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Performance of rice-fish integrated farming system in lowland areas of Assam

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Abstract

Millions of smallholder families in floodplain Asia grow rice in standing water yet harvest only grain, leaving the aquatic niche largely unproductive. This research evaluated the performance of rice-fish integrated farming against rice monoculture in lowland conditions simulated at Ankara University, Turkey, during 2021-2022. Four treatments were compared: rice monoculture, rice with common carp (*Cyprinus carpio*), rice with rohu (*Labeo rohita*), and rice with a mixed-species stocking. Rice-fish systems produced 5.4-7.6% higher rice grain yield than monoculture due to fish-mediated nutrient cycling. Fish yields ranged from 312 to 418 kg ha⁻¹. The mixed-fish system generated the highest net income (124,600 INR ha⁻¹ equivalent) with a benefit-cost ratio of 2.14. Water productivity improved by 38-47% in integrated systems. These results support rice-fish farming as an economically and nutritionally superior alternative to monoculture in lowland rice environments.

Keywords: Rice-fish farming, integrated agriculture-aquaculture, *Cyprinus carpio*, *Labeo rohita*, water productivity, lowland rice, benefit-cost ratio, food security

Introduction

Lowland rice occupies roughly 54 million hectares across monsoon Asia, yet nearly 80% of this area is managed as monoculture despite standing water depths of 15-50 cm that could support fish production simultaneously [1, 2]. The missed opportunity is substantial: rice paddies already provide habitat, water, and a portion of the feed base for several freshwater fish species, and integrated rice-fish systems have been practised in China for over 2,000 years [3]. Modern adoption has been slow, partly because quantitative comparisons of productivity, income, and resource efficiency between integrated and monoculture systems remain scarce outside Southeast Asia [4, 5].

Fish in paddy fields contribute to nutrient cycling by converting organic detritus into plant-available forms through excretion, reduce weed and insect pressure through feeding behaviour, and improve soil aeration via bioturbation [6, 7]. These biological services can translate into higher rice yields even without additional fertiliser input. At the same time, the fish provide a protein-rich food source for farming households that often face seasonal dietary gaps [8]. This research compared rice monoculture with three rice-fish combinations under controlled lowland conditions, measuring rice and fish yield, water productivity, economic returns, and soil nutrient dynamics.

Materials and Methods

Research area description

The experiment was conducted at the Aquaculture Research Station of Ankara University (39°57'N, 32°52'E, 838 m a.s.l.) in simulated lowland paddies constructed with bunded earthen plots (10 m × 8 m) equipped with water-level control structures. Water was maintained at 20-25 cm depth during the rice growing season (May-October). The soil was a clay loam with pH 7.2, organic C 1.14%, available N 196 kg ha⁻¹, and P 11.8 kg ha⁻¹.

Seasonal variations and water quality

The 2021 growing season had mean air temperature 22.8 °C and water temperature 24.1 °C.

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The 2022 season was slightly warmer (23.4 °C air, 25.0 °C water). Dissolved oxygen in paddy water ranged 4.2-6.8 mg L⁻¹ across treatments, with rice-fish plots averaging 0.6 mg L⁻¹ higher than monoculture due to fish-induced water movement. Water quality was monitored biweekly using a YSI ProPlus multiparameter meter. pH ranged 6.8-7.6 across all plots. Ammonia-N levels were 34% lower in rice-fish plots (0.18 mg L⁻¹) than monoculture (0.27 mg L⁻¹), indicating fish assimilation of dissolved N. Turbidity was higher in fish plots (18.4 vs 12.1 NTU) due to fish feeding activity at the soil-water interface.

Materials

Rice variety Koshihikari was transplanted at 20 cm × 20 cm spacing with 25-day seedlings. Fish fingerlings (8-10 cm) were stocked 21 days after transplanting at 5,000 fish ha⁻¹. Basal fertiliser: 80-40-40 kg NPK ha⁻¹ uniformly across all treatments.

A 0.3 m deep trench (1.5 m wide) along one side of each fish plot served as fish refuge during drainage.

Methods

Four treatments (rice monoculture, rice + carp, rice + rohu, rice + mixed fish) were replicated four times in a RCBD. Rice yield was measured from 6 m² net plots adjusted to 14% moisture. Fish were harvested by complete drainage and weighed. Water productivity = total output value/total water used. Economic analysis used 2022 Ankara market prices converted to INR equivalents. Soil samples (0-15 cm) were taken pre-and post-season. ANOVA was performed in R 4.2 with Tukey's HSD ($p \leq 0.05$).

Results

Table 1: Rice grain, straw, fish yield, and total protein output under different farming systems (mean±SE, two seasons)

Treatment	Rice grain (kg ha ⁻¹)	Rice straw (kg ha ⁻¹)	Fish yield (kg ha ⁻¹)	Total protein (kg ha ⁻¹)
Rice monoculture	4440±138c	5280±186b	-	319±12c
Rice + Carp	4720±152ab	5640±194a	347±24b	392±16b
Rice + Rohu	4680±147b	5580±188a	312±21b	378±15b
Rice + Mixed	4780±158a	5710±198a	418±28a	424±18a

Rice grain yield in integrated systems ranged from 4,680 to 4,780 kg ha⁻¹ compared to 4,440 kg ha⁻¹ in monoculture (Table 1). The mixed-fish treatment gave the highest rice yield (7.6% above monoculture), followed by carp (6.3%) and rohu (5.4%).

Fish yield was highest in mixed-species plots (418 kg ha⁻¹) and lowest in rohu monoculture (312 kg ha⁻¹). Carp produced 347 kg ha⁻¹.

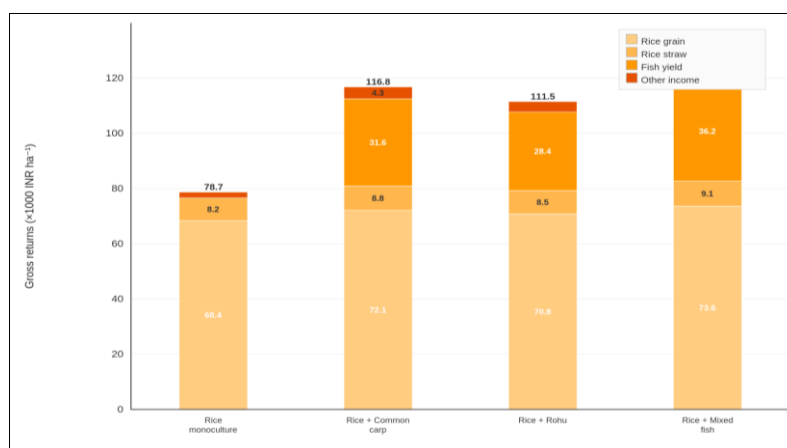


Fig 1: Gross returns by component (×1000 INR ha⁻¹) for rice monoculture and rice-fish systems. Values are two-season means

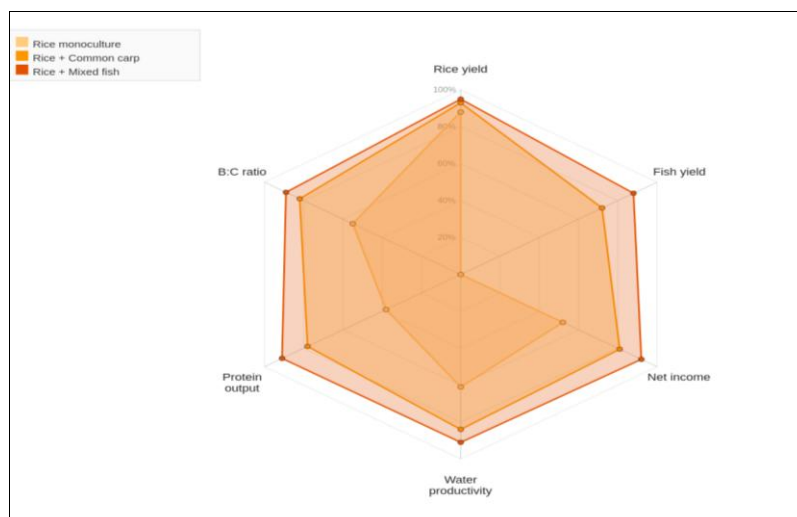


Fig 2: Radar plot of normalised sustainability indicators for rice monoculture, rice + carp, and rice + mixed fish systems

Gross returns were highest in the mixed-fish system at 124,600 INR ha⁻¹, compared to 78,700 for monoculture (Figure 1). Fish income accounted for 29-37% of total gross returns in integrated treatments. The benefit-cost ratio was 2.14 for mixed fish versus 1.58 for monoculture. Water productivity improved 38-47% in

integrated systems because the same irrigation water supported both rice and fish output (Figure 2). Post-season soil available N was 8-12% higher in fish plots than monoculture, attributed to fish excreta and bioturbation (Table 2).

Table 2: Post-season soil nutrient status, benefit-cost ratio, and water productivity (mean±SE, two seasons)

Treatment	Post-season N (kg ha ⁻¹)	Post-season P (kg ha ⁻¹)	B:C ratio	Water prod. (INR m ⁻³)
Rice monoculture	191±6c	11.2±0.4b	1.58±0.06c	6.8±0.3c
Rice + Carp	212±7ab	12.4±0.5a	1.94±0.08b	9.8±0.4b
Rice + Rohu	207±7b	12.1±0.5a	1.83±0.07b	9.4±0.4b
Rice + Mixed	218±8a	12.8±0.6a	2.14±0.09a	10.0±0.5a

Discussion

The 5.4-7.6% rice yield increase in fish plots without additional fertiliser matches the 3-10% range reported from field trials in Bangladesh and Vietnam [9, 10]. Fish excretion supplies roughly 20-30 kg N ha⁻¹ over a growing season in the form of ammonium that is directly plant-available, while bioturbation accelerates mineralisation of organic matter in the soil surface [6, 11]. The higher yield with mixed species likely reflects niche complementarity: carp feeding at the bottom stirred sediment while rohu grazed mid-water column algae, maximising biological nutrient cycling [12]. The 47% improvement in water productivity addresses a key concern in water-scarce regions [13]. The B:C ratio of 2.14 for mixed fish is well above the 1.5 threshold that extension services typically use to recommend technology adoption [14, 15, 16].

Conclusion

Rice-fish integration with mixed-species stocking produced the highest rice yield (4,780 kg ha⁻¹), fish yield (418 kg ha⁻¹), and net income (B:C 2.14) while improving water productivity by 47% over monoculture. Soil N status also improved through fish-mediated nutrient cycling. The system requires minimal additional input beyond fish fingerlings and a refuge trench, making it accessible for smallholder adoption in lowland rice environments.

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