CGIAR
INITIATIVE ON
Transforming Agrifood Systems in South Asia

Enhancing crop and labor productivity, profitability, and production economics through efficient crop diversification in Bangladesh

Comparing diversified cropping patterns in Dinajpur, Bangladesh

Research note 54

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ABOUT THIS NOTE

Rice-based cropping systems have a significant role in attaining self-sufficiency in food production and are considered to be the major contributor to the nation's food basket in Bangladesh. Nowadays concern has been raised over the sustainability of this system due to natural resource degradation (tillage practices, high wages of labor, and overuse of groundwater), reduction in profitability, and declining yield growth rates. Intensive tillage practices demand more resources, damage soil quality, and reduce crop yields and profit margins. Crop diversification, agriculture mechanization, and proper labor productivity may improve resource-use efficiency and increase the productivity and profitability of intensive cropping systems. This research study focuses on accelerating the transformation of our agrifood systems by introducing different diversified cropping options, especially highlighting the production economics, labor productivity, and mechanization for the northern part of Bangladesh. The research trial was established at the Bangladesh Wheat and Maize Research Institute (BWMRI) in Dinajpur, Bangladesh in August 2022.

KEY STUDY FINDINGS

1. The findings presented here are the result of one year, a full cropping cycle, all diversified cropping systems treatment (T3-T9), and clear differences in profitability, labor productivity, and input use efficiency.
2. Maize intercropped with leafy vegetables, sorghum, and Aman rice cropping pattern treatment (T5) is the best-performing cropping pattern in terms of net profit.
3. Labor needs are significantly increased in treatment (T5) Maize intercropped with leafy vegetables, sorghum, and aman rice cropping pattern compared to the most common practice in treatment (T2) Maize-fallow-Aman rice systems.
4. Labor cost is significantly lower in treatment (T6) Mustard-Groundnut-Aman rice cropping system due to following strip tillage practices for mustard and groundnut cultivation in Rabi and Kharif-1 season.

CIMMYT
INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE IFPRI
IRRI International Rice Research Institute
IWMI International Water Management Institute
CIP INTERNATIONAL POTATO CENTER

BACKGROUND

Bangladesh is a highly populated country; it is self-sufficient in rice but not in other crops. It is one of the most vulnerable countries to climate change. Overall, food security remains a significant challenge. The increasing scarcity of resources (water, labor, and energy) and rising production costs further make the rice-based cropping system less sustainable and less profitable (Alam et al., 2014). Crop production faces challenges such as stagnating crop yields, overuse of resources, and environmental degradation. Crop diversification represents a promising pathway towards a sustainable farming system (Wang et al., 2024). Conventional systems for rice and other crop cultivation require more tillage, labor, and water usage. Intensive tillage practices demand more resources, damage soil quality, and reduce crop yields and profit margins. Crop diversification, combined with agricultural mechanization and enhanced labor productivity, may improve resource-use efficiency and increase the productivity and profitability of intensive cropping systems (Hoque et al., 2022). Conservation Agriculture (CA), strip tillage, or reduced tillage practices can facilitate improved crop establishment and timely sowing, maintain or increase yields, reduce water and energy usage, lower production costs, and enhance income. These practices also improve soil quality while enhancing system resilience. Research in South Asia has shown that CA or strip tillage (ST), with residue retention, typically results in higher yields and profits from non-rice crops compared to rice (Gathala et al., 2013).

This agronomic research trial has multiple objectives, including efficient land and labor use to produce higher yields and nutrients for human consumption, improved climate resilience, and increased income for farmers. We emphasize an approach to examine trade-offs and interactions among these objectives within different cropping patterns to identify the best options for cereal-based crops in Bangladesh.

Above: Diversified agronomic research platform trial at Bangladesh Wheat and Maize Research Institute (BWMRI), Dinajpur, Bangladesh; photo: Washiq Faisal

OBJECTIVES

The Regional One CGIAR Initiative, Transforming Agrifood Systems in South Asia (TAFSSA), focuses on farm- and landscape-level research to promote resource conservation and enhance ecological services. The objective of this research study is to ensure food and economic security while maintaining sustainability by intensifying and diversifying the rice–rice system with other high-economic-value crops. Crop diversification is a valuable approach to increasing crop productivity, achieving stability and sustainability in production, and stabilizing farm income. This study provides new empirical evidence on the opportunities offered by diversified cropping patterns to balance the multiple objectives of food production, sustainable labor use, and farmer profitability.

DATA AND METHODS

The experiment used a randomized complete block design (RCBD) with nine treatments and three replications. The treatments included nine alternative cropping systems, varying in the intensification and integration of non-rice crops (cereals, legumes, oilseeds, fiber, fodder, and leafy vegetables) during the winter and spring seasons to evaluate yield and profitability. The setup consisted of three replications, totaling 27 plots. Each plot measured 17 meters in length and 11.5 meters in width, covering a total area of 195.5 m², as shown in Table 1. 70 cm wide permanent bunds separated plots. The bunds, lined with polythene, were designed to prevent water seepage between plots. The research site was located at the Bangladesh Wheat and Maize Research Institute (BWMRI) in Dinajpur, with GPS coordinates: 25.742715, 88.672334. Treatments 4 and 5 included split plots for different leafy vegetables, such as spinach, red amaranth (*lal shak*), coriander, and *napa shak*. A detailed description of the treatments is provided in Table 1. Additional details regarding the experimental setup and data collection can be found in the research protocol (Cheesman et al., 2022).

Popular high-yielding crop varieties were used, and the recommended fertilizer doses were applied for each crop. Soil tests were conducted annually, following the completion of the full cropping cycle.

All inputs required for crop production, along with economically valuable outputs, were recorded during each cropping season. The total variable costs were calculated to determine the total production cost. These variable costs included expenses for labor, tillage, machinery use (for planting), seed, fertilizer, agrochemicals, irrigation, weeding, harvesting, and threshing. Labor costs, based on an 8-hour person-day, were accounted for

Above: Fertilizer application during final land preparation. (Rabi crop- 2023); photo: Washiq Faisal land preparation, seeding /transplanting, irrigation, fertilizer and agrochemical application, intercultural operations (such as weeding and bundling), harvesting, and threshing/cleaning. Labor costs were computed using the wage rates of the research station where the field experiment was conducted.

Results were calculated for each of the three main cropping seasons in Bangladesh—Rabi, Kharif-1, and Kharif-2—over the study period (November 2022 to October 2023). Data were aggregated for each cropping pattern to facilitate comparisons.

STATISTICAL ANALYSIS

Statistical analyses were performed using R version 4.4.1 (R Core Team, 2024). The data were analyzed using a Randomized Complete Block Design (RCBD) with nine treatments and three replications to evaluate the effects of various treatments. All output data were compared using Tukey's Honest Significant Difference (HSD) test function from the agricolae R package, with significance set at $P < 0.001$.

Table 1: Diversified agronomic research platform trial at BWMRI, Dinajpur.

Treatment	Diversification options	Kharif-2	Rabi	Kharif-1
T1	Business as usual - 1	Aman rice	Fallow	Boro rice (BF)
T2	Business as usual - 2	Aman rice	Maize	Fallow
T3	Profitability & improved nutrition	Aman rice (BF)	Potato	Sweet corn
T4	Increased production & improved nutrition	Aman rice (BF)	Leafy vegetables	Boro rice (BF)
T5	Increased production & improved nutrition	Aman rice (BF)	Maize + leafy vegetables	Sorghum (fodder)
T6	Diversified production	Aman rice (BF)	Mustard	Groundnut
T7	Diversified production & improved nutrition	Aman rice (BF)	Carrot	Maize (early)
T8	Profitability & soil health	Aman rice (BF)	Wheat	Jute
T9	Diversified production & soil health	Soybean	Mustard	Maize

T5- Strip tillage (sorghum), T6-Strip tillage (Mustard + groundnut), T8- Strip tillage (wheat + Jute), T9- Permanent bed (Soybean + Mustard + Maize)

Table 2: Summarizes the results from the agronomic research platform trial after the one-year complete cropping cycle.

Treatment	REY (t/ha)	Production cost (US$/ha)	Net profit (US$/ha)	Labor cost (US$/ha)	Irrigation cost (US$/ha)	Water use efficiency (kg/m3)
T1	14.88 cde	2849.84 c	1436.40 d	1782.54 c	508.13 a	1.28 e
T2	13.44 e	2141.72 f	1710.46 d	1057.15 h	253.64 bc	1.98 de
T3	20.41 b	2789.03 d	3224.72 ab	1510.15 d	259.53 bc	3.06 bc
T4	26.18 a	4792.23 a	2554.90 c	1861.61 b	515.14 a	2.25 cde
T5	25.67 a	3965.31 b	3628.23 a	2036.36 a	273.54 b	3.52 b
T6	14.85 cde	1866.73 h	2455.82 c	1016.51 I	225.56 c	2.34 cd
T7	17.09 c	2217.40 e	2793.55 bc	1166.90 f	228.42 c	2.70 bcd
T8	14.78 de	1883.51 h	2416.36 c	1144.57 g	236.83 bc	2.23 cde
T9	16.27 cd	2065.18 g	2628.19 bc	1189.81 e	54.31 d	12.68 a
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

RESULTS

This study observed the highest net profit (3628.23 USD/ha) in Treatment (T5) Maize + Vegetables – Sorghum – Aman Rice due to the higher production and market prices of vegetables and maize. Treatment (T3) Potato – Sweetcorn – Aman Rice showed the second-highest net profit (3224.72 USD/ha) because of the high market price of sweetcorn (Figure 1). The lowest net profit was recorded for the traditional Treatment (T1) Rice – Rice System, which was 2.5 times lower than the net profit from Treatment (T5) Maize + Vegetables – Sorghum – Aman Rice.

The inclusion of leafy vegetables instead of fallow land increased profitability but required some additional labor in Treatment (T4) Vegetables – Boro Rice – Aman Rice. Treatments (T6) and (T9) showed the lowest production costs due to the use of strip tillage sowing, which significantly increased overall profitability (Table 2). However, leafy vegetables required extra labor, which raised the production costs for Treatments (T4) Vegetables – Boro Rice – Aman Rice and (T5) Maize + Vegetables – Sorghum – Aman Rice.

Treatment (T3) Aman Rice – Potato – Sweetcorn was found to be more profitable than the "business-as-usual" cropping patterns (Treatments T1 and T2) without requiring additional labor (Table 2). However, feedback from farmers highlighted the need to address local marketing challenges to realize the profitability of such diversified cropping systems fully.

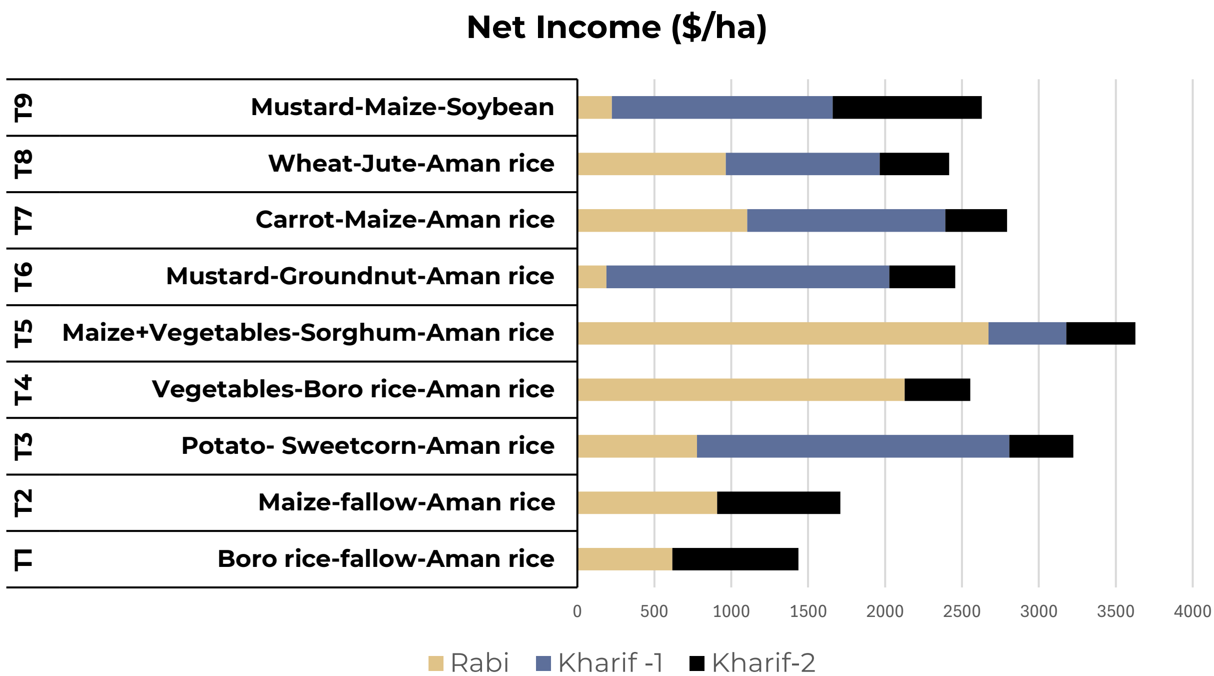
However, the development of the local market system for these crops has been highlighted by farmers. Net profit was calculated using fixed local market prices, the prices of vegetables and other crops are highly variable even within cropping seasons; this needs to be calculated for more accurate profitability assessments.

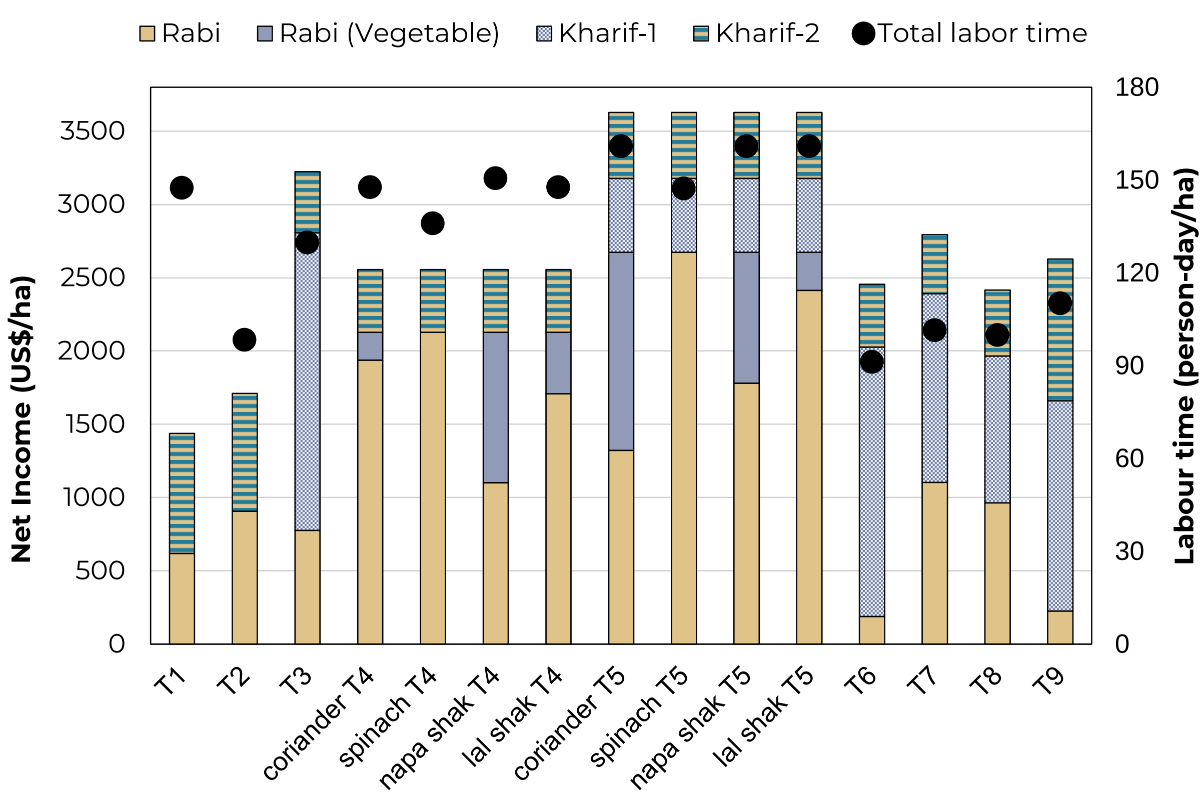
The main differences in labor use between different cropping systems or tillage options are accounted for by differences in labor required for different crops under different tillage options in different seasons. The different tillage systems had a significant impact on labor use for the different cropping systems (Figure 1).

Across the three cropping seasons in one year, the lowest number of person-days (91 person-day/ha) required for the treatment (T6) Mustard-groundnut-aman rice due to strip tillage sowing for mustard and groundnut in Rabi and Kharif-1 season. Among the other treatments, the highest labor use (161 person-day/ha) was required for Treatment (T5) Maize + vegetables – sorghum - aman rice for growing leafy vegetables with maize (Figure 1). In Treatment T2, sole maize cultivation required less labor and production cost due to less irrigation water application compared to boro rice in Treatment (T1).

Above: Strip tillage maize sowing. (Kharif-1 crop- 2023); photo: Washiq Faisal

Figure 1: Results from the diversified cropping pattern for net Income and total labor uses.





CONCLUSIONS AND RECOMMENDATIONS

This research study demonstrated that diversified cropping systems could significantly increase total productivity and net income compared to traditional rice–rice or rice–maize cropping systems in Bangladesh. The intensive use of labor and energy under conventional agronomic practices results in high production costs and greater labor requirements. Combined with low crop yields due to inefficient agronomic management, this leads to reduced gross margins. Crop diversification, along with a better understanding of the effects of tillage practices on crop productivity and profitability, can help identify the region's most productive and profitable systems.

Increasing productivity, profitability, and the long-term sustainability of cereal-based cropping systems remains a challenge, particularly for ensuring food and nutritional security among low- to middle-income rural populations. This challenge is primarily due to a lack of knowledge about modern tillage practices and appropriate machinery. However, significant financial benefits can be achieved when the right cropping systems are implemented with appropriate management practices and tillage techniques.

Our findings indicated that Treatment (T5) *Maize + Vegetables – Sorghum – Aman Rice* resulted in the highest economic and production efficiency, as well as net returns. Incorporating a leafy vegetable as an intercrop with maize or as a sole crop between two rice crops represents a relatively low-cost investment in terms of additional production expenses. For example, adding the leafy vegetable *napa shak* between two rice crops (T4) increased net profit from approximately 1437 USD/ha (T1) to 2468 USD/ha. Similarly, intercropping *napa shak* with maize and adding a fodder crop instead of leaving the land fallow during the Kharif-1 season (T5) increased net profit from approximately 1710 USD/ha (T2) to 2442 USD/ha (Table 2).

However, net income decreases if an unsuitable leafy vegetable is chosen, as competition may negatively affect maize performance. Without proper establishment of the leafy vegetable crop, potential losses cannot be compensated. Labor requirements showed minimal differences between T1 and T4, indicating that leafy vegetables grown as sole crops are not highly labor-intensive. Overall, vegetable-based systems demonstrated superiority in nearly all aspects compared to traditional rice–rice or rice–maize systems. Therefore, it is recommended that farmers transition from cereal-based systems to diversified cropping patterns, incorporating high-value alternative crops into conventional systems. Such practices provide additional revenue sources, enhance farm resilience, promote a diverse ecosystem, and support the long-term viability of farms through sustainable production and improved resource-use efficiency.

Nevertheless, these conclusions remain preliminary, as further data from multiple cropping years are needed. Additionally, a comprehensive analysis of the environmental footprint of each cropping system is crucial for recommending optimal practices in sustainable agriculture.

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Above: Groundnut crop at the research platform, BWMRI, Dinajpur. (Rabi crop-2023); photo: Washiq Faisal

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ABOUT TAFSSA

TAFSSA (*Transforming Agrifood Systems in South Asia)* is a CGIAR Regional Integrated Initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

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