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Direct-Seeded Rice (DSR): A Water Saving Technology for Rice Cultivation

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Rice cultivation is a cornerstone of global food security, yet conventional puddled transplanted systems are increasingly challenged by high water demand, rising labor costs, and climatic uncertainties. In this context, Direct-Seeded Rice (DSR) has emerged as a resource-efficient and climate-resilient alternative. This article provides a comprehensive overview of DSR, including its establishment methods, water-saving potential, agronomic benefits, challenges, recent technological advancements, environmental implications, and future prospects. DSR involves direct sowing of seeds into the field, eliminating the need for nursery raising and transplanting, thereby reducing labor and water requirements. It can be practiced through dry, wet, and water seeding methods, each suited to specific agro-ecological conditions. Evidence indicates that DSR can reduce water use by 20–50% while maintaining comparable yields through improved irrigation practices such as alternate wetting and drying. The system also offers advantages such as lower production costs, improved soil health, and enhanced operational efficiency. However, challenges including weed infestation, nutrient management, and variability in crop establishment remain key constraints. Recent innovations—such as precision agriculture tools, mechanization, herbicide-tolerant varieties, and climate-smart practices—are addressing these limitations and improving system reliability. Additionally, DSR contributes to reduced greenhouse gas emissions, groundwater conservation, and energy savings, reinforcing its environmental significance. Adoption is expanding across major rice-growing regions, supported by policy interventions, training programs, and technological advancements. Overall, DSR represents a transformative approach to sustainable rice cultivation, with strong potential to enhance productivity, profitability, and resource conservation under changing climatic conditions.

Keywords: Direct-Seeded Rice (DSR); Water-use efficiency; Climate-smart agriculture; Sustainable rice cultivation; Precision farming

Introduction

Rice is a staple food for more than half of the global population, particularly in Asia, where it plays a critical role in food security and rural livelihoods. However, traditional methods of rice cultivation, especially puddled transplanted rice (PTR), are highly water-intensive. With increasing water scarcity, labor shortages, and climate variability, there is an urgent need for more resource-efficient production systems. In this context, **Direct-Seeded Rice (DSR)** has emerged as a promising alternative technology that significantly reduces water use while maintaining productivity. DSR involves sowing rice seeds directly into the field rather than transplanting seedlings from a nursery. This method eliminates the need for puddling and continuous flooding, resulting in substantial water savings and reduced labor requirements. Recent research (Deb et al., 2025; Mubarak et al., 2025) has highlighted DSR as a viable climate-smart agricultural practice, particularly in regions facing groundwater depletion and erratic rainfall patterns.

Concept and Types of Direct-Seeded Rice

Direct-seeded rice (DSR) can be established through several methods, each tailored to specific field conditions, soil moisture status, and water availability. In **dry direct-seeded rice (dry DSR)**, seeds are sown directly into dry or moist soil using seed drills or by broadcasting prior to the onset of monsoon rains. This approach is particularly suitable for rainfed and upland ecosystems, where irrigation facilities are limited. It enables timely crop establishment and facilitates the use of mechanized equipment, making it increasingly popular among farmers facing labor shortages. In contrast, **wet direct-seeded rice (wet DSR)** involves sowing pre-germinated seeds onto puddled or saturated soil. This method is commonly adopted in irrigated lowland areas where water is readily available, allowing for better initial crop establishment and some suppression of weeds due to moist conditions. A third approach, known as **water seeding**, entails broadcasting seeds into standing water and is practiced in specific ecological niches, such as flood-prone or poorly drained fields. Each method offers distinct advantages depending on agro-climatic conditions and resource availability. However, among these, dry DSR has gained considerable attention in recent years due to its lower water requirement, reduced labor demand, and compatibility with modern farm machinery. Its adaptability to large-scale mechanized farming and potential to conserve water make it a promising strategy for sustainable rice cultivation under changing climatic scenarios.

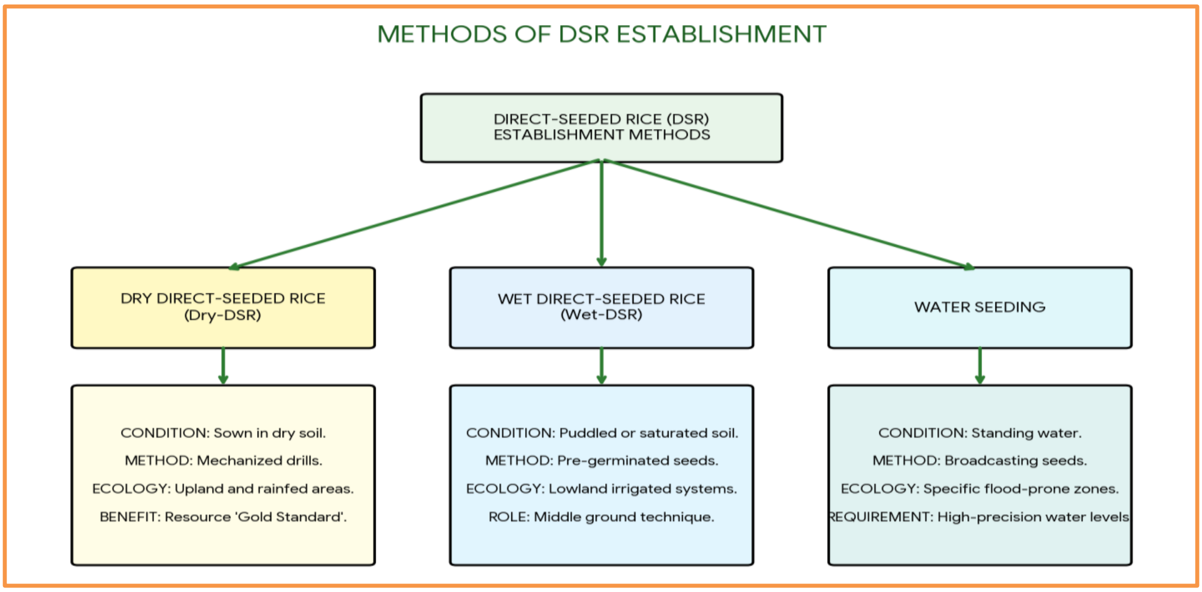

Figure 1. Flowchart: DSR Methods of Establishment

Water-Saving Potential of DSR

Water scarcity has emerged as a critical constraint in sustaining rice production, particularly in regions dependent on intensive irrigation practices. Conventional puddled transplanted rice systems require substantial volumes of water, often ranging between 3000 and 5000 liters to produce one kilogram of grain. In contrast, Direct-Seeded Rice (DSR) offers a more resource-efficient alternative by significantly lowering water consumption, with reported savings of approximately 20–50% depending on agro-climatic conditions, soil characteristics, and management practices (Deb et al., 2025). The enhanced water-use efficiency in DSR primarily results from the elimination of puddling, a process that typically accelerates water loss through seepage and deep percolation.

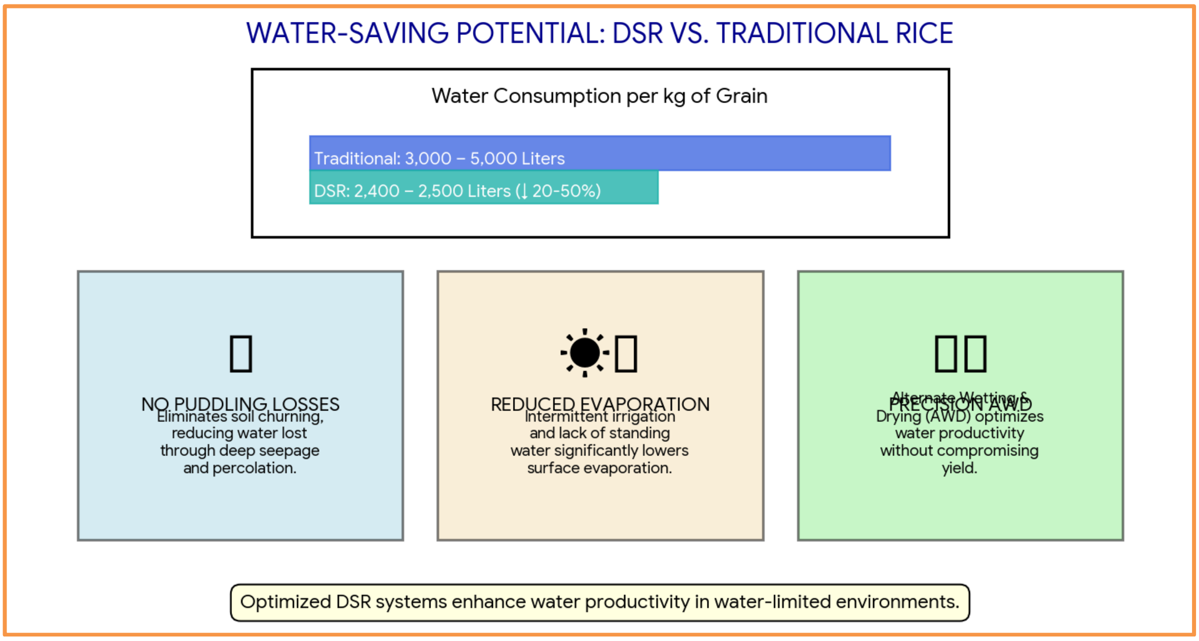

Figure 2: Direct-Seeded Rice (DSR) represents a vital shift toward sustainable water management in agriculture

Additionally, DSR fields are not continuously flooded, which reduces surface evaporation and promotes more judicious water use. The adoption of controlled irrigation strategies, particularly techniques such as alternate wetting and drying (AWD), further optimizes water application by maintaining soil moisture within critical thresholds rather than sustaining standing water. This not only conserves water but also improves root development and nutrient uptake. Empirical evidence indicates that well-managed DSR systems can maintain comparable yields to traditional methods while using substantially less water. For instance, Mubarak et al. (2025) reported that optimized irrigation scheduling under DSR conditions significantly enhances water productivity without negatively affecting crop performance. Consequently, DSR is increasingly recognized as a viable and sustainable solution for rice cultivation in water-limited environments, contributing to both agricultural resilience and long-term resource conservation.

Agronomic Advantages of DSR

Direct-Seeded Rice (DSR) offers several important agronomic advantages that make it an efficient and sustainable alternative to conventional transplanted rice systems. One of the most significant benefits is the reduction in labor requirement. Traditional rice cultivation involves labor-intensive operations such as nursery raising, seedling uprooting, and manual transplanting, whereas DSR eliminates these steps by allowing direct sowing of seeds into the field. This can reduce labor demand by nearly half, which is particularly advantageous in regions facing labor shortages. In addition, DSR enables early crop establishment since sowing can be carried out promptly with the onset of suitable soil moisture conditions. Timely establishment ensures better synchronization with rainfall patterns and enhances crop growth during critical stages. Another key advantage is the reduction in production costs. By minimizing the need for labor, irrigation water, and energy inputs, DSR lowers the overall cost of cultivation, thereby improving farm profitability. Studies such as Ahmed et al. (2025) have highlighted the economic benefits of DSR compared to conventional practices. Furthermore, DSR contributes positively to soil health. Unlike puddled transplanted systems, which often degrade soil structure, direct seeding maintains soil aggregation, improves aeration, and supports beneficial microbial activity. These improvements enhance nutrient cycling and long-term soil fertility. Collectively, these agronomic benefits make DSR a viable and resource-efficient approach for sustainable rice production.

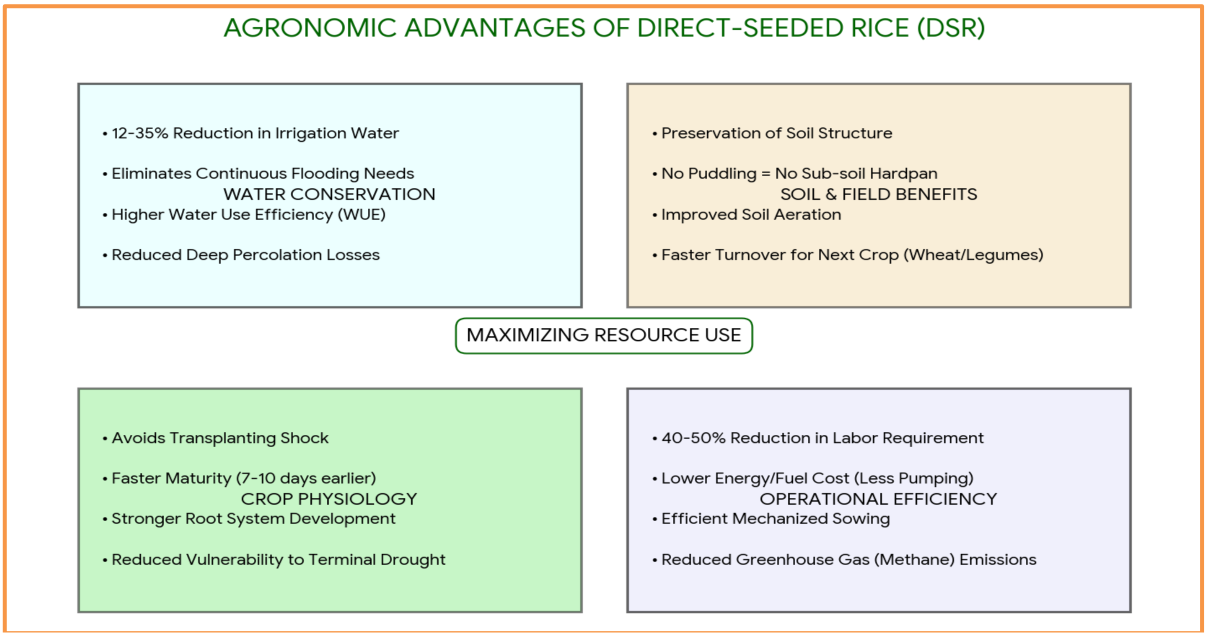

Figure 3 : Advantages of DSR in water saving at crop fields

Challenges in Adoption of DSR

Adoption of Direct-Seeded Rice (DSR), while promising, is constrained by several agronomic and management challenges that can limit its effectiveness under field conditions. Among these, weed infestation remains the most significant barrier, as the absence of continuous flooding—typical in transplanted systems—creates a favorable environment for weed emergence and competition. Effective control therefore relies heavily on timely herbicide application combined with integrated weed management strategies. Another critical issue is crop establishment; uneven germination and poor plant stands often result from inadequate land leveling, suboptimal seed quality, or improper soil moisture at sowing, ultimately affecting yield potential. Nutrient management also becomes more complex in DSR systems because non-puddled soils exhibit different nutrient dynamics, including higher risks of nitrogen losses through leaching and volatilization, necessitating precise and site-specific fertilizer application. Additionally, yield variability poses a concern, particularly in rainfed areas where erratic rainfall and improper management practices can lead to inconsistent crop performance. Despite these limitations, ongoing advancements in agronomic practices, improved seed technologies, precision farming tools, and better water and nutrient management strategies are gradually mitigating these constraints, thereby enhancing the reliability and wider adoption of DSR in diverse agro-ecological conditions.

Table 1. Recent Trends and Innovations in DSR (2025–2026)

S. No.	Trend / Innovation	Key Components / Technologies	Significance in DSR Systems	Supporting Studies (2025)
1	Precision Agriculture Integration	Soil moisture sensors; GPS-enabled seed drills; Remote sensing tools	Enables precise irrigation and nutrient application, enhancing input-use efficiency and crop performance	Deb et al.
2	Climate-Smart Agriculture Approach	Methane emission reduction; Drought resilience; Resource-use optimization	Improves environmental sustainability and strengthens adaptability under climate variability	Ahmed et al.
3	Herbicide-Tolerant Varieties	Development of weed-resistant rice cultivars	Facilitates effective weed management and minimizes yield losses in DSR systems	Recent breeding advancements

4	Mechanization and Smart Equipment	Zero-till seed drills; Drum seeders; Laser land levelers	Enhances operational efficiency, ensures uniform seed placement, and improves crop establishment	Field-based innovations
5	Improved Water Management Techniques	Alternate Wetting and Drying (AWD); Real-time irrigation scheduling	Reduces water consumption and energy use while maintaining optimal soil moisture conditions	Emerging irrigation studies
6	Economic Feasibility and Scaling	Cost-benefit optimization; Adaptability across agro-climatic zones	Demonstrates profitability and scalability of DSR, especially in water-scarce and labor-deficient regions	Dey et al.
7	Crop Establishment & Yield Stability Research	Improved agronomic practices; Enhanced varietal selection	Ensures consistent crop stand and stable yields under varying environmental conditions	Susanti et al.; Revathy et al.

Environmental Benefits of DSR

Direct-Seeded Rice (DSR) offers notable environmental advantages by addressing key sustainability challenges associated with conventional rice cultivation. One of its most important benefits is the reduction of greenhouse gas emissions. Traditional flooded rice systems create anaerobic soil conditions that promote methane production, a potent greenhouse gas. In contrast, DSR avoids prolonged flooding, thereby limiting anaerobic decomposition and significantly lowering methane emissions. Additionally, DSR contributes to the conservation of groundwater resources. Conventional rice cultivation requires large volumes of irrigation water, leading to excessive groundwater extraction, particularly in intensively cultivated regions such as northwestern India. By adopting DSR, farmers can reduce irrigation frequency and water demand, helping to preserve declining aquifers. Furthermore, DSR enhances energy efficiency in agricultural operations. Since less water is required, the need for pumping irrigation water decreases, resulting in lower energy consumption, especially in areas dependent on diesel or electric pumps. This reduction in energy use not only decreases production costs but also minimizes the overall carbon footprint of rice farming. Collectively, these environmental benefits position DSR as a sustainable and climate-resilient alternative for future rice production systems.

Adoption Status and Future Prospects

Direct-seeded rice (DSR) is increasingly being adopted across major rice-growing regions such as India, China, and several Southeast Asian countries, driven by the urgent need to conserve water, reduce labor dependency, and enhance production efficiency. Public institutions and agricultural agencies are actively encouraging its uptake through structured training programs that equip farmers with practical knowledge of DSR techniques. In addition, financial incentives, including subsidies for machinery like seed drills and laser land levelers, are making the technology more accessible. Field-based demonstration trials further play a crucial role by showcasing the real-world benefits of DSR under local conditions, thereby improving farmer confidence. Despite this progress, large-scale adoption still depends on several enabling factors. Strengthening farmer awareness and technical capacity is essential to ensure proper implementation.

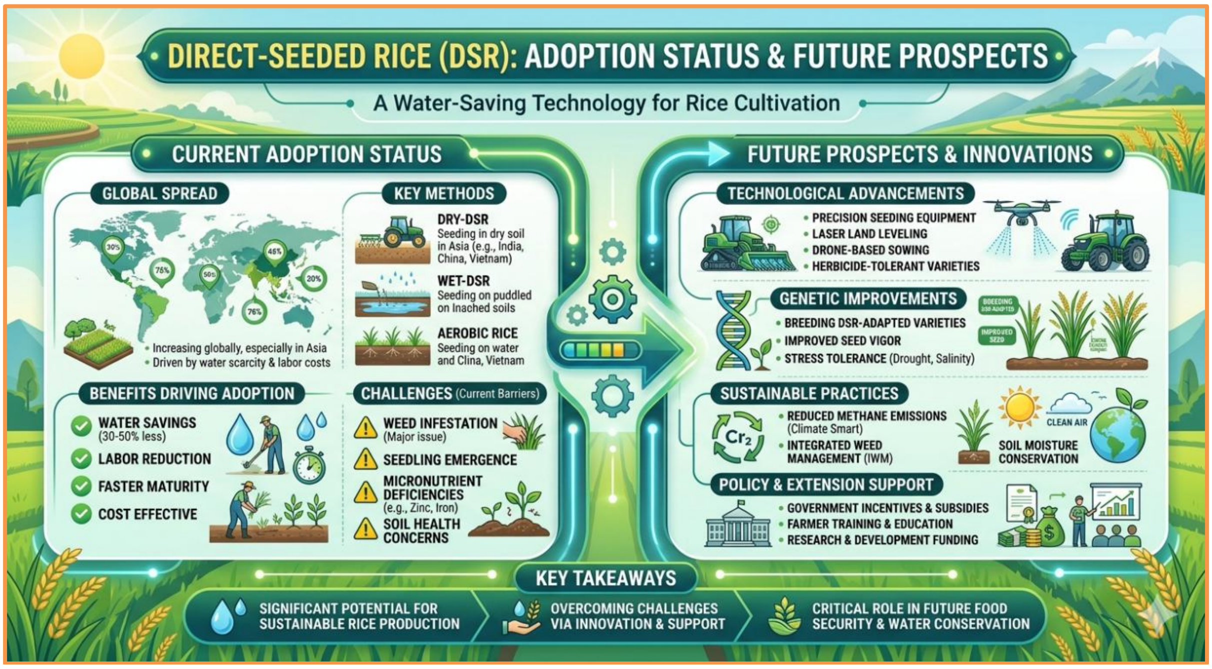

Figure 3. Direct-Seeded Rice (DSR) is a resource-efficient alternative to traditional puddled transplanting, significantly reducing the environmental footprint of rice cultivation

Equally important is the availability of high-quality seeds, appropriate herbicides, and suitable machinery at affordable costs. Robust agricultural extension services are needed to bridge the gap between research and field application. With sustained research efforts and supportive policy frameworks, DSR holds significant promise to reshape rice cultivation into a more resource-efficient, climate-resilient, and economically viable production system.

Conclusion

Direct-Seeded Rice (DSR) represents a paradigm shift in rice cultivation, offering a sustainable solution to the challenges of water scarcity, labor shortage, and climate change. By significantly reducing water use and production costs while maintaining productivity, DSR aligns well with the goals of modern agriculture. Recent advancements in precision farming, mechanization, and climate-smart practices have further enhanced the efficiency and feasibility of DSR systems. Although challenges such as weed management and crop establishment persist, ongoing research and technological innovations are steadily overcoming these barriers. As highlighted by recent studies (Deb et al., 2025; Mubarak et al., 2025; Dey et al., 2025; Ahmed et al., 2025; Revathy et al., 2025; Susanti et al., 2025), DSR is not just a water-saving technology but a comprehensive approach toward sustainable rice production. Its adoption at scale can play a crucial role in ensuring food security while conserving vital natural resources. In the face of growing environmental concerns and resource limitations, DSR stands out as a forward-looking solution that combines productivity, profitability, and sustainability—making it an essential component of the future of rice cultivation.

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