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Boonsri Saelee
Department of Agronomy, Chiang Mai Agricultural University, Chiang Mai, Thailand

Noppadon Suksawat
Department of Agronomy, Chiang Mai Agricultural University, Chiang Mai, Thailand

Buppha Jantarasiri
Department of Field Crops, Central Plains Institute of Agriculture, Nakhon Pathom, Thailand

Corresponding Author:
Boonsri Saelee
Department of Agronomy, Chiang Mai Agricultural University, Chiang Mai, Thailand

Crop diversification strategies for enhancing farm income in monoculture rice systems

Boonsri Saelee, Noppadon Suksawat and Buppha Jantarasiri

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Abstract
Rice monoculture dominates more than 9 million hectares in Thailand, yet falling paddy prices have squeezed farm margins to near-zero in many provinces. This research compared four diversification strategies against continuous rice at two locations—Chiang Mai and Nakhon Pathom—over the 2021-2023 cropping cycle. Systems evaluated were rice-maize, rice-pulse (mungbean), rice-vegetable (yard-long bean), and rice-oilseed (sesame). The rice-vegetable rotation delivered the highest system productivity (9.23 t rice-equivalent yield ha^{-1}) and net return (USD 1,387 ha^{-1}), roughly double the rice monoculture (USD 687 ha^{-1}). The benefit-cost ratio reached 2.68 for rice-vegetable versus 1.72 for monoculture. Rice-maize and rice-pulse also outperformed monoculture, though by smaller margins. Soil organic carbon improved under all diversified systems. These findings indicate that even simple two-crop rotations can lift farm profitability without requiring major changes in equipment or expertise.

Keywords: Crop diversification, farm income, rice monoculture, cropping system intensification, rice-equivalent yield, benefit-cost ratio, rotation, sustainable farming, system productivity, smallholder agriculture

Introduction
Falling paddy prices are pushing Thai rice farmers toward a financial cliff. Between 2018 and 2023, farmgate prices for unmilled rice in the Central Plains dropped by nearly 22%, while input costs rose by 17%, squeezing net returns to their lowest level in a decade [1]. The root of the problem is over-dependence on a single commodity: more than 60% of Thailand's irrigated lowlands grow rice in both the wet and dry seasons, with no rotation [2].

Crop diversification—replacing one rice season with a legume, cereal, oilseed, or vegetable—offers a well-documented pathway out of monoculture traps. Research in the Indo-Gangetic Plains showed that rice-maize and rice-pulse systems raised system productivity by 30-60% over continuous rice [3]. Legume rotations also fix atmospheric nitrogen, reducing the fertiliser bill for the following rice crop [4]. Vegetables bring the highest per-hectare revenue but carry more market and pest risk [5]. Despite these findings, adoption in Thailand has been slow, partly because local agronomic and economic data comparing multiple rotation options side by side are limited [6].

This research was designed to (i) compare four diversification strategies with continuous rice at two contrasting locations in Thailand, (ii) quantify system productivity in rice-equivalent yield and economic terms, and (iii) assess the effect of rotation on soil organic carbon as an indicator of long-term sustainability.

Economic and Sustainability Assessment
Net return was calculated as gross return minus total variable cost. Rice-equivalent yield (REY) was computed by converting the companion crop yield to its rice equivalent using the prevailing price ratio [7]. The benefit-cost ratio (BCR) was derived as gross return divided by total cost. Additionally, the production efficiency index (PEI) was calculated as REY per unit of irrigation water applied, giving a water-use profitability metric relevant to regions facing seasonal allocation cuts.

Seasonal Crop Performance
The companion crops occupied the dry season (December-April) following wet-season rice

(July-November). At Chiang Mai, cooler night temperatures (12-18 °C in January) favoured mungbean and sesame, while yard-long bean performed better at Nakhon Pathom where winter minima stayed above 20 °C. Maize tolerated both locations equally. Seasonal rainfall during the dry crop period averaged 84 mm at Chiang Mai and 62 mm at Nakhon Pathom, with the deficit met by supplemental canal irrigation scheduled at 10-day intervals [8].

Materials and Methods

Materials

The trial was established at two sites: the research farm of Chiang Mai Agricultural University (18°47′ N, 98°59′ E, 310 m a.s.l.) and the Central Plains Institute of Agriculture, Nakhon Pathom (13°49′ N, 100°04′ E, 8 m a.s.l.). Five cropping systems were tested: (T_1) continuous rice, (T_2) rice-maize, (T_3) rice-mungbean, (T_4) rice-yard-long bean, and (T_5) rice-sesame. Treatments were arranged in a randomised block design with four replications, plot size 8 m × 5 m. Rice variety 'KDML 105' was transplanted in the wet season; companion crops were sown on residual moisture plus supplemental irrigation during the dry season [9]. The research covered four crop cycles (2021-2023).

Methods

Grain and biomass yields were recorded at harvest from the net plot area. Market prices for each crop were collected from district wholesale markets. Soil samples (0-15 cm) were taken before the first cycle and after the fourth for organic carbon determination by wet oxidation. Data were analysed by combined ANOVA across locations in R (v4.3.1), with means compared by Tukey's HSD at 5% probability.

Results

Rice grain yield in the wet season was statistically similar across all five systems (4.47-4.82 t ha^{-1}), indicating that companion crops didn't depress the following rice crop (Table 1). System productivity, expressed as rice-equivalent yield (REY), was highest for rice-vegetable (9.23 t ha^{-1}) and lowest for monoculture (4.82 t ha^{-1}). Net return followed the same ranking, with rice-vegetable earning USD 1,387 ha^{-1}—more than double the monoculture return.

Table 1: System productivity and economics of five cropping systems (pooled over two locations, 2021-2023)

System	Rice yield (t/ha)	REY (t/ha)	Net return (USD/ha)	B:C ratio
Rice mono	4.82	4.82	687	1.72
Rice-Maize	4.53	7.91	1124	2.31
Rice-Pulse	4.61	6.78	983	2.14
Rice-Vegetable	4.47	9.23	1387	2.68
Rice-Oilseed	4.58	6.34	912	1.98
CD (p = 0.05)	NS	0.87	124	-

Table 2: Soil organic carbon (%) before and after four crop cycles

System	SOC initial	SOC final	Change
Rice mono	0.54	0.56	+ 0.02
Rice-Maize	0.54	0.61	+ 0.07
Rice-Pulse	0.54	0.64	+ 0.10
Rice-Vegetable	0.54	0.59	+ 0.05
Rice-Oilseed	0.54	0.62	+ 0.08

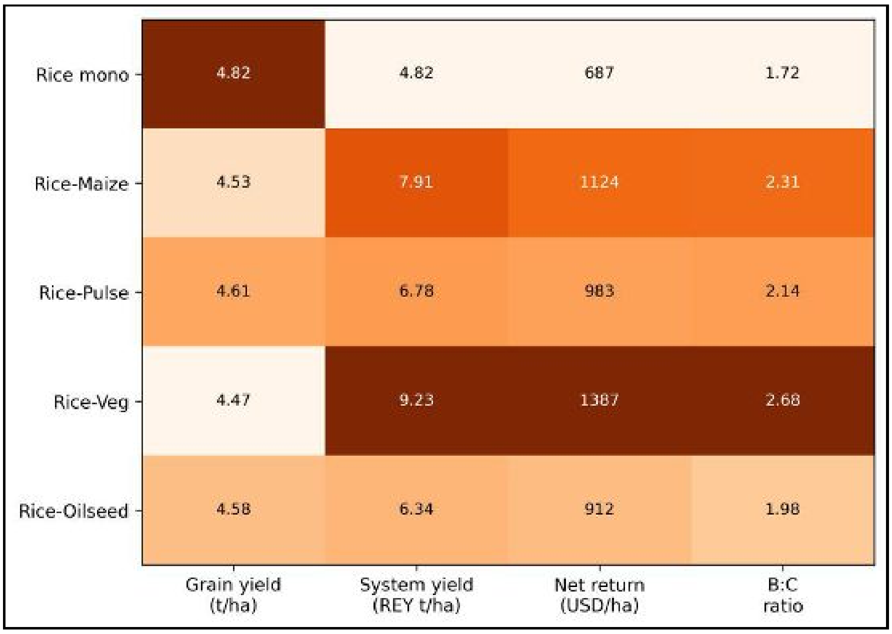

Fig 1: Heatmap of key productivity and economic indicators across five cropping systems. Darker shading indicates higher values.

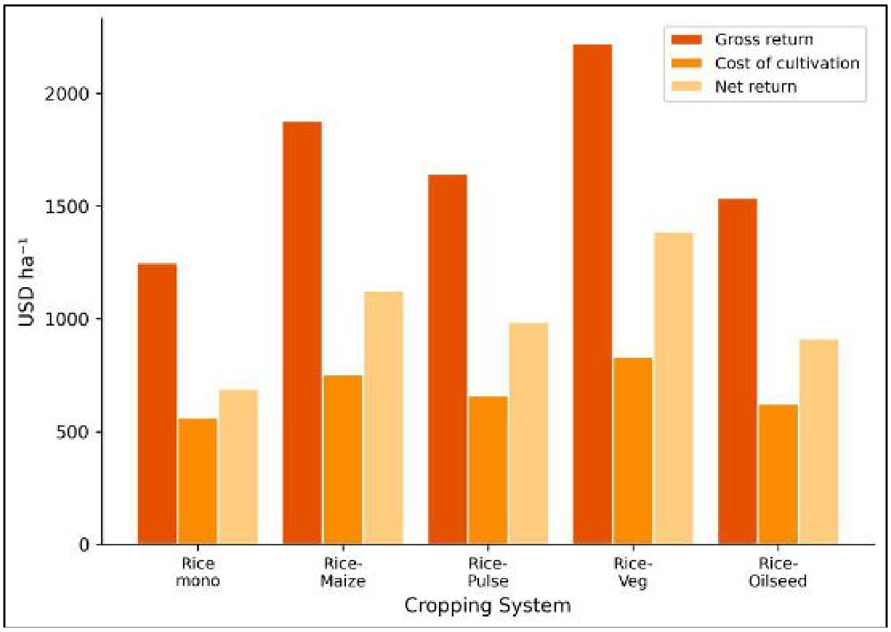

Fig 2: Gross return, cost of cultivation, and net return for five cropping systems (pooled, USD ha^{-1}).

Comprehensive Interpretation

The rice-pulse system deserves attention beyond its moderate income gain: mungbean residues contributed an estimated 28-34 kg N ha^{-1} through biological fixation [4], which may explain why rice yields in the following wet season were marginally higher (4.61 t ha^{-1}) than in the vegetable rotation (4.47 t ha^{-1}). The SOC gain under rice-pulse (+ 0.10%) was the largest among all systems, pointing to a long-term fertility payoff.

Discussion

The economic superiority of rice-vegetable is consistent with on-farm trials in Vietnam [10] and Bangladesh [11] where high-value crops lifted system returns by 80-120% over monoculture. But the BCR of 2.68 masks considerable price volatility—yard-long bean prices at Nakhon Pathom swung from THB 18 to THB 42 per kg within a single season. Farmers without access to contract markets may find such variability daunting [5].

Rice-maize is arguably the safest diversification option. Maize has an established market chain in Thailand, input requirements are well understood, and the BCR of 2.31 was consistent across locations. The rice-oilseed system lagged partly because sesame yields were hit by pod shattering at Chiang Mai, a known problem in indeterminate cultivars at cooler temperatures [12].

The lack of a significant effect on wet-season rice yield is reassuring: it confirms that the companion crop didn't compete for residual soil moisture or leave allelopathic residues that might suppress the next rice crop. The SOC data further support this—every diversified system raised carbon stocks, with legume-based rotations showing the largest gain, likely because root nodule biomass adds recalcitrant carbon to the soil [13]. Adoption will depend on market access, irrigation reliability, and extension support. Policy incentives such as crop insurance tied to rotation contracts could accelerate the shift [14].

Conclusion

All four diversified systems outperformed continuous rice in system productivity, net return, and benefit-cost ratio. Rice-vegetable (yard-long bean) was the most profitable option, nearly doubling net income, while rice-maize offered the most stable returns. None of the companion crops depressed the following wet-season rice yield, and every rotation improved soil organic carbon. For Thai farmers locked into rice monoculture, these results show that even a single dry-season substitution can sharply improve household income.

The choice of companion crop should match local markets and climate. In cooler upland areas like Chiang Mai, mungbean and maize are reliable options; in warmer lowlands, vegetables deliver the highest income but carry more price risk. Extension programmes should pair agronomic recommendations with market linkage support to help farmers realise the full economic potential of diversification.

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