

Salt-Tolerant Rice Varieties: Economic Impact, Adoption Pathways, and Policy Imperatives

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Introduction

Salt-affected soils pose a significant threat to agricultural productivity and food security in India, with around 6.74 m ha. Without appropriate preventive measures, the salt-affected area may increase to ~16.2 m ha by 2050¹. Rice crop is highly sensitive to salt stress, particularly during its seedling and reproductive phases². A meta-analysis shows that salinity stress significantly reduces the grain yield, with an almost 45-50% reduction in saline soils (> 6.5 dS/m)³. In heterogeneous saline-sodic fields, grain yield losses of 30–50% have been reported, largely due to spikelet sterility and poor grain filling⁴. In India, it is estimated that due to salt-affected soils the annual rice production loss is 3.01 mt⁵. The average production loss is 1.28 t per ha, which is equivalent

to ₹28,187 per ha at the Farm Harvest Prices (FHP) of 2023–24⁶. At aggregate level, the annual monetary loss is around ₹6,598 crores, highlighting the substantial economic burden imposed by salt-affected soils on rice production. For sustaining the rice production, development of salt-tolerant rice varieties (STRVs) is a cost-effective option, however the realisation of their potential is governed by a host of biotic and abiotic factors. Till date, the adoption patterns and economic impacts have not been understood beyond field trials, demonstrations, and success stories. To bridge this research gap, this policy brief assesses the adoption pathways and economic impact of STRVs. For sustaining the rice production in salt-affected lands, and thereby food security, the ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, has developed several STRVs. The most popular varieties include Basmati CSR30, CSR36, CSR43, CSR46, CSR56, CSR60, CSR76, CSR101 and CSR104. Key characteristics of the STRVs are given in table

Table 1. Key characteristics of the STRVs (salt-tolerant rice varieties) developed by ICAR-CSSRI, Karnal

Name of variety	Basmati CSR30	CSR36	CSR56	CSR 76	CSR 101
Year of release	2001	2005	2018	2022	2024
Maturity days	155	140	125	125-130	135-140
Tolerance limits					
• Salinity (ECe:dS/m)	<7.0	<7.0	<8.0	<7.0	<8.0
• Sodicty (pH _s)	<9.5	<9.8	<9.9	< 9.7	< 9.5
Yield (t/ha)					
• Normal soils	>3.0	>6.5	>7.5	6.5-7.00	7.0 to 7.5
• Salt-affected soils	>2.0	>3.5	>4.1	>4.5	>4.0
Grain type	Basmati	Long Slender	Long Bold	Long Slender	Long bold
Recommended ecology	Sodic lands of UP, HR and PB	Sodic lands of HR, UP and PY	Sodic and saline lands of UP and HR	Sodic lands UP	Saline and sodic lands of KL, KA, and TN

Note: HR, UP, PB, PY, KL, KA and TN stand for Haryana, Uttar Pradesh, Punjab, Puducherry, Keralam, Karnataka and Tamil Nadu, respectively.

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- ICAR-CSSRI. 2015. *Vision-2050*, ICAR-Central Soil Salinity Research Institute. Karnal, India pp.31. <https://cssri.res.in/vision-2050/>
- Manikandan, S., Premavathi, R., Kannan, V. S., Janaki, P., & Selvi, R. G. (2024). Role of farm size in adopting salinity-tolerant paddy varieties: A study in coastal districts of Tamil Nadu. *Plant Science*, 12(1): 01–09 <https://doi.org/10.14719/pst.6081>
- Zheng, C., Liu, C., Liu, L., Tan, Y., Sheng, X., Yu, D., Sun, Z., Sun, X., Chen, J., Yuan, D., & Duan, M. (2023). Effect of salinity stress on rice yield and grain quality: A meta-analysis. *European Journal of Agronomy*. <https://doi.org/10.1016/j.eja.2023.126765>
- Shah, S., Cheng, Z., Zhang, X., Khan, Y., Liang, Z., Arshad, S., Meng, Q., Zhen, P., Zhang, Z., Zhang, T., Li, J., Feng, Z., Mumtaz, M., & Wang, M. (2026). Rice growth and yield formation in heterogeneous sodic and saline-sodic soils: challenges and management strategies. *Frontiers in Plant Science*, 17, 1770941. <https://doi.org/10.3389/fpls.2026.1770941>
- Sharma, D.K., Thimmappa, K., Chinchmalatpure, A.R., Mandal, A.K., Yadav, R.K., Chaudhari, S.K., Kumar, S. and Sikka, A.K. (2015). *Assessment of production and monetary losses from salt-affected soils in India*. Technical Bulletin: ICAR-CSSRI/Karnal/2015/05. ICAR-Central Soil Salinity Research Institute, Karnal, India.

- Gol (2025). *Farm harvest prices of principal crops in India -2023-24*. Agricultural Marketing Division, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and farmer's welfare, Government of India, New Delhi.

1. With this background, this policy brief presents the adoption, productivity, and economic impacts of STRVs along with some workable policy recommendations for their wider dissemination.

Domain area for STRVs

STRVs could be instrumental in sustaining the crop productivity in salt-affected area. The total salt-affected rice-cultivated area is 3.45 mha (Table 2). Uttar Pradesh accounts for the largest share (37.3%), followed by West Bengal (15.4%), Andhra Pradesh (11.2%), and Gujarat (11.1%). These four states together comprise nearly 75% of the total salt-affected rice-cultivated area. Additionally, other states with sizable salt-affected rice-cultivated states are: Haryana (5.8%), Tamil Nadu (5.4%), and Punjab (3.9%).

Table 2. Domain area for salt-tolerant rice varieties

State	Salt-affected rice-cultivated (mha)	Share (%)
Uttar Pradesh	1.29	37.3
West Bengal	0.53	15.4
Andhra Pradesh	0.39	11.2
Gujarat	0.38	11.1
Haryana	0.20	5.8
Tamil Nadu	0.19	5.4
Punjab	0.13	3.9
others	0.34	9.8
Total	3.45	100

Source: ICAR-CSSRI, 2026.

Modelling effect of STRVs on crop yield under sodic and saline soil

A two-way fixed effects (TWFE) panel regression model was employed to capture the effect of STRVs on crop yield under sodic and saline soil conditions using panel data, compiled across multiple locations and years⁷. The economic surplus model provides net benefits to producers and consumers owing to the adoption of a technology. The widespread adoption of STRVs is expected to benefit both rice producers and consumers. Increased adoption of STRVs directly benefits producers through a shift in the supply curve and indirectly benefits consumers through a downward shift in prices. Assuming linear demand and supply curves, the incremental changes in producer surplus (ΔPS) and consumer surplus (ΔCS) were computed under closed economy framework⁸. The values of the parameters used in the economic surplus model are given in Table 3.

⁷ Henningsen, A., Low, G., Wuepper, D., Dalhaus, T., Storm, H., Belay, D., & Hirsch, S. (2026). Estimating causal effects with observational data: guidelines for agricultural and applied economists. *Journal of Agricultural Economics*, 77(2), 356-382.

⁸ Kumar, S., Sanwal, S., Kumar, A., Kushreshtha, N., & Yadav, R. K. (2025). *Economic impact of salt-tolerant wheat varieties* (Policy Brief No. 72). ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.

Table 3. Parameters used in the adoption and economic surplus model

Parameter	Symbol	Value	Source
Production quantity in domain areas (mt, TE 2008)	Q_0	9.28 mt	Authors' estimation based on the domain area and yield
Price (Rs. /t, 2008)	P_0	8500	MSP for year 2008
Increase in yield (%)	$E(Y)$	15.49	Authors' estimation
Increase in variable cost per ha (%)	$E(C)$	1.00	Authors' estimation
Adoption rate (%) in 2025	A_t	19.74	Using method developed by Bisen et al., (2025) ⁹ .
Maximum adoption rate (%)	A_{max}	28.42 (BAU) & 34.15 (OP)	Authors' estimation using logistic function for year up to 2035
Supply elasticity	ε_s	0.24	Kumar et al., 2010 ¹⁰
Demand elasticity	ε_d	-0.25	Kumar et al., 2011 ¹¹
EGR (%)	Exogenous growth rate	2.24	Authors estimation (2008 to 2025)
Seed multiplication ratio		80	https://seednet.gov.in/
Seeds replacement rate (%)		55	https://seednet.gov.in/

Note: BAU and OP stand for business-as-usual and optimistic scenarios, respectively.

Adoption of STRVs

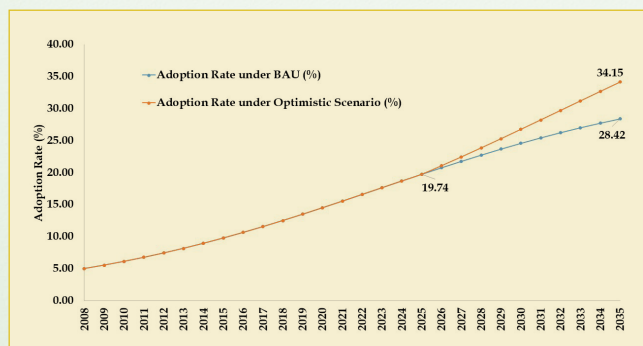
The adoption of salt-tolerant rice varieties (STRVs) is projected, using logistic function, under both the Business-as-Usual (BAU) and Optimistic scenarios (OP) as shown in Figure 1. Consulting with experts working at Institute and given the fact that some STRVs were developed and released before 2008, a conservative initial adoption rate (in 2008) of STRVs was taken as 5% adoption. Thus, estimated present (in 2025) adoption rate is 19.74% that is expected to reaching 28.42% under the BAU scenario and 34.15% under OP by 2035. The higher adoption rate, in future, can be attributed to the expansion of rice cultivation in salt-affected areas, which increased from 2.34 mha in 2015 to 3.45 mha at present (2026), coupled with growing demand of STRVs (particularly CSR 101 and CSR 105). This is worth mentioning that to meet the growing demand of STRVs, for the first time at ICAR-CSSRI, the seed multiplication licenses were granted to seven private firms in 2025 and nine firms in 2026 to enhance the seed availability.

⁹ Bisen, J.P., Kandpal, A., Jain, R., Mondal, B., Kumar, G.A.K, and Nayak, A.K. (2025). *Economic Evaluation of Climate-Resilient Rice Varieties*. Policy Paper 54, ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi.

¹⁰ Kumar, P., Shinoj, P., Raju, S. S., Kumar, A., Rich, K. M., and S. Msangi. (2010). Factor demand, output supply elasticities and supply projections for major crops of India. *Agricultural Economics Research Review*, 23(1), 1-14.

¹¹ Kumar, P., Kumar, A., Shinoj, P., Raju, S. S. (2011). Estimation of demand elasticity for food commodities in India. *Agricultural Economics Research Review*, 24(1): 1-14.

Figure 1. Present and projected adoption rate of salt-tolerant rice varieties



Performance of the STRVs under salinity and sodicity stress

The two-way random effects model indicated that the adoption of STRVs has a significant positive effect on rice yield in sodic and saline soils (Table 4). The coefficient of STRVs is positive and statistically significant ($\beta = 454.26 \text{ kg ha}^{-1}$), suggesting that cultivation of STRVs resulted in an average yield gain of about 454 kg ha^{-1} compared to non-STRVs, after controlling the effects of soil pH and unobserved location- and year-specific factors. As expected, soil pH has a negative effect on yield ($\beta = -294.63 \text{ kg ha}^{-1}$). Similarly, in saline soils, the estimated coefficient for STRVs is also positive and statistically significant ($\beta = 408.70 \text{ kg ha}^{-1}$), implying that adoption of STRVs increase the yield by 409 kg ha^{-1} relative to other prevailing varieties (Table 5). Electrical conductivity (EC), an indicator of soil salinity stress, exhibited a significant negative effect on yield ($\beta = -154.50 \text{ kg ha}^{-1}$). This finding suggests that increasing salinity and sodicity levels adversely affect rice productivity, more precisely with a one-unit increase in EC associated with an average yield reduction of about 155 and 295 kg ha^{-1} , respectively. Overall, the results provide empirical evidence that cultivation of STRVs helps improving rice productivity in salt-affected soils as compared to other prevailing improved/normal varieties.

Table 4. Effect of STRVs on yield in sodic soils

Variable	Estimate	Std. Error	z-value	Pr(> z)
Intercept	5276.20	1584.91	3.33	0.001
STRVs	454.26	156.18	2.91	0.004
pH	-294.63	162.30	-1.82	0.069
Random effects				
Location	Yes			
Year	Yes			

Notes: - Breusch–Pagan Lagrange Multiplier (LM) test: $\chi^2 = 228.98$, $df = 1$, $p\text{-value} < 0.000$, decision RF is preferred over pooled model. Hausman Test: $\text{chisq} = 0.54408$, $df = 2$, $p\text{-value} = 0.7618$; decision= >0.05 RE preferred over FE model. $N=676$; Wald Chi-square statistic ($\chi^2=14.83$, $df=2$ $p<0.001$).

Table 5. Effect of STRVs on yield in saline soils

Variable	Estimate	Std. Error	z-value	Pr(> z)
Intercept	3779.73	407.95	9.27	0.000
STRVs	408.70	128.81	3.17	0.002
EC	-154.50	51.12	-3.02	0.003
Random effects				
Location	Yes			
Year	Yes			

Notes: - Breusch–Pagan Lagrange Multiplier (LM) test: $\chi^2 = 31.502$, $df = 1$, $p\text{-value} = 0.001$, decision RF is preferred over pooled model. Hausman Test: $\text{chisq} = 0.014874$, $df = 2$, $p\text{-value} = 0.9926$; decision= >0.05 RE preferred over FE model. $N=467$; Wald Chi-square statistic ($\chi^2=56.85$, $df=2$ $p<0.001$).

Economic impact of STRVs

For the assessment period 2008–2025 under the business-as-usual scenario (adoption rate: 19.74%), the adoption of STRVs generated a total economic surplus of ₹13,390 crore, comprising ₹6,563 crore of consumer surplus and ₹6,828 crore of producer surplus. On an annual basis, the corresponding consumer, producer, and total surpluses were estimated at ₹364.6 crore, ₹379.3 crore, and ₹743.9 crore, respectively. The relatively balanced distribution of benefits indicates that both producers and consumers gained substantially from the diffusion of STRVs. Under the optimistic adoption scenario extending to 2035 with an adoption rate of 28.42 percent, the total economic surplus is projected to increase markedly to ₹34,314 crore, of which ₹16,817 crore accrues to consumers and ₹17,497 crore to producers. The annual surplus generated under this scenario is estimated at ₹1,225.5 crore, including ₹600.6 crore for consumers and ₹624.9 crore for producers. With a further increase in adoption to 34.15 percent by 2035, the total economic surplus is expected to rise to ₹36,216 crore, comprising ₹17,738 crore in consumer surplus and ₹18,478 crore in producer surplus. The corresponding annual benefits are estimated at ₹634.0 crore for consumers, ₹660.0 crore for producers, and ₹1,293 crore in total. Overall, the results demonstrate that wider adoption of STRVs in salt-affected areas can generate substantial economic gains for both producers and consumers. Increasing the adoption rate from the current trajectory to the optimistic scenarios could nearly triple the total economic surplus, highlighting the significant potential of STRVs for sustaining rice production in country.

Table 6. Estimated value of economic surplus under varying adoption rates of STRVs

Economic surplus	Value (Rs. Crores)		
	Business as usual		Optimistic Scenario
	2008-2025 (AR:19.74%)	2008-2035 (AR: 28.42%)	2008-2035 (AR: 34.15%)
Consumer surplus	6563 (364.6)	16817 (600.6)	17738 (634)
Producer surplus	6828 (379.3)	17497 (624.9)	18478 (660.0)
Total economic surplus	13390 (743.9)	34314 (1225.5)	36216 (1293)

Note: Figures in parentheses are the annual values of surplus.

Impact of STRVs beyond borders: The success of CSR 36 in Kenya

Salt-affected soils is one of the key constraints to sustain crop productivity across millions of hectares of rice-growing lands in Africa. In Kenya, particularly in the coastal and northeastern regions, large tracts of land remain underutilized due to high soil salinity and sodicity. To address this challenge, the International Rice Research Institute (IRRI), in collaboration with the Kenya Agricultural and Livestock Research Organization (KALRO), introduced CSR 36, a salinity- and sodicity-tolerant rice variety, for cultivation in both irrigated and rainfed ecosystems. CSR 36 has demonstrated remarkable performance under adverse soil conditions. Multi-location on-farm validation trials revealed yields of 5.5–6.0 t/ha in sodic soils with pH levels as high as 9.8 and electrical conductivity ranging from 6–10 dS/m, compared to only 2.4–3.8 t/ha obtained from the widely grown Basmati 370 under similar conditions. Beyond its stress tolerance, CSR 36 possesses desirable market and consumer traits, including soft texture after cooking, non-stickiness, medium maturity, and ratooning ability. The launch of CSR 36 is expected to significantly expand rice cultivation in Kenya, particularly within the Bura and Hola irrigation schemes, which together cover approximately 24,000 acres and are predominantly affected by sodic soil conditions. For rapid scaling of CSR 36, the policymakers should prioritize seed multiplication, extension support, and targeted investments in salt-affected regions to accelerate adoption, enhance rice productivity, improve food security, and promote climate-resilient agriculture¹².

Policy implications

Based on the findings that STRVs increase rice yields by about 409–454 kg ha⁻¹, yet current adoption remains only 19.74% in the salt-affected rice cultivated areas. The low adoption STRVs is due to limited availability of STRVs' seed, low farmer awareness, inadequate extension and demonstration supports. The following section offers the policy implications to overcome these constraints faced by the farmers, and suggestions for strengthening the seed availability, institutional support, awareness creation, and targeted dissemination in salt-affected regions.

Mainstream STRVs in state seed rolling plans: States with substantial salt-affected rice areas should prioritize the inclusion of STRVs in annual seed rolling and seed replacement programmes. State departments of agriculture should set district-wise seed production targets and ensure regular breeder, foundation, and certified seed multiplication of recommended STRVs. Special attention

should be given to Gujarat, Andhra Pradesh, Tamil Nadu, Odisha, Bihar, Karnataka, and Maharashtra, where large salt-affected areas (1.22 mha, 35.2% of rice-cultivated salt-affected areas) remain underserved by existing seed plans. A coordinated institutional framework involving ICAR-CSSRI, State Agricultural Universities (SAUs) and *Krishi Vigyan Kendras* (KVKs) is needed to accelerate varietal dissemination. STRVs must be promoted through various programmes and schemes (e.g., sub-mission on seeds & planting materials) in the targeted salt-affected areas.

Prioritize salt-affected districts for targeted scaling: Given that nearly three-fourths of the salt-affected rice area is concentrated in Uttar Pradesh, West Bengal, Andhra Pradesh, and Gujarat, adoption efforts should initially focus on these high-potential regions. District-level targeting based on salinity maps and soil health databases would improve programme efficiency and maximize returns on public investment.

Improve physical and economic access to quality seeds of STRVs: Seed availability should be increased through decentralized seed production systems including involvement of private seed firms, village-level seed hubs, and last-mile distribution networks in salt-affected regions. Establishing an online seed booking and delivery platform, supported by public agencies and seed companies, can help overcome the scattered demand for STRVs. Strategic public-private partnerships can further improve seed production, storage, and distribution efficiency.

Expand demonstrations and extension outreach in salt-affected hotspots: Low awareness remains a major barrier to adoption. Targeted awareness campaigns should be undertaken through KVKs, Farmer Producer Organizations (FPOs) using the tools of the digital extension (e.g., mobile-based advisories, AI-enabled systems) along with GIS-based targeting in salt-affected areas. Additionally, the large-scale frontline demonstrations and cluster demonstrations should be conducted in villages with high salinity and sodicity affected areas. Demonstration plots comparing STRVs with existing farmer varieties can visibly showcase yield advantages and risk reduction benefits. Successful farmer fields should be developed as learning sites for neighbouring farmers to encourage peer-to-peer diffusion.

Overall, the mainstreaming STRVs through strengthened seed systems, targeted scaling, and effective extension is critical to accelerate their adoption in salt-affected regions. These measures can accelerate STRV adoption beyond the projected business-as-usual pathway, enhance productivity in salt-affected ecosystems, reduce production losses, and contribute to long-term food and livelihood security in vulnerable rice-growing regions.

August 2026

¹² IRRI. (2023). Salinity-tolerant rice variety set to boost rice yield in stress-prone areas in Kenya.
<https://www.irri.org/news-and-events/news/salinity-tolerant-rice-variety-set-boost-rice-yield-stress-prone-areas-kenya>