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Is DSR Economically Viable?

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Punjab agriculture, once a development model for other Indian states, is now facing a dual challenge of slowing down agricultural growth and preserving natural resources, agro-biodiversity, and the environment amidst the changing climate. Agricultural growth has decelerated drastically, from 5.2% per annum from 1970-71 to 1990-91 to 2.3% from 2010 to 2021-22, primarily due to the poor performance of the crop sub-sector.

Driven by the nation's food security needs, Punjab's agricultural production system, fueled by technological change and enabling policies, has evolved as a specialized rice-wheat system, occupying about 85% of the gross cropped area. The climatic conditions of Punjab do not favor the cultivation of water-guzzling crops like rice. Yet, rice emerged as a mono-crop in the kharif season, cultivated in 86% of the area.

As the area under rice cultivation expanded, farmers' reliance on groundwater increased, leading to over-extraction. The share of groundwater in the total irrigated area increased from 55% in 1970-71 to 71.6% in 2021-22. The increasing water demand for irrigation forced farmers to switch to high-capacity submersible pumps, leading to a further decline in groundwater level. The problem was aggravated by the state's policy of free electricity supply to agriculture. Since 1997, Punjab has been providing free electricity for irrigation. The state's current level of groundwater development is 163%, i.e., 63% higher than its rechargeable rate. Figure 1 shows the trend in rice area and groundwater level.

To prevent the over-extraction of groundwater, in 2009, the state government enacted a legislation called 'The Punjab Preservation of Subsoil Water Act' to align paddy sowing towards the onset of the monsoon. Despite the Act being in force, the over-extraction continued almost at the same rate as before, i.e., 0.45 meters per annum. Its effect is reflected in the significant deceleration of yield growth of rice, from 2.5% per annum from 1970-71 to 1990-91 to 0.74% per annum from 2001-02 to 2021-22.

Nevertheless, agriculture remains crucial for the livelihood of the state's farmers and the nation's food security. Punjab accounts for about 10% of the country's total rice production but contributes 22% to the central rice pool for the public distribution system and buffer stocking. The Government of India procures about 95% of the total rice produced in the state.

Arresting the depletion of groundwater resources is crucial for the sustainability of agriculture. There are several technological options to arrest the falling groundwater level. Direct seeding of rice (DSR) is one of

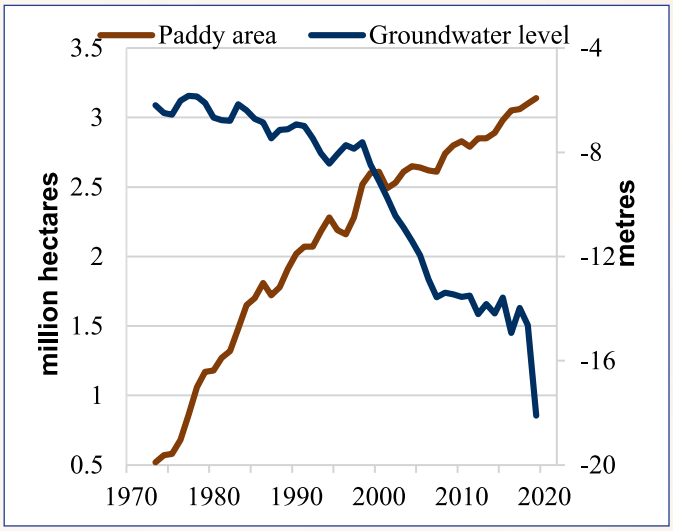

Figure 1. Trend in paddy area and groundwater level in Punjab, 1973-2019

Source: Statistical Abstract of Punjab, various issues

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the options. Traditionally, rice is cultivated following the Puddled Transplanting Rice method (PTR), which requires significant water, energy, and labor. In comparison, the DSR has the potential to save these scarce production inputs[3]. The yield benefits of DSR are, however, uncertain. Therefore, assessing the net economic benefits of DSR is imperative.

Punjab's agriculture heavily relies on migrant labor. During the COVID-19 pandemic, reverse labor migration from Punjab led to a significant labor shortage. In response, farmers started adopting DSR. Yet, its adoption has not picked up as expected, primarily because of the uncertainty in its effects on crop yield. This brief note makes an assessment of the potential economic impacts of DSR[4].

Estimation procedure

Economic surplus is a widely used method of impact assessment of agricultural technologies because of its minimal data requirement and flexibility to accommodate behavioral changes in demand- and supply-side factors. It allows scaling up benefits from the farm level to regional as well as national levels[5]. It also informs us about the distribution of the gains between producers and consumers. The economic surplus is estimated as follows:

Consumer surplus

$$\Delta CS = P_0 Q_0 Z_t (1+0.5\ \varepsilon_d Z_t)$$

Producer surplus

$$\Delta PS = P_0 Q_0 (K_t - Z_t) (1+0.5\ \varepsilon_d Z_t)$$

Total surplus

$$\Delta TS = \Delta CS + \Delta PS$$

Where ΔCS is the change in consumer surplus, ΔPS is the change in producer surplus, and ΔTS is the sum of changes in consumer and producer surplus. Q_0 is the initial production level, P_0 is the initial price, ε_d is the absolute price elasticity of demand, and ε_s is the price elasticity of supply. K_t is the vertical shift in the supply function expressed as a proportion of the initial price. Z_t is the reduction in price due to technology-led increase in output supply.

The adoption rate of DSR in Punjab was estimated at 19% in 2021[6], ten years after its introduction. Based on experts' opinions, it may reach 30% by 2035. The adoption rate has been projected employing the logistic function[7].

Data and assumptions

Data for estimating economic surplus have been compiled from several sources, including farm surveys, focused group discussions, and published literature and databases. Table 1 shows the values of parameters and their sources.

Table 1. Values of parameters used in estimating economic surplus

Parameter	Value	Source
P_0: Initial price (Rs/ton)	20397	CACP, MoA&FW, GoI
Q_0: Initial production (million tons)	16.25	DES, MoA&FW, GoI
E(Y): Yield change (%)	-3, 0, +3,	FGDs, expert consultation
E(C): Variable cost change (%)	-14, -17	FGDs, expert consultation
A^{max}:maximum adoption rate (%)	30	Expert consultation
t:Time to reach max adoption (years)	24	Expert consultation
ε_s: Supply elasticity	0.236	Kumar *et al.* (2010)[8]
ε_d: Demand elasticity	-0.247	Kumar *et al.* (2011)[9]
p: Probability of success	1	Expert opinion
d: Depreciation rate	0	Expert opinion
Discount rate (%)	5	Birthal *et al.* (2012)[10]

The Government of India has been consistently procuring about 95% of the paddy produced in the states at its pre-determined Minimum Support Price (MSP) recommended by the Commission of Agricultural Costs and Prices (CACP), Ministry of Agriculture and Farmers Welfare (MoA&FW), Government of India (GoI). Hence, we have considered MSP as producer price. In 2022-23, MSP for paddy was Rs. 20397/ton. Data on rice area and production were taken from the website of the Directorate of Economics and Statistics (DES), MoA&FW.

Research on DSR was conducted without any significant research funding before 2010. The technology

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was released for adoption in 2010. Concrete data on the research and development cost is available since 2010 only. Therefore, research costs incurred in evolving/ refining DSR at PAU were estimated, considering the time researchers spent and expenditure on their salaries from 2010 to 2017. It was adjusted for inflation using the Wholesale Price Index (WPI) at a constant 2022-23 price. Since DSR has already been adopted, its probability of success is 100%. Importantly, DSR is the practice, the benefits of which are unlikely to depreciate.

DSR reduces the requirement for water and electricity by 28% and labor by almost half (Table 2). Together, these cause a reduction of 14% in the variable cost with the provision of free electricity at present and 17% with full cost recovery of electricity.

The yield gains from DSR are uncertain as emerged from the discussions with various stakeholders, including farmers. The yield gains from DSR over PTR may vary between -3% to +3%. Hence, we have estimated the economic surplus under three scenarios: (i) no change in yield (i) 3% lower yield, and (iii) 3% higher yield.

Economic impact of DSR in Punjab

Recommendation for DSR was first given in PAU Package of Practice in 2010. In 2012, DSR occupied 8,900 hectares in Punjab, which increased to 23,000 hectares in 2019. However, during the COVID-19 pandemic, it surged to 5 lakh hectares in 2020 and 6 lakh hectares in 2021[6,11]. By 2035, DSR is projected to spread over 9.49 lakh hectares i.e., 30% of the rice-cropped area[12].

Table 2. Effects of DSR on input use per ha

Particulars	DSR	PTR	% Change
Labor (hrs)	159	312	-49*
Irrigation (hrs/ha)	145	202	-28*
Water use (m^3)	6273	8721	-28*
Electric power use (KWh)	1625	2259	-28*
Total variable cost with free electricity (Rs.)	39937	46267	-14
Electricity cost for pumping groundwater# (Rs.)	9184	12794	-28
Actual variable cost (Rs.)	49121	59061	-17

Note:
*denotes significance at 5% level
#The electricity cost for pumping groundwater is estimated by multiplying the electricity usage with the cost of power generation.
Source: Authors' survey. DSR: Direct Seeded Rice; PTR: Puddled Transplanted Rice

Ex-post assessment

With no electricity tariff and a yield penalty of -3%, the total economic surplus due to the adoption of DSR during 2010 to 2021 was estimated at Rs. 259 crores or Rs. 22 crores per annum (Table 3). However, with a yield advantage of +3%, it increased to Rs. 3938 crores or Rs 328 crores per annum. Interestingly, DSR could generate a surplus of Rs. 175 crores per annum, even without affecting crop yield.

With the full recovery of electricity tariff, DSR could generate an annual surplus of Rs. 60 crores in case of a yield penalty of 3%, Rs. 213 crores with no yield effect, and Rs. 365 crores in case of a yield advantage of 3%.

Table 3. Economic surplus from adoption of DSR for 2010-2021 (Rs. crores)

Yield change	ΔCS	ΔPS	ΔTS	Annual
Cost reduction: -14% with free electricity				
+3%	1924	2014	3938	328
0%	1029	1077	2106	175
- 3%	126	132	259	22
Cost reduction: -17% with full cost recovery of electricity				
+3%	2138	2237	4375	365
0%	1250	1308	2558	213
-3%	354	370	724	60

Ex-ante assessment for 2022-2035

Projections of the economic surplus to 2035 indicate that the DSR with free electricity and a 3% yield penalty will generate a surplus of Rs 164 crores per annum (Table 4). Expectedly, the highest annual surplus of Rs 2790 crores is estimated with full recovery of electricity tariff and 3% yield gain.

Table 4. Economic surplus from the adoption of DSR for 2022-2035 (Rs. crores)

Yield change	ΔCS	ΔPS	ΔTS	Annual
Cost reduction: -14% with free electricity				
+3%	17174	17975	35149	2511
0%	9122	9547	18668	1333
-3%	1119	1171	2290	164
Cost reduction: -17% with full cost recovery of electricity				
+3%	19086	19975	39061	2790
0%	11082	11598	22680	1620
-3%	3131	3277	6409	458

[11] https://indianexpress.com/article/cities/chandigarh /rise-in-direct-sowing-of-rice-this-year-punjab-farmers-save-ground-water-6501223/

[12] Based on experts' opinion

Assessment of benefits since 2010

DSR is expected to occupy over 30% of the rice-cropped area by 2035. If the current policy of free electricity were to continue, then even with no yield effect, the DSR would generate a potential surplus of Rs. 799 crores per annum (Table 5). Expectedly, it almost doubles if there is a yield advantage of +3%. It remains positive even with a yield penalty of -3%.

Suppose the government withdraws the policy of free electricity. In that case, the adoption of DSR yields significant net gains even if there is a yield penalty. Interestingly, the DSR benefits both producers and consumers almost equally.

Table 5. Economic surplus from the adoption of DSR for 2010-2035 (Rs. crores)

Yield change	ΔCS	ΔPS	ΔTS	Annual
Cost reduction: 14% with free electricity				
+ 3%	19099	19989	39088	1503
0	10150	10624	20774	799
– 3%	1245	1303	2549	98
Cost reduction: 17% with full cost recovery of electricity				
+ 3%	21224	22213	43436	1671
0	12332	12906	25238	971
– 3%	3485	3647	7133	274

Policy implications

DSR appears to be an effective way to preserve natural resources and reduce the electricity subsidy burden. Although its effects on crop yield are uncertain, the benefits accruing due to savings in irrigation and labor costs are sufficient to outweigh the revenue loss due to yield penalty, if any. These findings underscore some important policy implications:

First, farmers' perceptions of the benefits and risks are often a deterrent to adopting new technologies and practices. Hence, there is a need to create awareness among farming communities about the potential long-term benefits of adopting DSR and other such resource conservation technologies. Towards this, there is a need to strengthen the extension system to demonstrate their benefits on a wider scale.

Second, farmers are often risk averse because of the uncertainty in yield effects. Nevertheless, given the resource conservation benefits of DSR, the government may incentivize farmers, equivalent to the revenue forgone, if any, due to its adoption.

Third, there is a need for continuous refinement of DSR practices and breeding crop varieties suitable for direct seeding. Herbicide tolerant varieties should be a priority, as DSR is associated with a high infestation of weeds. Further, it is equally important to quantify and assign a monetary value to the non-tradable ecosystem services associated with DSR, which is essential for designing an incentive structure for its faster adoption.

Acknowledgements

We gratefully acknowledge the financial support provided by ICAR-NIAP for this study under the network project on Impact Assessment of Agricultural Technology. We are also thankful to the subject experts of the Department of Plant Breeding and Genetics, Agronomy, and Director Seeds, PAU for providing the necessary information. We sincerely thank Prof. P. S. Birthal, Director of ICAR-NIAP, for the invaluable comments and suggestions, which have significantly enhanced the quality of this work.

September 2024

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Design & printed by: M/s. Royal Offset Printers, New Delhi # 9811622258