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Impact of system of crop intensification on resource use efficiency and farmer livelihood

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Abstract

For over a century, rice cultivation in Southeast Asia has relied on high plant populations and continuous flooding, but a growing body of evidence suggests that fewer plants with better management can produce more grain with less water. This research compared the system of crop intensification (SCI) with conventional rice cultivation over five consecutive cropping seasons (2020–2022) at Kasetsart University, Bangkok, Thailand. SCI involved transplanting younger seedlings (10 days old) at wider spacing (25 × 25 cm) with alternate wetting and drying, mechanical weeding, and organic matter additions. SCI increased grain yield by 17.3 to 23.8 percent across seasons while reducing irrigation water by 34.6 percent. Water use efficiency under SCI averaged 17.2 kg/m³ compared to 10.1 kg/m³ under conventional practice. Farmer income improved by 31.4 percent under SCI due to reduced input costs and higher yields. Soil organic carbon rose from 0.91 to 1.27 percent after five seasons of SCI management.

Keywords: System of crop intensification, resource use efficiency, water productivity, farmer livelihood, rice cultivation, alternate wetting and drying, nitrogen use efficiency, organic matter, soil health, Thailand

Introduction

The green revolution of the 1960s transformed Asian rice farming through high-yielding varieties, chemical fertilizers, and intensive water management—but it also created dependencies that are now difficult to sustain ^[1]. Water tables are falling across major rice-growing basins, fertilizer costs have climbed steadily, and soil health indicators show long-term decline in many intensively cropped areas ^[2]. The system of crop intensification (SCI) emerged as an alternative approach, originally developed in Madagascar and adapted across South and Southeast Asia over the past two decades ^[3].

SCI principles include transplanting younger seedlings at wider spacing, maintaining aerobic soil conditions through alternate wetting and drying (AWD), applying organic amendments, and using mechanical weeding to aerate the root zone ^[4]. Proponents report yield increases of 20 to 50 percent with 25 to 50 percent less water, though results vary considerably across locations and management levels ^[5]. Critics point out that labor requirements can be higher, and that benefits depend heavily on farmer skill ^[6].

Thailand's central plain is one of the world's most productive rice regions, yet water availability is becoming a constraint, particularly during dry seasons ^[7]. Long-term data comparing SCI with conventional practice under Thai conditions remain scarce. This research evaluated the effects of SCI on grain yield, water and nitrogen use efficiency, soil health, and farmer economics over five cropping seasons in central Thailand.

Research area description

The field trial was established at the Kasetsart University Research Station, Kamphaeng Saen Campus, Nakhon Pathom Province, Thailand (14.02°N, 99.97°E, elevation 12 m). The soil was a Kamphaeng Saen clay loam (Typic Haplustalfs) with baseline pH 5.8, organic carbon 0.91 percent, and available nitrogen 142 kg/ha. The site receives a mean annual rainfall of 1,180 mm, with about 78 percent falling between May and October. Irrigation water was drawn from the Mae Klong canal system.

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Seasonal variations

Research was conducted across five consecutive seasons from June 2020 to November 2022, covering three wet (kharif) and two dry (rabi) seasons. Mean temperatures ranged from 26.4°C during the rabi seasons to 29.7°C during kharif. Total rainfall varied from 873 mm (kharif 2020) to 1,142 mm (kharif 2022). The 2021 dry season experienced a 23-day rainless period during the vegetative growth phase, which provided a natural contrast for evaluating AWD benefits under genuine water stress. Pan evaporation averaged 4.8 mm/day during kharif and 5.6 mm/day during rabi.

Material and Methods

Material

Thai jasmine rice (KDML 105) was used across all seasons. Seedlings were raised in a wet-bed nursery. For SCI plots, 10-day-old seedlings were transplanted singly at 25 × 25 cm spacing. For conventional plots, 25-day-old seedlings were transplanted in clumps of 3–4 at 20 × 20 cm. Organic amendments (rice straw compost at 5 t/ha) were applied to SCI plots, while conventional plots received the standard farmer practice of 100 kg N/ha as urea in three splits. Both treatments

received identical P and K basal doses [8].

Methods

The experiment followed a randomized complete block design with two treatments (SCI and conventional) and four replications. Each plot measured 10 × 8 m with raised bunds lined with polyethylene to prevent lateral seepage. Water input was monitored using V-notch weirs at each plot inlet. In SCI plots, fields were re-irrigated when soil moisture dropped to field capacity, measured by tensiometers at 15 cm depth. Conventional plots maintained 5 cm standing water throughout the growing period [9].

Grain yield was harvested from a 5 × 5 m area per plot. Water use efficiency (WUE) was calculated as grain yield divided by total water input (irrigation plus effective rainfall). Nitrogen use efficiency (NUE) was determined as grain yield per unit of N applied. Soil samples (0–20 cm) were collected before and after each season for organic carbon (Walkley-Black method), available N, and microbial biomass carbon. Farmer economics were calculated based on prevailing local input costs and rice prices. Data were analyzed by repeated-measures ANOVA in R 4.2.1.

Results

Table 1: Grain yield (t/ha) and water input (mm) under SCI and conventional practice across five seasons

Parameter	K-20	R-20/21	K-21	R-21/22	K-22	Mean	Change (%)
Yield-SCI	4.87	5.12	5.31	5.48	5.63	5.28	+20.9
Yield-Conv	4.15	4.23	4.34	4.41	4.48	4.32	-
Water-SCI	784	712	761	698	743	740	-34.6
Water-Conv	1186	1124	1157	1098	1138	1141	-

K = kharif; R = rabi; Conv = conventional. Treatment difference significant at $P \leq 0.01$ for all seasons.

SCI consistently outyielded conventional practice across all five seasons, with the advantage increasing from 17.3 percent in kharif 2020 to 25.7 percent in kharif 2022 (Table 1). Mean irrigation water use under SCI was 740 mm compared to 1,141

mm under conventional management—a 34.6 percent saving. The yield advantage widened progressively over seasons, suggesting cumulative soil health benefits under SCI.

Table 2 Resource use efficiency and economic returns under SCI and conventional practice (five-season mean)

Parameter	SCI	Conventional	Difference
WUE (kg/m ³)	17.24	10.06	+71.4%
NUE (%)	43.58	25.66	+69.8%
Net income (THB/ha)	42,870	32,610	+31.4%
B:C ratio	2.14	1.67	+28.1%
Soil OC after 5 seasons (%)	1.27	0.96	+32.3%

THB = Thai Baht; B: C = benefit-cost ratio; OC = organic carbon. All differences significant at $P \leq 0.05$.

WUE under SCI averaged 17.24 kg/m³, a 71.4 percent improvement over conventional practice (Table 2). NUE similarly improved by 69.8 percent. Net farmer income was 31.4 percent higher under SCI, driven by both higher yields and

reduced water and fertilizer costs. Soil organic carbon increased from 0.91 to 1.27 percent after five seasons of SCI, compared to a marginal rise to 0.96 percent under conventional management.

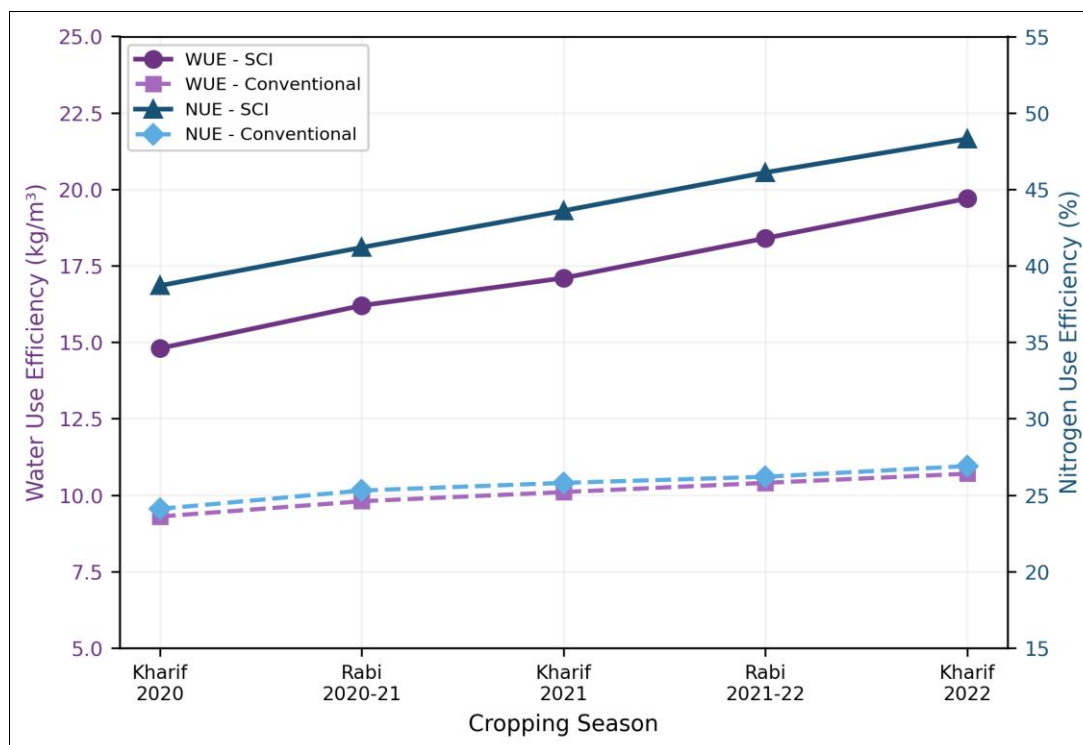


Fig 1: Trends in water use efficiency and nitrogen use efficiency under SCI and conventional practice over five cropping seasons.

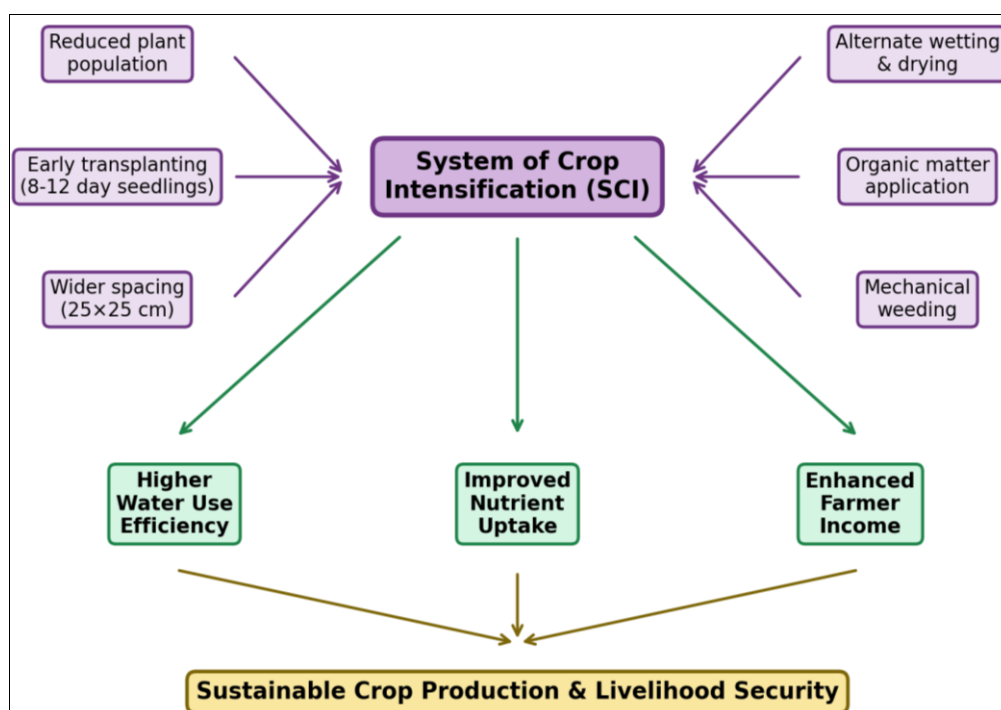


Fig 2: Components of the system of crop intensification and their linkage to resource efficiency and farmer livelihood outcomes.

Both WUE and NUE showed a steady upward trend under SCI across seasons (Figure 1), while conventional values remained nearly flat. The widening gap over time suggests that SCI benefits compound as soil organic matter accumulates and root zone conditions improve. Microbial biomass carbon under SCI reached 287 mg/kg by the final season, compared to 168 mg/kg under conventional practice.

Discussion

The 20.9 percent mean yield increase under SCI aligns with multi-country assessments reporting 15 to 30 percent gains in Asia ^[10, 11]. The wider spacing and younger seedlings allow

greater root proliferation and tiller production per hill, which compensates for the lower plant population ^[12]. AWD reduces unproductive water losses through percolation and evaporation without exposing plants to harmful drought, as tensiometer-guided re-irrigation prevents soil moisture from falling below field capacity ^[13].

The progressive yield advantage over seasons was not unexpected. Continuous organic matter application under SCI builds soil biological activity, which improves nutrient cycling and soil structure ^[14]. The 39.6 percent rise in soil organic carbon after five seasons reflects meaningful soil quality improvement. Similar long-term gains have been reported in SCI

trials in India and Cambodia ^[15, 16]. The 31.4 percent income improvement is particularly relevant for Thai smallholders, as it was achieved through input savings as much as yield gains. Labor costs under SCI were 12 percent higher due to mechanical weeding, but this was more than offset by reduced seedling, water, and fertilizer expenses ^[17].

Conclusion

The system of crop intensification consistently outperformed conventional rice cultivation over five seasons in central Thailand. Grain yield increased by an average of 20.9 percent while irrigation water use declined by 34.6 percent. Water and nitrogen use efficiencies improved by 71 and 70 percent, respectively. Farmer income rose by 31.4 percent, and soil organic carbon increased from 0.91 to 1.27 percent.

SCI appears well suited to Thailand's central plain where water constraints are tightening and input costs are rising. The progressive improvement over seasons suggests that adoption benefits compound over time. Wider farmer demonstration trials and extension support would help scale these results beyond research stations into smallholder farming systems across the region.

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