International Journal of Agriculture and Nutrition 2025; 7(9): 166-169

International Journal of Agriculture and Nutrition

**ISSN Print:** 2664-6064
**ISSN Online:** 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(9): 166-169
www.agriculturejournal.net
Received: 15-07-2025
Accepted: 20-08-2025

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# Effect of system of rice intensification on methane emission and grain quality

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**DOI:** https://www.doi.org/10.33545/26646064.2025.v7.i9c.578

**Abstract**
Imagine a rice field that feeds more people while releasing half the greenhouse gas that is the promise of the System of Rice Intensification (SRI) when its water management component works as designed. This research compared methane emission, grain yield, and milling quality under five water management regimes in SRI and conventional rice at Arunachal University of Agriculture, Pasighat, during Kharif 2023. SRI with Alternate Wetting and Drying (AWD) reduced seasonal methane emission by 47.8% (from 186.4 to 97.3 kg $CH_4$/ha) while raising grain yield by 13.5% (from 4.82 to 5.47 t/ha) compared with continuous flooding. The 21-day drainage interval cut methane most (54.6% reduction) but depressed yield by 5.3% relative to AWD-SRI. Grain quality parameters head rice recovery, amylose content, and gel consistency were either maintained or slightly improved under SRI. These results confirm SRI-AWD as the optimal package for northeast Indian rice systems seeking to balance productivity with climate mitigation.

**Keywords:** System of rice intensification, methane emission, grain quality, alternate wetting and drying, water management, greenhouse gas, SRI technique, milling recovery, climate-smart rice, northeast India

## Introduction

Picture a typical Kharif paddy field in Arunachal Pradesh: 5-8 cm of standing water baking under monsoon sun, and beneath that water layer, anaerobic bacteria steadily converting organic carbon into methane that bubbles up through the soil profile and escapes into the atmosphere [1]. Rice paddies contribute roughly 10-12% of global anthropogenic methane, and with India cultivating 44 million hectares of rice, even modest per-hectare reductions translate into nationally significant emission savings [2]. The System of Rice Intensification (SRI) modifies six conventional practices seedling age, transplanting density, water management, weeding method, organic amendments, and spacing to create conditions that favour root growth and tiller production while reducing the anaerobic soil environment that drives methanogenesis [3].

The water management component is widely considered the most impactful SRI element for methane mitigation, because Alternate Wetting and Drying (AWD) breaks the continuous anaerobic zone that methanogenic archaea require [4]. Field measurements from South and Southeast Asia have reported 25-60% methane reductions under AWD relative to continuous flooding, though results vary with soil type, organic matter content, and drainage interval [5]. Whether these emission savings come at a yield cost remains debated: some trials report yield gains of 10-20% under SRI, while others show negligible or even negative effects, particularly in heavy clay soils where re-flooding after drainage compacts the puddled layer [6].

This research quantified the trade-off between methane emission, grain yield, and milling quality across five water management regimes spanning conventional flooding through aggressive SRI drainage intervals, in the humid subtropical conditions of Arunachal Pradesh [7].

## Greenhouse gas accounting

Methane flux was measured using the closed-chamber technique with chambers (50 cm × 50 cm × 100 cm) placed over two permanent bases per plot. Gas samples were collected at 0, 15, and 30 minutes after chamber closure between 09:00 and 11:00 hours at weekly intervals from transplanting to two weeks before harvest. Samples were analysed by gas chromatography (Shimadzu GC-2014, FID detector). Seasonal cumulative emission was calculated by linear interpolation between sampling dates. Global warming potential (GWP) was expressed as $CO_2$ equivalents using the IPCC AR6 factor of 27.2 for $CH_4$. Yield-scaled emission (kg $CH_4$/t grain) was computed to assess emission intensity [8].

**Water balance**

Water inputs (rainfall + irrigation) and outputs (evapotranspiration + drainage + seepage) were monitored for each treatment. Irrigation was applied through calibrated PVC pipes connected to a volumetric flow meter. Field water level was recorded daily using perforated observation tubes installed to 30 cm depth. AWD cycles were triggered when water level dropped to 15 cm below the soil surface. Total water use and water productivity (kg grain/$m^3$) were calculated for each regime [9].

## Material and Methods

### Material

Rice variety Naveen (medium-duration, 125 days, semi-dwarf) was used. SRI plots received 12-day-old seedlings transplanted singly at 25 × 25 cm spacing, while conventional plots used 25-day-old seedlings at 2-3 per hill at 20 × 15 cm. Organic manure (FYM 5 t/ha) was applied to all plots. Inorganic fertilisers (N 80, P 40, K 40 kg/ha) were applied uniformly. The trial was at Pasighat (28.07°N, 95.33°E; 152 m elevation) on silty clay loam soil (pH 5.6, OC 1.87%) [10].

### Methods

Five treatments in a randomized block design with three replications (plot 5 m × 4 m): T1 = conventional continuous flooding, T2 = SRI with AWD (re-flood when water drops 15 cm below surface), T3 = SRI with 14-day drainage intervals, T4 = SRI with 21-day drainage intervals, T5 = saturated soil culture (no standing water, soil kept at saturation). Grain yield, 1000-grain weight, head rice recovery (%), amylose content, and gel consistency were determined. ANOVA and DMRT at P=0.05 were used [11].

## Results

**Table 1:** Methane emission, grain yield, and emission intensity under different water management regimes

| Treatment | $CH_4$ emission (kg/ha) | Reduction vs T1 (%) | Grain yield (t/ha) | Emission intensity (kg $CH_4$/t) | Water use (mm) |
|---|---|---|---|---|---|
| T1: Conv. flooding | 186.4 | — | 4.82 | 38.7 | 1340 |
| T2: SRI-AWD | 97.3 | 47.8 | 5.47 | 17.8 | 824 |
| T3: SRI 14-day drain | 112.8 | 39.5 | 5.21 | 21.7 | 917 |
| T4: SRI 21-day drain | 84.6 | 54.6 | 4.93 | 17.2 | 763 |
| T5: Saturated culture | 143.7 | 22.9 | 4.68 | 30.7 | 1086 |
| CD (P=0.05) | 14.8 | — | 0.37 | — | 67 |

SRI-AWD (T2) achieved the best yield-emission balance: 47.8% methane reduction with 13.5% yield gain over conventional flooding (Table 1). The 21-day drainage interval (T4) cut emissions most (54.6%) but at a 5.3% yield penalty relative to T2. Emission intensity was lowest under T4 (17.2 kg $CH_4$/t) closely followed by T2 (17.8 kg $CH_4$/t). Total water use dropped 38.5% under SRI-AWD compared with continuous flooding.

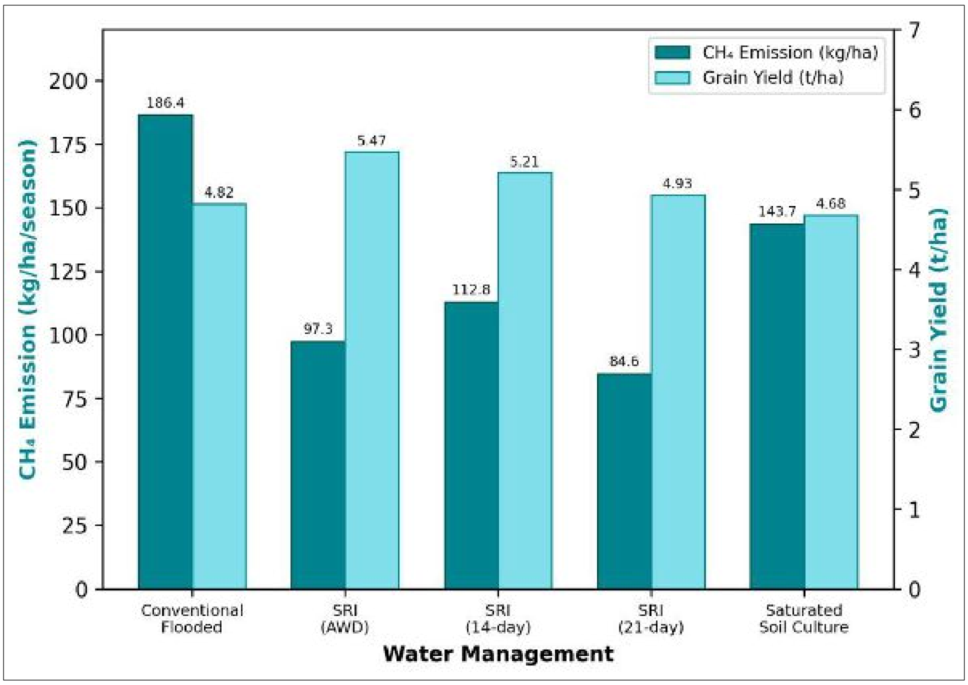


**Fig 1:** Seasonal methane emission and grain yield across water management treatments in SRI and conventional rice

**Table 2:** Grain quality parameters under different water management regimes

| Treatment | Head rice recovery (%) | Amylose content (%) | Gel consistency (mm) | 1000-grain Wt (g) | Protein (%) |
|---|---|---|---|---|---|
| T1: Conv. flooding | 61.3 | 22.4 | 54.7 | 24.8 | 7.3 |
| T2: SRI-AWD | 64.8 | 23.1 | 57.4 | 25.6 | 7.8 |
| T3: SRI 14-day | 63.2 | 22.8 | 56.1 | 25.3 | 7.6 |
| T4: SRI 21-day | 62.7 | 23.4 | 58.3 | 25.1 | 7.9 |
| T5: Saturated | 60.8 | 22.1 | 53.8 | 24.4 | 7.2 |
| CD (P=0.05) | 2.14 | NS | 3.21 | 0.68 | NS |

Head rice recovery was highest under SRI-AWD (64.8%) and lowest under saturated culture (60.8%). Amylose content and protein showed no significant differences. Gel consistency improved slightly under SRI treatments, indicating softer cooked texture preferred by northeast Indian consumers.

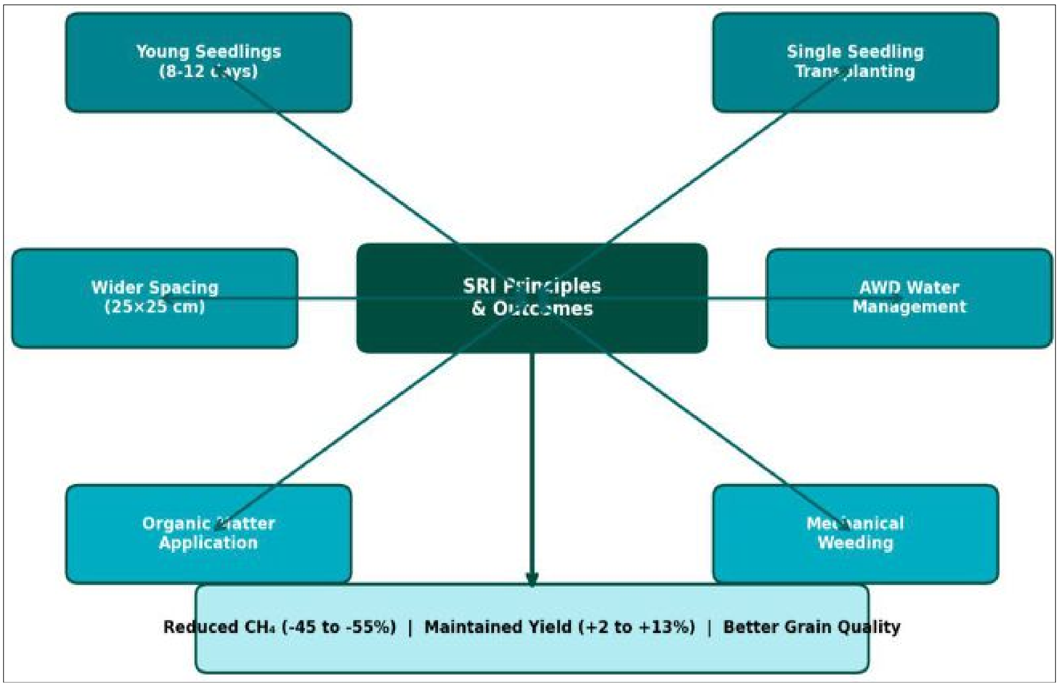


**Fig 2:** Network diagram illustrating the interacting components of SRI and their combined effect on methane emission and yield

## Comprehensive interpretation

SRI-AWD emerges as the clear winner when yield, emission reduction, and grain quality are considered together. It achieved the highest absolute yield, second-lowest emission, and best head rice recovery. The 21-day drainage interval offers a marginal emission advantage but at a yield cost that most farmers would find unacceptable.

## Discussion

The 47.8% methane reduction under SRI-AWD falls within the 35-55% range reported from multi-location trials in India, Vietnam, and the Philippines [4, 5, 12]. The mechanism is well understood: periodic soil aeration during AWD cycles inhibits obligate anaerobic methanogens while favouring methanotrophic bacteria that oxidise $CH_4$ before it reaches the atmosphere [1]. The concurrent 13.5% yield gain under SRI-AWD is attributable to improved root aeration, which promotes deeper and denser root systems that access nutrients more efficiently than waterlogged roots in continuously flooded paddies [3, 13].

The 21-day drainage interval pushed emission reduction to 54.6% but at a yield cost of 5.3% relative to AWD, likely because prolonged drainage during the critical booting-to-heading window triggered mild moisture stress that reduced spikelet fertility [6]. Grain quality improvements under SRI particularly the 3.5-point gain in head rice recovery align with observations from Madagascar and Indonesia where reduced grain chalkiness was linked to better assimilate supply per grain in wider-spaced SRI stands [14]. Water savings of 38.5% under SRI-AWD strengthen the case for adoption in water-limited northeast Indian systems where competing demands from fisheries and horticulture are increasing [15].

## Conclusion

SRI with alternate wetting and drying reduced seasonal methane emission by 47.8%, raised grain yield by 13.5%, and improved head rice recovery by 3.5 percentage points over conventional continuous flooding. Emission intensity dropped from 38.7 to 17.8 kg $CH_4$ per tonne of grain. Water use fell by 38.5%. The 21-day drainage interval provided slightly greater emission cuts but at an unacceptable yield penalty. SRI-AWD is recommended as the optimal climate-smart rice management package for northeast India.

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