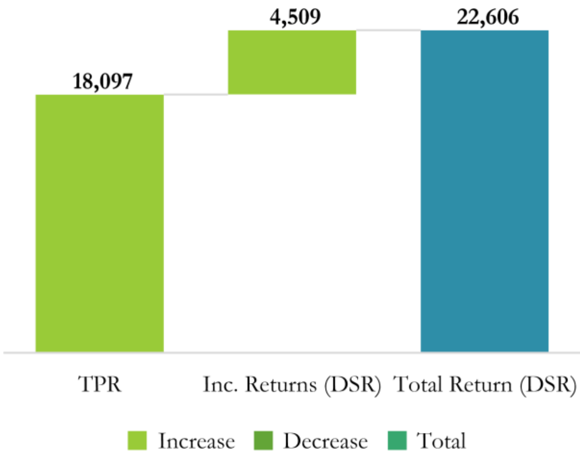


Figure 2: Net Returns (INR/ha)

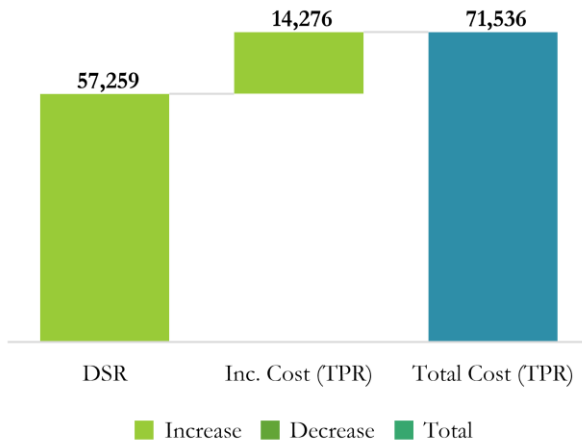


Figure 3: Production cost (INR/ha)

[4] Xu, L.; Li, X.; Wang, X.; Xiong, D.; Wang, F. Comparing the Grain Yields of Direct-Seeded and Transplanted Rice: A Meta-Analysis. Agronomy 2019, 9, 767. https://doi.org/10.3390/agronomy9110767
[5] Soriano, J.B., Wani, S.P., Rao, A. N., Sawargaonkar, G. L. And Gowda, A. C. 2018. Comparative evaluation of Dry-Seeded and Transplanetd Rice in Dry Zone of Karantaka, India. Philippine Jornal of Sciencs, 147(1): 165-174.
[6] Aerone, Philippe & Mataia, Alice & Austria, Chona & Tiongco, Marites & Laborte, Alice. (2023). Adoption and Performance of Direct-seeded Rice (DSR) Technology in the Philippines. Philippine Journal of Science. 152. 10.56899/152.01.37.

According to another recent study[7] adopting DSR technology can save INR 5,192 per acre over TPR. Land preparation and irrigation costs are significantly lower for dry DSR adopters than for wet DSR farmers, bringing an additional crop income of INR 2,467 per acre for dry DSR farmers.

Challenges of DSR Cultivation and Mitigation Strategies:

Although DSR seems to be a sustainable alternative to puddle rice cultivation, it has disadvantages that need to be mitigated before a wider adaptation can be expected, especially in low- to middle-income countries of Asia and Southeast Asia. Some of the downsides of DSR technology are listed in Table 1.

Table 1: Challenges of the DSR Technology and Mitigation Strategies

Challenges	Criticality	Mitigation Strategies
Risks in crop establishment	Poor and uneven establishment of seedlings can lead to lower yield in DSR. The uneven distribution of seed sowing through broadcasting leads to varying plant density per area, uneven growth, and crop stand. It makes DSR more vulnerable to *lodging*.	Mechanized and precision sowing will be critical to ensure uniform plant density. Additionally, changing the plant type through contemporary breeding tools will bring hardiness to rice plants, preventing lodging.
Higher weed infestation	DSR faces challenges related to weed management due to *higher weed infestation*. Additionally, the *weedy rice* has also been observed to be a constraint in the DSR system.	Commercialization of herbicide-tolerant, with tolerance to a wide spectrum of herbicides, rice varieties, and hybrids. The availability of herbicide-tolerant varieties (non-GM) and mechanization (large farms) are two of the critical reasons for the adoption of DSR.
Change in soil microbiome	The DSR system can lead to a change in the soil microbiome, and more pests can adversely affect the yield at the soil level, especially the root-knot nematodes.	Integration of organic amendments, such as compost, green manures and biochar. Use of biological products of disease and pest management and for increasing access to nutrients through soil interactions of the microbiome.
Limited availability of options for mechanization	Mechanization is critical for different farm operations that reduce labor. However, there is a limited availability or lack of it either with the farmers or at a community level to serve different	Mechanization companies can help develop machines for precision leveling and seed sowing that can be deployed at large farms as well as smaller

[7] Shiladitya Dey, Kumar Abbhishek, Suman Saraswathibatla, Abhishek Kumar Choubey, Hari Babu Rongali, Aruna Upamaka, Published: February 21, 2024, Empirical evidence for economic viability of direct seeded rice in peninsular India: Action-based research; Vol 10, Issue 5, E26754 https://doi.org/10.1016/j.heliyon.2024.e26754

Challenges	Criticality	Mitigation Strategies
	farmers. It has been observed that in large farms, the use of a laser land leveler has provided very efficient sowing in the DSR system.	farms with minor modifications.
Nutrient Deficiency	Nutrient deficiency, especially Fe, has also been observed due to aerobic conditions in DSR.	Application of nutrients in basal dose as well as foliar applications.
Higher Nitrous Oxide emissions	Several studies have reported that N_2O emissions under DSR cultivation are 40-50% higher than that in TPR[8].	Optimizing fertilizer management practices [9] and using low-emitting rice varieties [10] can help reduce nitrous oxide emissions.
Soil type limitations	Research indicates light-textured sandy-loam soils will not be suitable for DSR cultivation since they cause iron deficiency.	The application of iron sulfate (FeSO4) could help remedy this iron deficiency.

Though the benefits of DSR are evident, the transition from TPR to DSR faces several obstacles in a country like India, where the availability of water and free electricity to farmers hinders the adoption of such technologies. However, as water and labor are becoming increasingly scarce, there is a need for stakeholders in the rice ecosystem to come together to increase the adoption of sustainable cultivation systems, including DSR.

[8] Bhatia, A. Kumar, A. Das, T. K., Singh, J., Jain, N. And Pathak, H. 2013. Methane and Nitrous Oxide emissions from soil under direct seeded rice. *Int. J. of Agricult.. Stat. Sci.* Vol. 9 (2): 729-736

[9] Gaihre, Y. K., Singh, U. Bible, W. D., Job Fugice Jr. and Sanabria, J. 2020. Mitigating N2) and NO emissions from Direct Seeded Rice and Urea Deep Placement. *Rice Science*, 27(5): 434-444.

[10] Ahmed, Z. et al. (2022). Greenhouse Gas Emissions and Mitigation Strategies in Rice Production Systems. In: Ahmed, M. (eds) Global Agricultural Production: Resilience to Climate Change. Springer, Cham. https://doi.org/10.1007/978-3-031-14973-3_8

Role of Public and Private sector in DSR adoption

DSR Initiatives driven by the public sector

Public sector organizations under Indian Council of Agricultural Research (ICAR) like Indian Institute of Rice Research (IIRR) and State Agricultural Universities (SAUs) are playing an important role in increasing DSR adoption. The role of the International Rice Research Institute (IRRI), Manila, has also been pivotal in developing and popularizing DSR rice varieties and hybrids in Asian countries. The focus of the private sector has been to promote hybrids under the DSR system through various packages combining seeds and agrochemicals to improve agronomic practices.

The contribution of ICAR institutes in India and SAUs is significant in developing & testing and increasing the adoption of DSR through extension. Some of their contributions are as follows:

a. **Collaborative research:** The ICAR and the IRRI have joined hands to create integrated direct-seeded rice systems that are specifically tailored to the unique conditions of India through this partnership[11]. ICAR and IRRI aim to transform rice cultivation in India, making it more efficient, sustainable, and profitable for farmers. The focus of the collaborative research is also on nutritional quality enhancement, climate-resilient rice systems, and capacity development.
b. **Technology transfer:** ICAR facilitates the dissemination of knowledge and best practices regarding DSR through extension services through its institutes and SAUs by conducting workshops and developing and disseminating educational materials.
c. **Variety development:** ICAR has been instrumental in the development and improvement of rice varieties that possess higher yields[12] and are better adapted to upland and DSR cultivation. ICAR is also conducting trials under All India Coordinated Research Product to select the most suited rice varieties for the DSR systems.

[11] IRRI deepens its partnership with the Government of India through ICAR.

[12] Roy, S. et al. (2023). Rice. In: Ghosh, P.K., Das, A., Saxena, R., Banerjee, K., Kar, G., Vijay, D. (eds) Trajectory of 75 years of Indian Agriculture after Independence. Springer, Singapore. https://doi.org/10.1007/978-981-19-7997-2_6

d. **Capacity Development:** ICAR and SAUs offer comprehensive training programs to farmers and researchers. These programs aim to equip them with the necessary skills and knowledge to implement DSR effectively.

IRRI, Manila has been instrumental in the development and adoption of DSR in the Philippines and collaboration with organizations like PhilRice, other agricultural organizations in the region and the private sector. The key contributions of IRRI, in addition to capacity development among farmers and researchers in the region, include the following:

i. ***Development of Advanced Rice Varieties:*** In collaboration with local partners in the region, IRRI has successfully engineered and cultivated advanced rice varieties and hybrids that offer numerous benefits. These varieties are capable of producing higher yields while also being highly resistant to diseases and pests and are designed to withstand conditions of extreme flooding and drought. The development of these innovative rice strains represents a significant breakthrough in sustainable agriculture, paving the way for more efficient and resilient food production systems in the Asian region and the world.

ii. ***Direct-Seeded Rice Consortium (DSRC):*** IRRI has been a key proponent of the DSRC[13] initiative, focusing on improving mechanized and precise direct-seeding practices for DSR. The consortium's focus is to address gaps in DSR practices through science-based solutions for crop and weed management, GIS-guided sowing windows, and evaluation of new rice cultivars adapted to DSR conditions.

iii. ***Partnerships with PhilRice:*** IRRI collaborates with PhilRice, among other organizations, within the DSRC to enhance resource-efficient and sustainable rice production practices. This collaboration aims to benefit not only business entities but also smallholder farmers across Asia by disseminating technologies that increase rice productivity and farmers' income.

Another important innovation is the development Iron-Coating Technology for Direct Seeded Rice (DSR) by the National Agriculture and Food Research Organization, Japan in 2004. This method involves coating rice seeds with iron powder to increase their specific gravity, allowing them to be sown directly in flooded paddies without the need for forced drainage, thereby reducing problems with weeds and eliminating the occurrence of seed-borne diseases. JFE Steel Corporation who are part of DSRC have tested the performance of this technology in flooded paddies in the Philippines. Through this partnership, JFE Steel aims to compile an international manual on rice direct seeding with iron-coated seeds through the collaboration of the members of the DSRC.

Several private companies have launched their programs or packages of practices to increase DSR adoption in India, South Asia, and Southeast Asian countries.

1. JFE Steel has joined the DSR Consortium to test iron coating in Asia[14].
2. Bayer, a leading global company, has launched ***DirectAcres***, a rice cultivation program focused on DSR: The program aims at making farmers successful in their first attempt of adopting DSR by addressing all critical pain points related to DSR system in a comprehensive solution package – selection of right seeds, weed management inputs & advisory, access to mechanized seed sowing, digitized agronomy recommendations and continuous farmer assistance. The program was commercially piloted in 5000 Hectares in 2023 in the states of Punjab, Haryana, UP and Odisha and

[13] IRRI eyes public-private sector support for wider DSR adoption.
[14] JFE Steel Joins Direct Seeded Rice Consortium, tests for performance of Iron-Coating Technology of rice in Asia

plans to expand to 8 states covering more than 15,000 Ha in 2024. The DirectAcre test program of ~100 Ha was also kicked off in Philippines with drone sowing for Wet DSR, partly in association with PhilRice. Bayer plans to support over 2 million smallholder rice farmers and bring one million hectares under the DirectAcres program by 2030. Likewise, Bayer recently declared a vision of expanding the DirectAcre program to 1 million hectares by 2030[15] and is collaborating with various stakeholders in the journey including (ICAR, USAID , IRRI etc.).

3. ***FullPage DSR Technology*** is a rice cropping solution promoted by Savannah Seeds. It is a new generation of technology that improves herbicide tolerance, yields, early-season diseases, and insect protection in rice. FullPage DSR is an environment-sustainable technology that supports 25-30% water saving and reduces methane emissions by 25-30%.
4. Corteva, a leading company for hybrid rice, is also engaged with farmers through several initiatives like ***AcreNext***, a next-generation rice farming program to engage with rice farmers to enhance the understanding and knowledge of the benefits of adopting DSR to improve the productivity and profitability of rice farmers. Corteva is also working with Water Resources Group, a World Bank initiative, to help 50,000 farmers in Uttar Pradesh replace TPR with DSR. Corteva also partnered with PRADAN, an NGO in Bihar and Jharkhand, to build the capacity of over 15,000 farmers for DSR cultivation.

The adoption of Direct Seeded Rice (DSR) has been steadily increasing, with significant successes in South and Southeast Asian countries due to water scarcity and labor shortages. The potential for further growth remains significant, especially in regions facing similar challenges and in countries focusing on sustainable agriculture practices to counter the impacts of climate change. Multifaceted efforts are being directed at improving adoption and optimize DSR cultivation (Figure 4). Education, training, and awareness campaigns can help facilitate wider DSR adoption, enhancing productivity and resource conservation in rice cultivation.

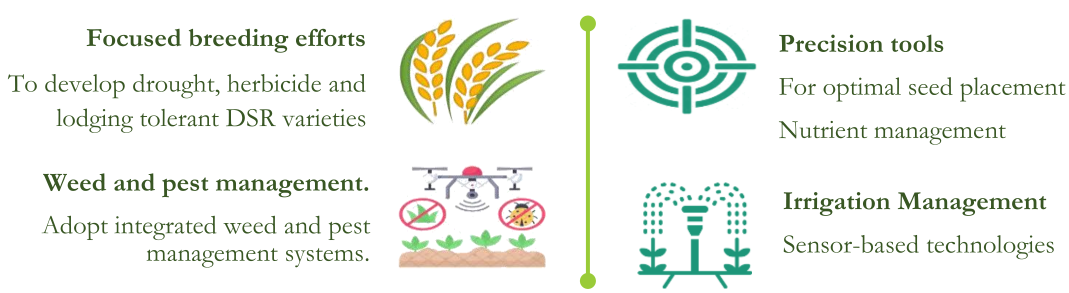


Figure 4: Emerging trends in DSR cultivation

Breeding for DSR

The current focus of the seed industry is on the direct use of varieties bred for transplanted puddled rice (TPR) under the DSR system supported by a package of practices to help the rice crop adapt to dry/ adverse environmental conditions at various stages of crop growth. These packages of practices aim at crop adaptation through healthy seedlings establishment, weeds, pests & disease management to get on par or higher yields than TPR.

---

[15] Bayer introduces agricultural system for direct-seeded rice with potential to reduce greenhouse gas emissions and water use by up to 40 percent.

However, the modern high-yielding rice varieties have been bred for TPR systems, which do not fit completely when grown under DSR and show 10-30% yield reductions. This approach of direct use/ adapting TPR varieties under DSR may not be ideal in the long run, and varieties bred specifically for DSR systems with suitable traits be more suitable for wide-scale adoption of DSR. The DSR seedlings require specific adaptive traits to overcome the challenges across the plants' developmental phase. The DSR-specific cultivars require desirable traits such as high yield with shorter duration, weed suppressive, resistance to lodging, erect leaves, tolerance to pests and diseases, and adaptation to moisture and nutrient stresses.

There is a need to identify potential candidate QTLs/genes and deploy them in specific breeding programs to develop high-yielding DSR-suited varieties. Some recent advances in precise phenotyping and NGS-based trait mapping have led to the identification of promising donors and QTLs/genes for DSR-favourable traits that can be employed in marker-assisted selection (MAS) breeding[16] (Table 2).

Among the various agro-morphological characteristics, ***root system architecture*** is one of the major traits for increasing productivity in DSR systems. Designing root system architecture suitable to adverse conditions can provide a solution to the constraints in DSR. Candidate genes such as early root growth enhancer PSTOL1, surface rooting QTL qSOR1, deep rooting gene DRO1, and numerous transporters for their respective nutrients and stress-responsive factors have been identified and validated under different circumstances. Identifying the desired QTLs and transporters underlying these traits and then designing an ideal root architecture can help in developing a suitable DSR cultivar and aid in further advancement in this direction[17].

Table 2: Desirable traits, QTLs/genes for developing DSR varieties[6,7,8]

Traits for DSR	Genes	QTLs
Early uniform emergence		qEUE11.1, qEUE3.1, qEMM1.1
Early vigor		qEVV9.1
Early root growth	PSTOL1	
Deep rooting	DRO1	
Surface rooting		qSOR1
Root length		qRL8.1, qRL8.2, qRL9.1
Root hair length		qRHL1.1
Root hair density		qRHD1.1, qRHD5.1
Nodal root number		qNR5.1, qNR4.1
Anaerobic germination		qAG9.1, qAG9.2
Nutrient uptake	PSTOL1, OsPT1, OsPT8, OsNRT	qNU5.1, qPU5.2, qFeU5.2
Rice blast Resistance	R genes Pi2, Pi5, Pi9, Pi21 & Pi54; Defense-regulator (DR) genes Pid2, Pid3, Pid4	
Brown spot Resistance		qBS2, qBS9 and qBS11, BSq11, qBSR11-kc
Nematode tolerance		qMGR4.1, qMGR7.1, qMGR9.1
Drought tolerance		qDTY12.1, qDTY2.3, qDTY3.2, qDTY3.1
Lodging resistance		qLDG3.1, qLDG4.1, SCM3

[16] Sagare *et al.,* (2020). More and more of less and less: Is genomics-based breeding of dry direct-seeded rice (DDSR) varieties the need of the hour? *Plant Biotechnology Journal*, 18(11), 2173-2186. https://doi.org/10.1111/pbi.13454 .
[17] Panda *et al.*, (2021). Proofing Direct-Seeded Rice with Better Root Plasticity and Architecture. *International Journal of Molecular Sciences,* 22(11), 6058. https://doi.org/10.3390/ijms22116058

At International Rice Research Institute (IRRI), South Asia Hub Hyderabad, complex crosses were made among donors possessing QTLs for Dry DSR suitable traits, viz. qEUE11.1, qEUE3.1, qEVV9.1, qRHD1.1, qNR5.1, qLDG3.1, qLDG4.1, qAG9.1, qAG9.2, Pi9, etc. The marker-assisted backcross breeding strategy is being implemented to pyramid these QTLs in the background of the popular variety MTU1010[16]. IRRI, through the Direct Seeded Rice Consortium (DSRC), has been engaged with both the public and private stakeholders working towards integrating innovations in DSR. DSRC is a collaborative effort of public and private organizations aiming to develop and optimize innovations, practices, and methodologies to facilitate wider adoption of DSR.

Enabling environment by an NGO in Andhra Pradesh

A successful example of developing an ecosystem for DSR cultivation in India can be seen in Andhra Pradesh. Praanadhaara, an NGO based in Vijayawada, is supporting nearly 20,000 farmers to adopt DSR technology. Praanadhaara provides various services like mechanization, crop management advisory and marketing support to farmers.

Under the DSRC India trials, hybrids produced higher yields than inbred cultivars, and additionally, hybrids were found to be more weed-competitive[18]. The National Rice Research Institute (NRRI), Cuttack, in collaboration with IRRI, has started breeding programs for the introgression of reported QTLs such as ***anaerobic germination*** (qAG9.1, qAG9.2) and ***lodging tolerance*** (qLDG3.1, qLDG4.1) to develop high-yielding DSR varieties[17]. From 2024, DSR-bred entries will be included in the All India Coordinated Research Project on Rice (AICRPR) trials.

There is a need for a national strategy to prioritize DSR trait introgression in varieties and hybrids. A road map needs to be developed in consultation with all stakeholders involved in the DSR ecosystem.

[18] IRRI (2020). DSRC 2019 Annual Research Report.

Value Chain Elements

Crop Management under DSR Cultivation

DSR can be categorized into dry and wet techniques. Dry DSR involves seeding in non-flooded or partially flooded fields and is suitable for regions with sufficient rainfall or irrigation. On the other hand, wet DSR entails seeding in continuously flooded fields and is appropriate for areas with consistent water availability, albeit requiring careful water management. The selection between dry and wet DSR depends on local water resources, availability of labour and environmental conditions, allowing for adaptability across different regions. (Fig 5)[19].

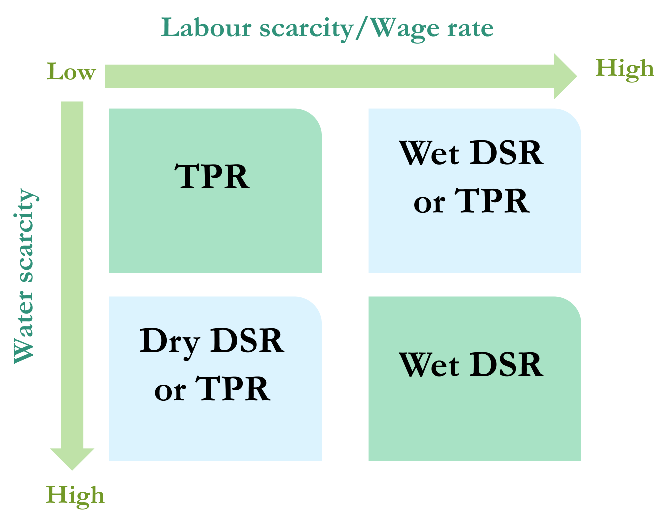


Figure 5: Factors affecting DSR adaptability (adopted from Chaudhary *et al.,* 2023)

Successful DSR cultivation begins with the selection of high-quality, disease-free seeds. Proper seed treatment and priming enhance germination rates. Farmers need to prepare well-levelled fields, sow seeds at recommended rates, and ensure timely and adequate irrigation. Effective crop monitoring and pest management are vital for the success of DSR. To overcome challenges in transitioning to DSR, farmers can adopt integrated weed management practices, which include utilizing herbicides, cover cropping, and mechanical weeding for efficient

[19] Chaudhary, A., Venkatramanan, V., Kumar Mishra, A. *et al.* Agronomic and Environmental Determinants of Direct Seeded Rice in South Asia. *Circ.Econ.Sust.* **3**, 253–290 (2023). https://doi.org/10.1007/s43615-022-00173-x

weed management for the success and widespread adoption of direct-seeded rice. Additionally, the use of pesticides and pest-resistant rice varieties can aid in pest control. Weed management and optimal fertilizer use as per the soil requirements is also crucial. Improved irrigation scheduling and water-saving techniques are also essential for DSR success. Regular monitoring, early intervention for issues, and precise water management are essential for optimal crop growth. Additionally, proper crop rotation and residue management further promotes DSR success.

Training and extension services play an empowering role in equipping farmers with the knowledge and support needed to transition successfully to this sustainable and efficient cultivation method.

Mechanization

DSR system of rice cultivation, when combined with mechanization (mDSR) and best agronomic practices, BAP), helps attain higher efficiency and productivity. mDSR offers potential productivity gains and significant cost savings compared to traditional manual operations. This can significantly reduce agronomic inputs such as seed volume as well as fertilizer and pesticide inputs. In addition, it can also reduce the risk of lodging during harvest, thereby reducing losses. Farmers currently adopting DSR technology typically broadcast dry paddy seeds into well-pulverized soil. However, this method often leads to uneven seed dispersion at variable depths, leading to poor seed germination and inadequate crop establishment. To address this challenge, the Rice-Wheat Seeder equipment can help by regulating seed rates and placing seeds at desired depths while maintaining optimal plant-to-plant distances within rows, typically ranging from 8-15 cm. This allows farmers to cultivate paddy in well-defined rows spaced 20 cm apart, creating opportunities for mechanical weeding tools to be utilized effectively in between rows for weed management.

The International Rice Research Institute (IRRI) and its partners in Cambodia have initiated the ***Excellence in Agronomy (EiA) Initiative*** in Cambodia since 2020. One of its key activities involves conducting participatory trials to evaluate and demonstrate integrated management practices like mechanized Direct-Seeded Rice (mDSR) and best agronomic practices (mDSR+BAP) for farmers.

IRRI is implementing projects based on mDSR in regions like India (Odisha), Cambodia[20], and Thailand in collaboration with local organizations to demonstrate and scale up mechanized direct-seeded rice. The DSR-Odisha Project has demonstrated the economic benefits of mDSR. Except for the cost of hybrid rice seed, all other expenses associated with mDSR were lower compared to traditional farming practices. As a result, the cost of cultivation in mDSR amounted to USD 471/ha, significantly lower than the USD 582 / ha incurred in TPR cultivation, representing a 19% reduction. Moreover, mDSR exhibited a clear yield advantage, producing 6.42 tons per hectare compared to TPR's 4.45 tons per hectare, marking a notable 44% increase in yield. Additionally, the overall cost of production was USD 73 per ton in mDSR, considerably lower than USD 131 per ton in TPR, indicating a 44% decrease in production costs[21].

Supply Chain

While Direct Seeded Rice (DSR) holds significant potential benefits for smallholder farmers, its widespread adoption faces challenges. These include not only limited demand from farmers but also a scarcity of DSR

[20] Creating a path for scaling mechanized direct-seeded rice in Cambodia
[21] Mechanized seeding helps Odisha farmers do away with fallows and increase the productivity of their rice-based cropping system

services provided by machinery owners. Another element that would impact DSR adoption will be the development of market linkages of DSR produce to help farmers get better prices. As we strive for sustainable and profitable rice production, addressing these constraints becomes crucial. There are several constraints, both from the demand and supply sides, in adopting the DSR technology, as depicted in Figure 6.

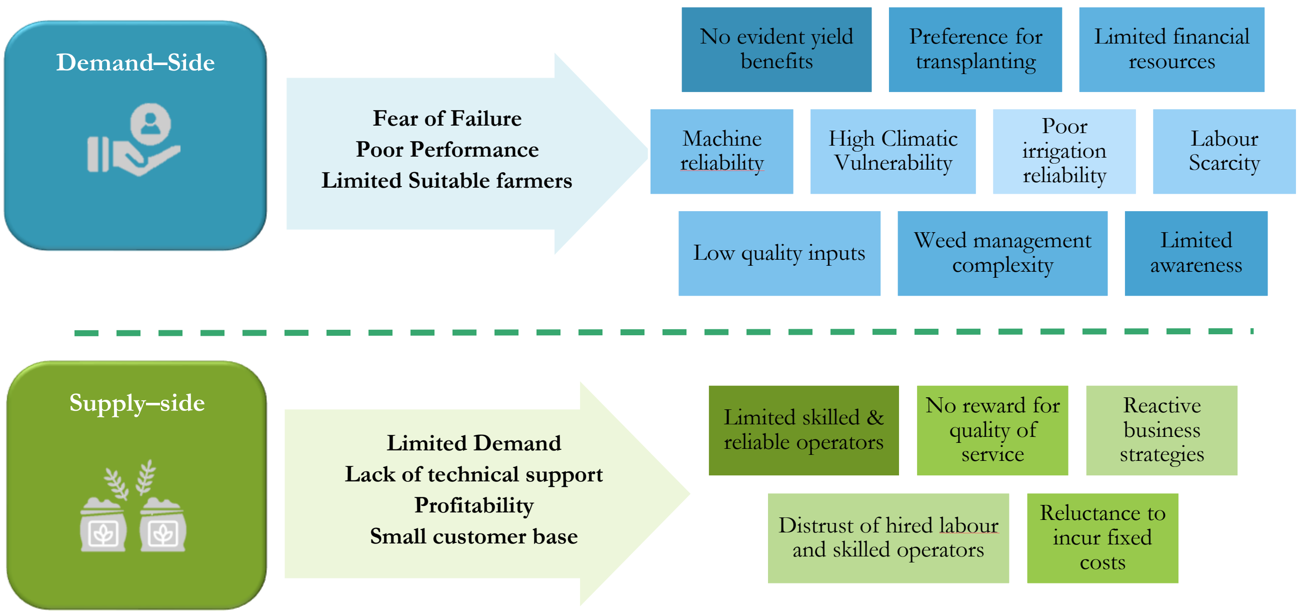


Figure 6: Supply and Demand Side elements of DSR.

Policy Support

With the impacts of climate change becoming increasingly visible and being felt across the globe, governments have been supporting farmers through policies and other incentives. Currently, South Asian countries are grappling with severe groundwater depletion, with agricultural groundwater withdrawal reaching 91%, surpassing the global average of 71% (FAO 2022). Rice cultivation has adverse effects on the environment due to traditional cultivation methods. High population density coupled with water-intensive farming practices, especially TPR, is one of the leading causes of groundwater depletion in the Asian region. It will be imperative for South Asian countries to develop an ecosystem to expand the acreage of sustainable practices such as the DSR system of rice production.

Such an ecosystem, in the long run, will not only help increase the crop productivity and income of farmers but also help governments meet their Nationally Determined Contribution (NDC) goals[22]. For India, agriculture is the second highest GHG emitting sector after energy, contributing around 14% of total emissions, excluding Land Use, Land-use Change, and Forestry (LULUCF). The Indian government has been focusing on implementing programs to assist farmers in reducing emissions and building resiliency. Though the Indian government has not signed the Methane Pledge despite being one of the few top emitters globally, the government is pushing for sustainable technologies across sectors, e.g., increasing the production of solar power. State governments are also making efforts to increase the adoption of sustainable technologies like DSR.

In addition to government support at the policy level, as well as financial incentives, agricultural research institutes like the Indian Institute of Rice Research (IIRR), private sector seed companies like Bayer, Corteva, Savannah, SeedWorks, etc., and IRRI are working to develop rice varieties adaptable for DSR cultivation. Looking at DSR, some state governments in India have provided policy support and financial incentives directed at farmers and other stakeholders.

[22] Country Summary, India

Financial Incentives

Currently, Punjab and Haryana are incentivizing farmers to adopt DSR rice. While Haryana is providing direct cash transfers of ₹ 5,000 per acre, the Punjab government is providing a cash incentive of ₹1,500 per acre. The Haryana government has recently removed the maximum acreage limit of 2.5 acres, allowing larger farmers to avail of the cash transfer scheme for DSR cultivation. Haryana government is also providing a subsidy of ₹40,000 for the purchase of zero-tillage, direct-seeded rice machines. Though the Haryana government is subsidizing equipment purchases, it would be ideal if they could provide subsidies in terms of percentages for different equipment as several makes/models of machines are available in the market.

In 2021, the farmers in Haryana cultivated rice using the DSR technique on 17,444 acres, slightly below the target of 20,000 acres. The area under DSR in Haryana increased to 72,900 acres during 2023 and 311,365 acres by 21 June 2023, surpassing the target of 225,000 acres. There was an additional incentive for farmers who responded to water conservation schemes by honoring them with the title of "*Amrit Krantikari Mitra*." These efforts have led to a decrease in water extraction in 7 districts out of 12 in just two years,

The Punjab government had set an ambitious target for DSR adoption in 2023 and aimed to bring ***five lakh acres under DSR*** in 2023 but could achieve only ***38% of the target***. In 2022, farmers in Punjab used DSR technology on ***2.12 lakh acres***. For the 2024 *Kharif* season, the state agriculture department is targeting 7 lakh acres under the DSR method.

A decade ago, the Tamil Nadu government also provided financial incentives (INR 3,000 – 4,000) for adopting DSR; however, it has been withdrawn. The farmers who benefited from DSR cultivation are still using DSR for rice cultivation in selected districts of the state.

In India, the policy level or financial incentives are not uniform and vary from state to state. This, coupled with limited information dissemination to the beneficiaries, makes it difficult for them to avail the benefit of such incentives. There needs to be a harmonized policy that can be adopted across rice-cultivating regions of the country. This can be supported by an ecosystem (Figure 7) of players to promote DSR and increase its adoption in the country.

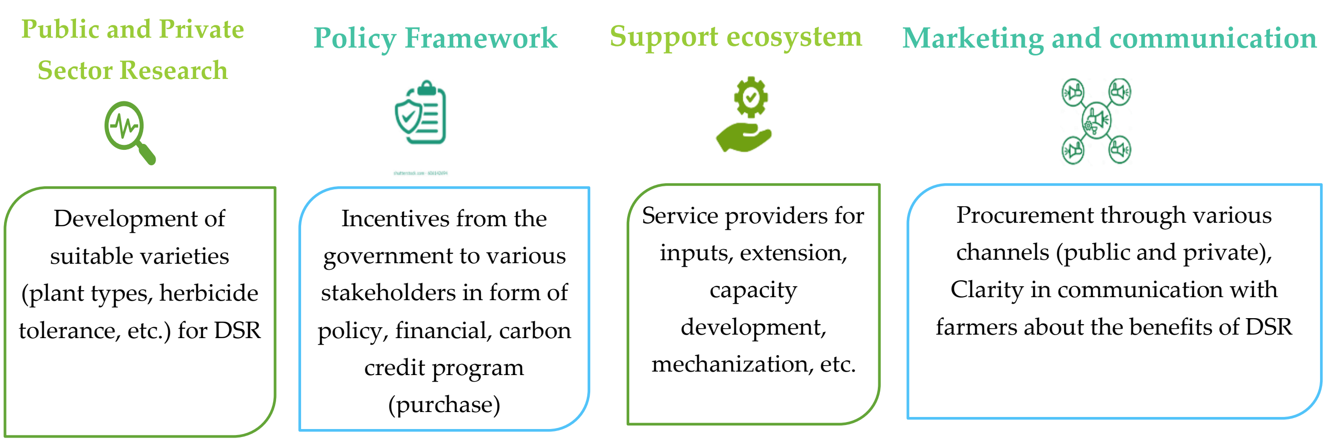


Figure 7: Ecosystem for successful adoption of DSR.

In addition to such incentives, efforts are also being made by several organizations to support the adoption of sustainable and climate-friendly farming practices in the agricultural value chain (inputs, extension, capacity development, mechanization, etc.)

Global efforts in driving DSR adoption

The successful adoption of DSR in the USA and Southeast Asian countries like the Philippines and Vietnam provide examples of strategies that India can adopt. Similar efforts have also been observed in other South and Southeast Asian countries like Sri Lanka. In the Philippines, the percentage of rice farmers adopting DSR ranges from 31-43%. The adoption varies across different rice cultivation zones. Isabella is one of the country's leading rice-producing zones. The farmers of Isabella gained higher yields and reduced their production costs through DSR using a drum seeder. **The rice growers in Isabella obtained yields ranging from 5.7 to 6.7 t/ha and net income from ~ $ 873 - $ 1568**. Among these farmers, the early technology adopters obtained higher yields, approximately 9 t/ha, with net income up to $ 2,050.

In the USA, 100% of rice cultivation is through Direct-Seeded Rice. The development and commercialization of herbicide-tolerant rice varieties (non-GM), that provide tolerance to herbicides used to control weedy rice, have helped achieve 100% adoption of DSR. Mechanization and support ecosystem (both pre-and post-production) have also played a major role in DSR adoption in the USA.

In January 2024, the local government unit of Santa Cruz, Zambales, Philippines, enacted two ordinances[23] that aim to help farmers save on planting and fertilizer costs. These are focused on increasing the adoption of the direct-seeded rice (DSR) system and the integration of the balanced fertilization strategy (BFS) program or Abonong Swak recommended by the Department of Agriculture–Philippine Rice Research Institute (DA-PhilRice). In implementing the ordinance on DSR adoption, PhilRice's Policy Research and Advocacy Project encouraged the municipal agriculture office to integrate the technology in the agricultural extension efforts, develop a curriculum on DSR, capacitate farmers on technology use, allocate an annual budget on technology promotion, and ensure availability of DSR-related machines in the area.

The successful adoption of DSR technology in the countries mentioned above demonstrates that with the availability of appropriate varieties, agronomic practices, traits, and mechanization, a higher DSR adoption can be achieved in India.

[23] Ordinances eye less rice production cost in Zambales.

Environmental Benefits of DSR

Carbon credits as an additional source of income from DSR

An increase in the adoption of DSR rice can help reduce methane emissions, as puddled rice cultivation is one of the leading causes of methane emissions from agricultural activities. Global methane emissions from rice fields over the last decade have been estimated to be 27 ± 6 Tg/year (1 Teragram – 109 kilogram). The reduction in methane emissions from rice fields can contribute to a global net reduction. In India, CH_4 emitted from paddy fields is 3.396 teragrams per year or 71.32 MMT CO_2 equivalent[24]. DSR adoption can be an effective method to reduce methane emissions. The Carbon credits are generated when farmers adopt sustainable practices that help trap carbon in the ground, replenish the soil, and reduce GHG emissions. The potential methane emission (CH_4) reductions from rice fields due to an increase in DSR adoption can be quantified and audited, and carbon credits can be issued. An estimated reduction to the tune of 1.6 – 11.4 million MT CO_2 equivalent (Figure 8) is expected with the adoption of DSR in the range of 15 – 40% of the rice area in India[25].

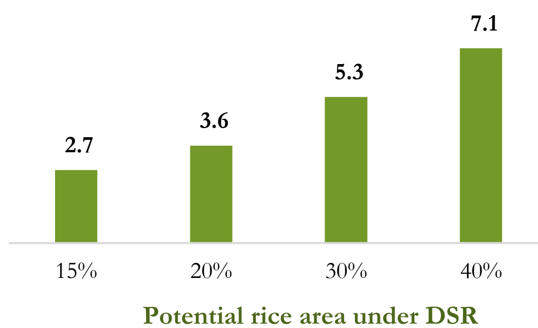


Figure 8: Estimated reduced GHG emission (million Mt CO_2 equivalent at different levels of DSR Adoption

[24] From Plate to Plough: Fix rice farming to avoid a bumper emissions harvest

[25] EPA GHG Calculator

In India, the government plans to develop the Indian Carbon Market (ICM), where a national framework will be established to decarbonize the Indian economy by pricing greenhouse gas (GHG) emissions through trading carbon credit certificates. Corporations like ITC purchase rice as a commodity through their value chains. By adopting DSR, these corporates can use carbon credits to meet their 'beyond value chain mitigation' targets and take responsibility for their ongoing emissions. These mitigation outcomes can become reportable towards value chain targets, such as Scope 3 activities[26]. The scope 3 activities are the result of activities from assets not owned or controlled by the reporting organization but that the organization indirectly affects in its value chain. The Gold Standards Foundation, Geneva, has recently developed a new methodology, in collaboration with inputs from IRRI, to slash methane emissions from rice cultivation to empower smallholder farmers[27]. DSR can help farmers earn carbon credits through reduced GHG emissions, sustainable practices like no-tillage, and organic biomass. The carbon credits are generated through DSR would provide an additional income source to farmers. For example, in India, the value of one carbon credit is US $40, equivalent to a reduction of one ton of CO_2 emissions[28].

Collaborating with private firms such as Grow Indigo (a company that specializes in sustainable agriculture practices) can prove to be highly beneficial for farmers looking to engage in direct-seeded rice (DSR) cultivation. In addition to providing technical assistance, these firms can also assist farmers in selling carbon credits that are generated through their sustainable farming practices. By doing so, farmers can not only adopt eco-friendly cultivation practices but also earn additional income through the sale of carbon credits.

DSR FOR CARBON CREDIT

An Indian farmer, Jitendra Singh from Haryana, cultivated rice in 325 ha. He has gradually shifted to climate-friendly cultivation. The prospect of benefiting from generating carbon credits through sustainable agriculture to sell for additional income convinced Singh to change to DSR. He first heard about the carbon credit program in 2019 from Grow Indigo, a JV between India-based seed firm Mahyco Grow and U.S.-based agriculture technology company Indigo Ag, which produces and sells farm-linked carbon credits. Singh tested DSR on 20 acres of his farm initially. Singh also doesn't set the stubble on fire, but he mulches and spreads it across the field. He then plants wheat seeds directly without tilling.

The model can be adopted on a wider scale once DSR reaches a significant acreage to help India meet a percentage of its emissions reduction goals as per the NDC. The carbon credit market in India is at a very nascent stage, with several organizations in India, like Grow Indigo, Bayer, Varaha ClimateAg, Core CarbonX Solutions, Carbon Fixes, Equator Geo etc., playing a critical role in helping various stakeholders.

Bayer is also having an initiative on sustainable production of low carbon called "***The Good Rice Alliance***". The project is operational in **11 states** covering **~45k Ha**, encouraging farmers to adopt climate-smart practices like **Alternate Wetting and Drying (AWD)** and **Direct Seeded Rice (DSR) while incentivizing for generating carbon offsets**.

---

[26] Scope 3 Inventory Guidance.
[27] Methodology for Methane Emission Reduction by Adjusted Water Management Practice in Rice Cultivation. Methodology for Methane Emission Reduction by Adjusted Water Management Practice in Rice Cultivation
[28] Carbon Credit For Farmers In Punjab And Haryana For Adopting Sustainable Agri-Practices

In the 2023-34 budget, the Indian government announced a ***Green Credit Programme*** to leverage a competitive market-based approach and incentivize voluntary environmental actions of various stakeholders. Some of the green credit activities that are relevant to sustainable agriculture practices like DSR are as follows:

i. ***Water-Based Green Credit:*** To promote water conservation, water harvesting, and water use efficiency/savings, including treatment and reuse of wastewater.

ii. ***Sustainable Agriculture-Based Green Credit:*** To promote natural and Regenerative Agricultural practices and land restoration to improve productivity, soil health, and nutritional value of food produced.

The Green Credits, which are a form of currency that incentivize environmentally friendly practices, are anticipated to be available for trading on a domestic market platform. This platform is different from the carbon market, which is focused on reducing carbon emissions. The Green Credits, on the other hand, are designed to encourage actions that benefit the environment in various ways, such as reducing waste, conserving energy, or using renewable resources. By enabling the trading of sustainable credits, the focus will be on incentivizing individuals and organizations to undertake eco-friendly practices and reduce their carbon footprint. These credits are essentially a representation of the environmental benefits that result from such actions, such as reduced greenhouse gas emissions or conservation of natural resources.

However, the success of this voluntary program will depend on the development of robust methodologies, standards, and reporting & verification mechanisms. These frameworks will ensure that the credits are accurately quantified, verified, and tracked, and that the claims made by the participants are legitimate. For instance, a methodology could outline the procedures for measuring the carbon emissions saved by replacing conventional agricultural practices like TPR with sustainable practices like DSR, natural farming etc. A reporting and verification mechanism could provide a platform for participants to submit their data and for independent auditors to verify it.

The implementation of this program has the potential to create a market for sustainable practices, where the credits can be traded like any other commodity. This market-based approach could drive innovation, efficiency, and cost-effectiveness in the pursuit of environmental sustainability.

For the scheme to be successful, it would be crucial to establish a robust domestic market and demand for green credits. Currently, there is no global platform for green credits, comparable to carbon credits, which means that the scheme's effectiveness would depend heavily on the creation of such a platform. This would require a well-designed system for the issuance, tracking, and trading of green credits, as well as a clear and consistent set of standards for what qualifies as green credit. Without these elements, the scheme would struggle to generate meaningful incentives for companies and individuals to invest in and support environmentally sustainable projects.

The Way Forward

Promoting the adoption of direct-seeded rice (DSR) in India requires a multi-faceted approach at various levels involving multiple stakeholders, including government support. A multi-faceted set of approaches needs to be addressed to drive accelerated and sustainable adoption of DSR. Few of the imperative elements have been indicated hereunder:

Research Systems

Research and Development: To date, almost all the initiatives to promote the adoption of DSR have mainly focused on testing and trialing popular varieties/hybrids for DSR cultivation in both public and private institutions. Only 2-3 varieties have been bred for DSR cultivation by ICAR. This is not enough. There is an urgent need to invest in research and development (with Marker Assisted Breeding for the key DSR-specific traits) to develop high-yielding DSR varieties and hybrids that are suitable for different agro-climatic zones and specific soil profiles in India. A platform needs to be created to encourage collaboration between agricultural research institutions, universities, and leading seed companies to accelerate the development and dissemination of improved DSR products. The introduction of technologies such as Clearfield®, Full-Page, etc. (herbicide-tolerance; non-GM) in India will tremendously enhance the adoption of the DSR system, where weed management is one of the major constraints.

Considering the number of variations of DSR systems (such as dry and wet DSR) prevalent in various regions of the country, there is a need to create comprehensive data on water use efficiency, GHG emissions, and cost of cultivation and have a **centralized database** for its analysis.

Agricultural Systems

Agronomic Practices for DSR: Developing a well-suited agronomic package of practices specifically designed for specific locations (agroclimatic zones, based on various parameters like soil type, water avialability and suitable DSR systems (Wet/Dry DSR) will be critical for increasing the adoption of DSR in the country. Key aspects to focus under this package of practices are:

Increasing Water Use Efficiency (WUE): Promote water-saving technologies and practices such as alternate wetting and drying (AWD) and laser land leveling to optimize water use efficiency in DSR cultivation. Implement water pricing mechanisms to incentivize farmers to adopt water-saving practices and discourage excessive water use.

Weed Management: Develop integrated weed management strategies for DSR cultivation, including the use of herbicides, mechanical weeders, crop rotation, and cover cropping. Provide training to farmers on safe and effective herbicide use to minimize environmental and health risks.

Increasing Nutrient Use Efficiency: Since DSR differs from traditional transplanted rice cultivation in terms of water and nutrient dynamics, nutrient management practices need to be tailored to suit the specific requirements of DSR. Nitrogen is a critical nutrient for rice growth and yield. In DSR, nitrogen management is particularly important due to the potential for nitrogen losses through volatilization, leaching, and denitrification. Split nitrogen applications can help synchronize nitrogen supply with crop demand and reduce losses. Phosphorus and potassium are essential for root development, flowering, and grain filling in rice. Band placement of phosphorus fertilizer during seeding can enhance phosphorus availability to rice roots in DSR systems. Micronutrients are crucial for rice growth and development, and iron deficiencies, especially, can impact crop growth in the DSR system, which can be mitigated by applying basal doses and foliar sprays. By implementing effective nutrient management practices in DSR, farmers can optimize nutrient use efficiency and improve crop yields and quality.

Increasing Access to Farm Machinery: Development and enhancing access to farm machinery for land preparation and seed planting, like levelers and seed drills/planters, will be critical in rice growing areas, increasing the adoption of DSR. The farm equipment can be made accessible to farmers in a ***service model*** that can be established at the village level or by supporting young farmers as entrepreneurs. This can be facilitated by village panchayats, KVKs, and/or SAUs extension departments, who can build expertise among service providers for operating these machines, especially for smallholder farmers.

Policy Level Factors

Policy Support for Farmers: Government(s) can formulate supportive policies and regulatory frameworks to address challenges related to land tenure, credit access, and market linkages for DSR farmers. Streamlining land leasing regulations to facilitate land consolidation and promote mechanization in DSR cultivation will be an important step. Additionally, enhancing smallholder farmers' access to credit and insurance services to mitigate risks associated with DSR adoption will help in the long run.

Recognition for farmers/ villages adopting DSR may help in promoting the wider adoption of DSR. For example, in Haryana, farmers who have responded to water conservation schemes are honored with the title of "***Amrit Krantikari Mitra***" (revolutionary angel friends).

Procurement and Distribution: Another key element for increasing the adoption of DSR-grown rice in India will be incentivization in procurement. This can be done through a strategic shift among various stakeholders. The Indian government can establish procurement policies that prioritize sustainably grown rice, including DSR, for public distribution systems and government food procurement programs. By setting procurement standards and providing incentives for sustainably produced rice, the government can create a market demand that encourages farmers to adopt environmentally friendly practices.

Financial Incentives: The government(s) can provide financial incentives such as subsidies or grants to farmers for purchasing DSR machinery (like seed drills and planters), seeds, and other necessary inputs. This can help reduce the initial investment required for transitioning to DSR. It will be important to ensure that these financial incentives can be either uniform across all states or linked to the production/productivity of DSR rice.

Extension Services: Strengthen extension services to develop capacity and technical support to farmers on best practices for DSR cultivation and service providers on supporting various on- and off-farm operations. SAUs, KVKs, and seed companies, with their extensive reach in the rice belts, can also play a crucial role in this. This can include demonstrations, field days, and farmer field schools to showcase the benefits of DSR and train farmers in proper land preparation, seeding techniques, weed management, and water conservation practices.

Addressing post-harvest elements to drive adoption

Overcoming the need for more suitable plant machinery at rice mills for processing direct-seeded rice (DSR) in India requires a concerted effort from multiple stakeholders. Some of the critical elements are indicated in Fig 9:

Adaptation of existing machinery

- Modification and adoption of existing rice milling machinery to accommodate the processing requirements of DSR rice, if any. Retrofitting and upgrading the existing equipment will be a more feasible and cost-effective solution compared to developing entirely new machinery. The manufacturers and technical experts can be engaged to identify necessary modifications and optimize equipment performance for processing DSR rice.

Technology Transfer and Training

- Facilitate technology transfer and knowledge exchange programs to introduce advanced rice milling technologies and best practices for processing DSR rice. Organize training workshops, seminars, and demonstration sessions for rice mill operators, technicians, and engineers to familiarize them with the operation and maintenance of DSR rice processing machinery. Provide technical assistance and support to ensure effective implementation of new technologies.

Financial Incentives and Subsidies

- Offer financial incentives, subsidies, and grants to rice mill owners and operators to upgrade their facilities with suitable machinery for processing DSR rice. Government-sponsored schemes and programs can help offset the costs associated with equipment acquisition, installation, and maintenance. Provide incentives for investing in environmentally friendly and energy-efficient rice milling technologies.

Figure 9: Addressing post-harvest elements to drive adoption.

Driving Adoption through Market Development, Communication and Awareness Building

Another key element for increasing the adoption of DSR-grown rice in India will be incentivization in ***procurement*** and ***milling.*** This can be done through a strategic shift among various stakeholders. Some of the approaches to bring about this shift have been indicated in below figure (Fig 10):

Market Development, Certification, and Labelling Programs

Establishment of market linkages and value chains for DSR produce

Private sector incentivization to invest in infrastructure development, storage facilities, and processing units

Farmer-producer organizations (FPOs) and cooperatives can help in DSR produce marekting and gain better prices.

Branding or certification and labeling program to certify DSR as sustainable can help farmers receive better prices.

Consumer Awareness Campaign

- Launching audio-visual, print, and social media campaigns to increase consumer awarenes about sustainable and eco-frinedly rice production
- These will help promote the importance of sustainable agriculture, water conservation, and reduced carbon footprint
- In the lomg run these efforts will increase the consumer demand for sustainably produced rice and encourage retailers and food companies to source sustainably grown rice at competitive prices.

Establishment of partnerships with value chain players

The establishment of **partnerships with retailers, food companies, and restaurant chains** will encourage sourcing and procurement of DSR-grown rice.

Such partnerships, coupled with supply chain agreements to support farmers who adopt DSR and other environmentally friendly practices, will also drive DSR adoption.

Figure 10: Driving Adoption through Market Development, Communication and Awareness Building

Impacting environmental gains through the Carbon Credit Program

The introduction and efficient implementation of carbon credit and green credit programs for DSR growers in India can offer several advantages:

Financial Benefits: Participation in a carbon credit program can provide DSR growers with financial incentives in the form of payments for reducing greenhouse gas (GHG) emissions or sequestering carbon in soil. These financial rewards can help offset the costs associated with adopting DSR cultivation. By rewarding DSR growers for implementing practices that reduce GHG emissions, carbon credit programs encourage the adoption of environmentally friendly farming methods.

Capacity building and knowledge sharing: Successful implementation will require capacity development, training, and knowledge-sharing activities to help farmers adopt climate-smart practices and participate effectively in carbon market mechanisms. By providing technical assistance and extension services, carbon credit programs can empower DSR growers with the knowledge and skills needed to implement sustainable farming practices and maximize carbon sequestration potential.

A carbon credit program for DSR growers in India will help align the country's NDC goals with economic incentives, promote sustainable agriculture, and contribute to global efforts to address climate change.

Through a concerted effort by all stakeholders in the rice value chain and support from governments, India can accelerate the adoption of direct-seeded rice and achieve sustainable agricultural development goals while addressing challenges such as water scarcity, labor shortages, and climate change resilience. The awareness campaigns and extension programs to educate farmers, policymakers, and other stakeholders about the agronomic, economic, and environmental benefits of DSR cultivation will play a critical role in achieving a shift from TPR to the DSR system of rice cultivation.

Global Climate Benefits and better market access through carbon credit programs

Adoption of DSR and other climate-smart agricultural practices can contribute to global efforts to mitigate climate change by reducing emissions of methane and other GHGs from agricultural activities. This can help the country in meeting their NDC goals, especially the emission reduction from agricultural activities.

Participation in a carbon credit program can help DSR growers access carbon markets and certification schemes, which can enhance the marketability of their produce and attract premium prices from environmentally conscious consumers. Certification as a carbon-neutral or carbon-negative product can improve market access and competitiveness for DSR growers in domestic and international markets.

Conclusion

DSR emerges as a sustainable and profitable rice cultivation practice. As global demand for rice is expected to increase due to the rising population, DSR offers an efficient, climate-resilient alternative to traditional rice cultivation practices. Significant adoption of DSR will help in conserving water, reducing labor, and reducing GHG emissions from agriculture in general and rice cultivation in particular. Mechanized DSR will empower youth and women farmers, making it an attractive choice. However, to increase DSR adoption in India, a concerted effort from all stakeholders –agri-input companies and companies for farm mechanization, extension services, crop management advisory, and governments – will be crucial. As the world is facing visible impacts of climate change, DSR has the potential to offer a climate-resilient solution for rice cultivation.

Federation of Seed Industry of India (FSII)

10th Floor, Vandhana Building,
Tolstoy Marg, New Delhi – 110001
L : +91 11 2373 1127 | M: 91-98115-91461
E : govaffairs@fsii.in | W: www.fsii.in

Sathguru Management Consultants

Plot 54, Sagar Society, Road No. 2,
Banjara Hills, Hyderabad - 500034
L: +91 40 6627 6200
E: agribusiness@sathguru.com | W : www.sathguru.com