From Monoculture to Multi-Benefit: The Multifunctional Landscape Approach, Kampong Thom province, Cambodia

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Executive Summary

This study assessed the economic performance, productivity, and technical feasibility of an integrated rice-prawn-vegetable farming system in rainfed lowland rice areas of Santuk District, Kampong Thom Province. Using field data from two smallholder farmers, the system was compared against traditional rice monoculture to evaluate its potential to improve income, maintain rice yields, and optimize resource use.

Key Findings:

- Cost Structure: Prawn production dominated costs (83-87%), mainly for seed, labor, and feed. Fixed costs for canals and fencing accounted for 8-11% after depreciation, confirming prawns as the primary investment driver.
- Profitability: Net profits increased dramatically, USD 2,333.41 for Nara and USD 778.91 for Yon, 25-36 times higher than rice-only systems.
- Revenue Contribution: Prawns generated over 94% of total revenue (USD 4,911 for Nara; USD 2,671 for Yon), while rice provided supplementary income and food security.
- Productivity: Rice yields (1.67-3.89 t/ha) were maintained, and bund vegetables added value without extra land. After 45 days, prawn weight reached 22.32 g per head for Nara and 20.44 g for Yon, indicating strong biological performance under the integrated rice-prawn system.
- Projected Performance: Prawns are expected to reach marketable size within 150 days, with harvests of 396 kg (Nara) and 208 kg (Yon), at 8-12 prawns per kg. Estimated margins exceed USD 4.82/kg, demonstrating high income potential from rice-prawns integration.

Despite higher labor and management demands, the integrated system demonstrated strong technical and economic viability. With targeted support and improved practices, it offers significant potential to enhance smallholder incomes, diversify livelihoods, and promote sustainable resource use in Cambodia’s rainfed lowlands.

1. Introduction

1.1 Background

Traditional rice monoculture, in Cambodia, depends heavily on chemicals, applying 140-220 kg/ha of fertilizer for modest yields of 2.7-4.3 t/ha (CDRI, 2021), and incurring a cost of USD 925 to 1,020/ha (MDPI, 2022). Integrated systems offer a sustainable alternative: nutrient recycling and biological interactions improve productivity, while vegetables and trees enhance land-use efficiency and diversify outputs. These systems can raise soil organic matter by 15-40% and cut methane emissions by about 30% (Lu & Li, 2006; Kaewpuangdee et al., 2024; Ma et al., 2024). In Kampong Thom's rainfed lowlands, where water fluctuations and climate risks prevail, integration strengthens resilience without expanding land area.

The Multi-Functional Landscape (MFL) Project aims to validate integrated land-use systems that enhance productivity, income, and ecosystem services. A cornerstone of the rice-prawn-vegetable system is to enable smallholders to produce rice, freshwater prawns (*Macrobrachium rosenbergii*), vegetables, and multipurpose trees within a single farm unit.

This polyculture hinges on sophisticated spatial and temporal integration: rice occupies the main field, prawns grow in perimeter trenches or canals, and vegetables with trees, e.g., moringa, coconut, thrive on raised dikes. Initially, rice and prawns are kept separately to allow for seedling establishment and prawn acclimation. Later, connected habitats allow prawns to forage among rice plants, benefitting from shade and organic matter while recycling nutrients and controlling pests.

1.2 Objectives

The project established farmer-managed demonstration plots to:

1) Evaluate Profitability: Quantifying the economic advantages of integrated rice-prawn systems over traditional monocultures.
2) Capacity Building: Provide hands-on learning and identify scaling opportunities for local farming communities.
3) Validate Technical Feasibility: Develop a replicable model for local partners and farmers to observe and adopt.

2. System Design and Multifunctionality

2.1 Concept of Integrated Polyculture

This integrated rice-prawn-vegetable system transforms a single rice field plot into a multiple output farm. Its design combines land, water, crops, and aquatic species, reflecting the MFL concept, supporting food production, income, and environmental health in one area.

- Rice serves as the main crop in rainfed lowlands, while also providing shade, organic matter, and shelter for prawns or fish.
- Freshwater prawns share the field and refuge canals, feeding on natural food such as Golden Apple Snails, a common rice pest, as well as plant residues and organic matter. In return, they recycle nutrients and improve field health.
- Vegetables, like leafy greens and herbs, grow on raised field bunds, turning protective structures into productive areas. They benefit from field moisture and nutrients, adding food and income for the households.

This integrated approach shifts farmers from single crop systems to multifunctional landscapes that improve livelihoods, strengthen food security, and protect the environment.

2.2 Comparative Advantages

Unlike monoculture rice farming, the rice-prawn-vegetable system diversifies production from a single land parcel. Rice ensures food security, prawns provide high-value protein and income, and vegetables increase overall productivity. The MFL approach increases land-use efficiency. On one demonstration farm, profit per square meter rose 25-36 times compared to rice alone.

3. Methods

3.1 Farmer Selection and Site Profiles

In collaboration with Provincial Department of Agriculture, Forestry and Fisheries, National Fisheries Administration, and Provincial Fisheries Administration Cantonment, the Project selected two lead stakeholders, Mrs. Nam Nara and Mrs. Un Yon, based on criteria including:

- Proximity to a reliable water source, within 50-100 meters.
- High level of commitment to peer-to-peer learning and maintaining their demonstration plots.
- Sufficient household labor for specialized tasks, prawn care, and pond preparation.
- Accessibility: Demonstration plots should be easily accessible to other farmers and community members for peer learning.

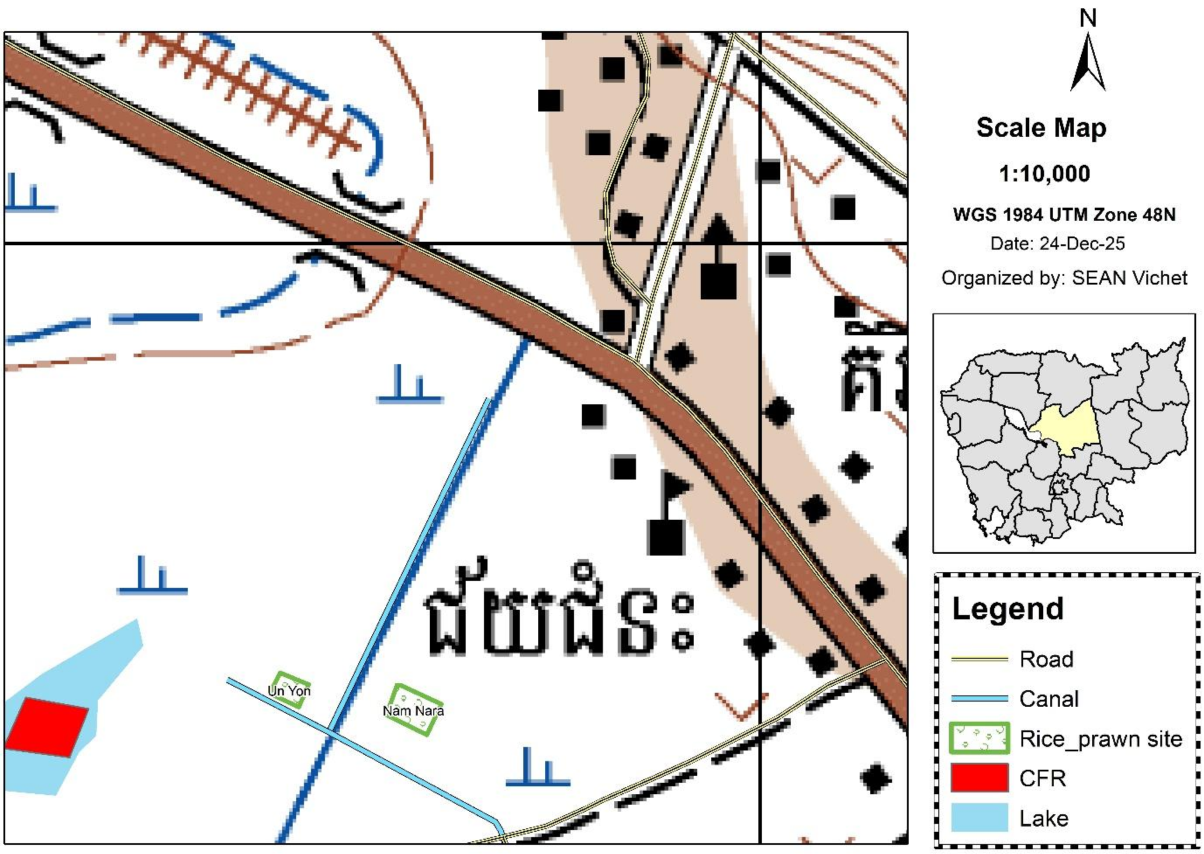

Figure 1. Field site location map of MFL demonstration plots, Santuk District, Kampong Thom province

3.2 Field Modifications

Before the demonstration, both farms were used exclusively for rice cultivation. Restructuring involved the construction of canals, refuge trenches, and raised dikes: Nara's farm: Allocated 1,199 m² to canals/dikes and 1,300 m² to vegetables and fruit trees, reducing the rice area from 6,300 m² to 3,801 m² to maximize total system value. Un Yon's farm: Dedicated 800 m² to canals and 1,600 m² to vegetables and fruit trees, adjusting the rice field area to 1,800 m².

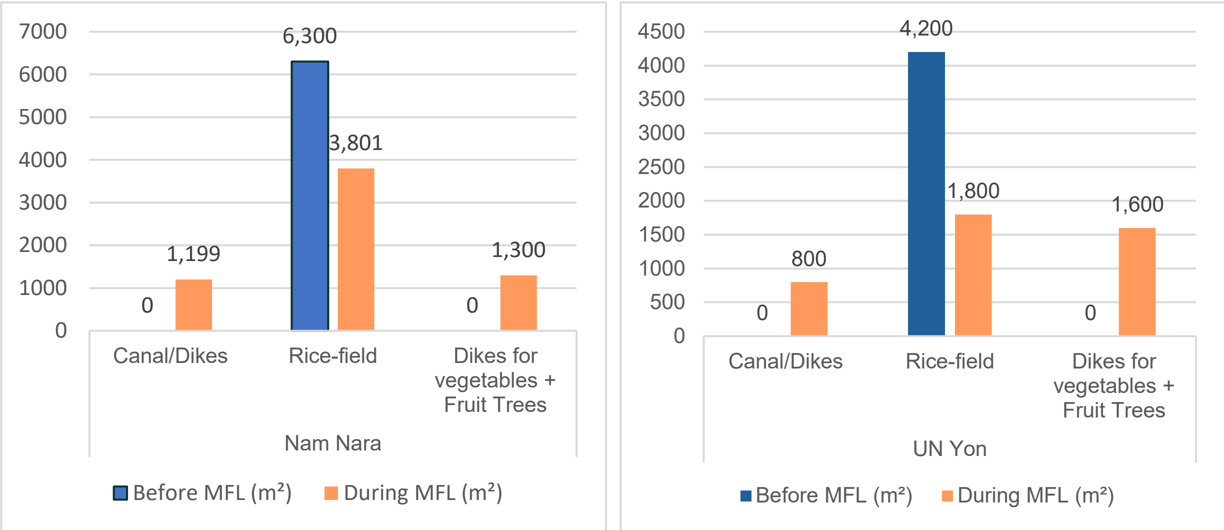

Figure 2: Field Layout and Modifications for Rice-Prawn-Vegetable Integrated Farming

3.3 Adapted Cropping Calendar

The demonstration plots follow a triple-cropping rice calendar, with vegetables cutting across the seasons, following rice harvest.

- Early Dry Season (January-April): Short-duration rice (OM5154).
- Pre-monsoon (May-July): Second rice crop of the same variety.
- Main Wet Season (August-February): Integrated rice-prawn phase using Champei Sar 70 (short-term rice variety) and aromatic variety - Phka Romdol (medium-term rice variety) and freshwater prawns, with prawns harvested progressively into the dry season.

3.4 Production Management Practices

3.4.1 Water and Field Management

Effective water and field management were key to the success of the integrated rice-freshwater prawn system. The farmers used a free-flow canal system to regulate water efficiency, reduce energy use, and maintain suitable habitats for both rice and prawns. Key practices included:

- Water depth: 15-25 cm in rice paddies; 80-120 cm in canals and trenches for prawn refuge
- Screening: Fine-mesh screens on all inlets and outlets to prevent prawn escape and block predators
- Field levelling and bund maintenance: Regular checks and repairs to prevent leaks and rat holes
- Sediment and organic matter control: Manual rice harvesting and straw removal to minimize soil disturbance and protect water quality
- Predator management: Fencing along dikes and screened water structures in line with biosecurity standards

3.4.2 Water Quality, Feeding, and Routine Management

To maintain optimal conditions in the refuge canals, farmers performed partial water exchanges of about 30% every 1-2 weeks to sustain dissolved oxygen, remove metabolic waste, and prevent ammonia and nitrite toxicity. Quicklime and dolomite were applied after water filling to stabilize pH and alkalinity, supporting prawns' health and molting - critical periods, when prawns are highly stressed (FAO, 2001).

The project prioritized biosecurity by eliminating chemical pesticides and minimizing synthetic fertilizers. Farmers adopted a dual-component feeding strategy:

- Commercial pellets: 25-35% protein.
- Golden Apple Snail: a locally harvested, high-protein rice pest.

Feeding rates ranged from 10-12% of body weight for juveniles to 3-4% near harvest. To optimize nutrition intake and reduce waste, feed was offered twice daily, 30% in the morning, 70% in the evening, aligning with the prawns' nocturnal feeding behavior.

Routine management included:

- Regular inspection of rice plots, canals, and trenches
- Biosecurity, vigilant predator monitoring, and maintenance of dike fencing/screens, and
- Record keeping of prawn growth, survival, feed use, and water parameters.

Both farmers stocked prawn Post-Larvae (PL_{60}) of *Macrobrachium rosenbergii* on 28 September 2025 within rainfed rice paddies, sharing water between rice fields and prawn canals as part of an integrated system. Sampling for monitoring was conducted in mid-November 2025, with prawns expected to be harvested after the full five-month cycle in February 2026. Rice was cultivated during the wet season using locally preferred varieties under low chemical input conditions, and vegetables were planted along raised field dykes to utilize residual moisture. Detailed information on inputs, feed composition, feed conversion ratios (FCR), and crop management practices for each farmer is provided in Annex 1.

3.5 Cost-Benefit Analysis Approach

A cost-benefit analysis (CBA) compared the integrated rice-freshwater prawn-vegetables system with the 2024 baseline of traditional rice monoculture among participating farmers. Data was collected throughout the production cycle and standardized to a USD/m^2 for comparability across farm sizes.

Costs were classified into two main categories:

- Variable costs: Rice seed, fertilizers, prawn juveniles, feed, and water management
- Fixed costs: Canal excavation, containment structures, fencing, and mesh (allocated via depreciation)

Performance matrix:

- Rice yield (kg/ha)
- Prawn yield (kg/field)
- Gross revenue is based on actual sales at prevailing local prices

Investment indicators:

- Cost-Benefit Ratio (CBR): Revenue / total costs
- Return on Investment (ROI): (Net Profit / Total Cost) x 100
- Standardization to USD/m² ensures accurate comparisons across farm sizes

4. Results and Findings

For this analysis, baseline data were drawn from the 2024 monoculture practice, while prawn-related parameters reflect only the initial 45-day period of a production cycle that is planned to extend to 150 days.

4.1 Baseline Rice Monoculture

In 2024, the farmers followed a rice monoculture system, cultivating two to three crops per year. Nara harvested 2.4 tons from 6,300 m² (yield: 0.052 kg/m² or 3.81 t/ha), with total production costs of USD 357.12 and a net profit of USD 92.88 (CBR: 1.26). Yon farmed 4,200 m², yielding 0.256 tons (yield: 0.061 kg/m² or 6.10 t/ha), with costs of USD 234.50 and a net profit of USD 21.75 (CBR: 1.09).

Table 1. Baseline Rice Production and Economic Performance (2024)

Farmer	Land Size (m^2)	Total Cost (USD)	Revenue (USD)	Net Profit (USD)	CBR	ROI (%)
Nara	6,300	357.12	450.00	92.88	1.26	26.0
Yon	4,200	234.50	256.25	21.75	1.09	9.3

A detailed comparative analysis with the integrated rice-prawn-vegetable system is presented in the discussion section.

4.2 Cost Structure of the Integrated System

The production costs for prawns, fig. 3, account for 87.1% (Nara) and 83.2% (Yon), driven by prawn seed (juveniles), labor, and feed (commercial pellets and snails). Rice production costs comprised 4-6% due to low input utilization practices, while fixed costs (canal excavation, fencing) were 8-11% post-depreciation.

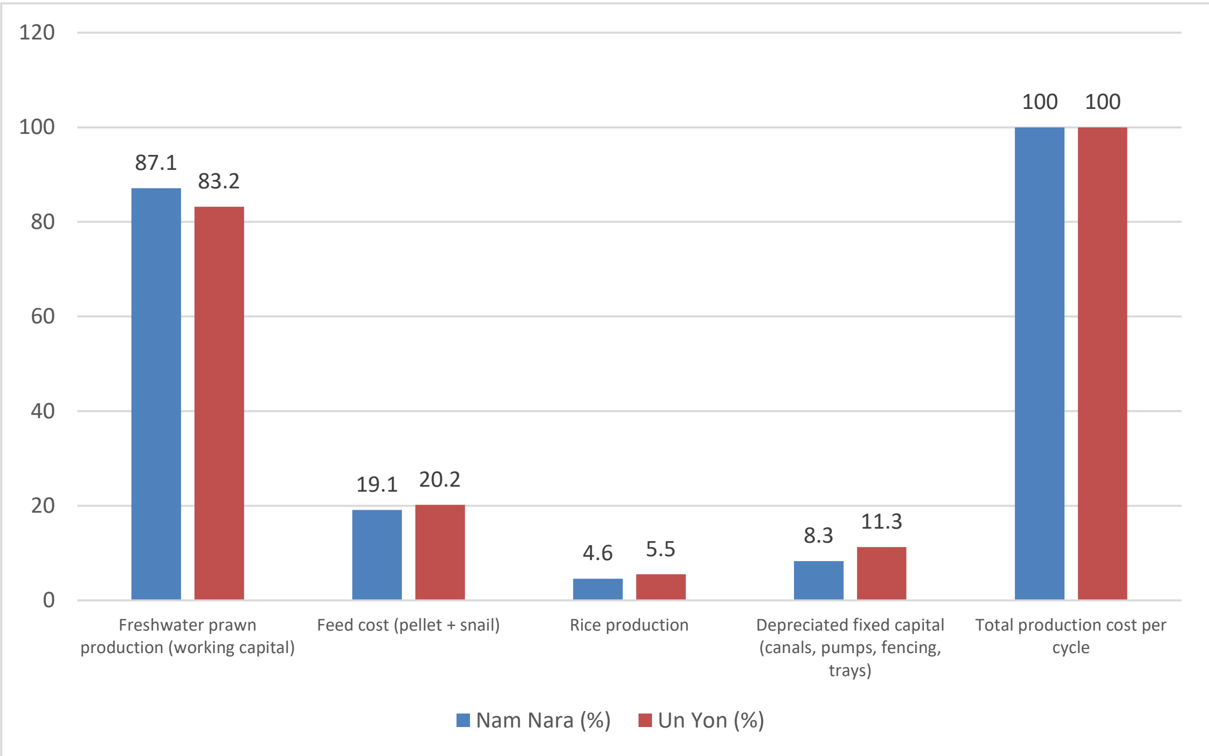

Figure 3. Percentage Cost Share of prawns, feed, rice, and capital per cycle in Nara's and Yon's.

4.3 Revenue and Performance Comparison

As shown in Figure 4, the net profits under the integrated rice-prawn system were higher than under baseline rice farming for both Nara and Yon. The figure also indicates higher net profit per square meter in the integrated system, demonstrating more efficient land use across different farm sizes.

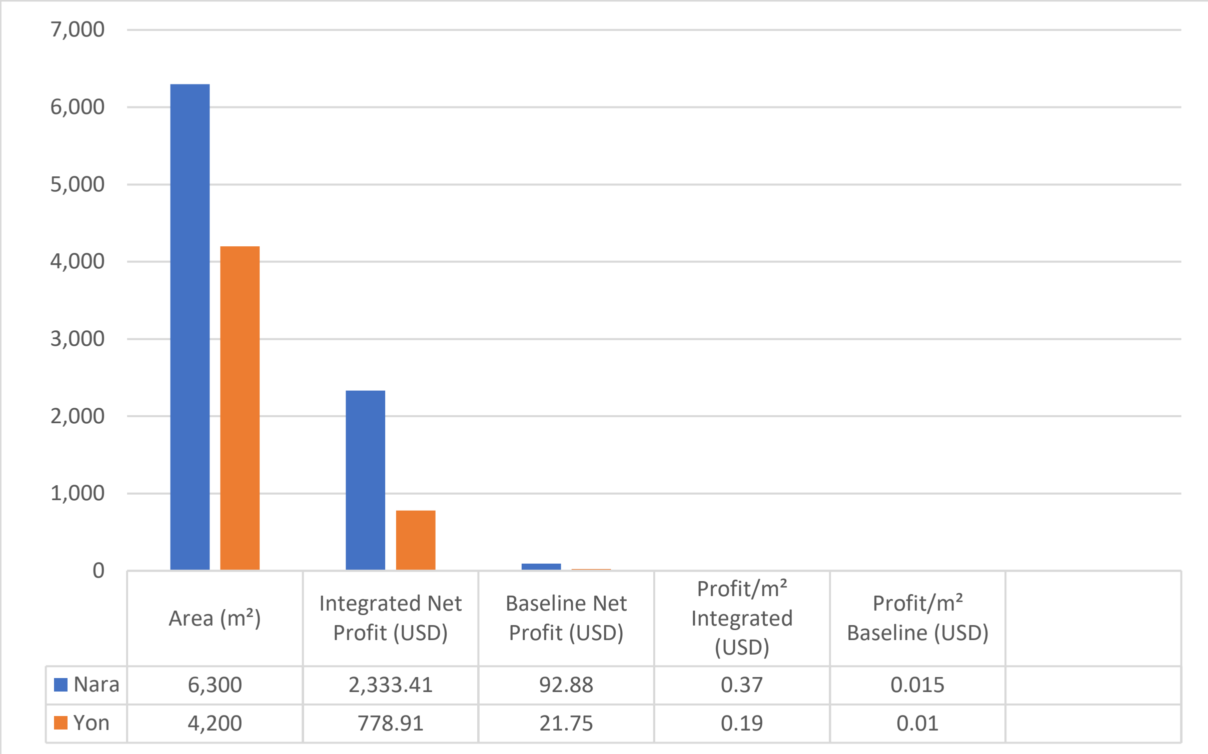

Figure 4. Net profit comparison between monoculture and integrated systems

Table 2 shows that freshwater prawns account for most total revenue for both farmers, while rice contributes a much smaller share. This revenue structure directly reflects the higher net profits achieved through the integrated system compared to baseline rice production.

Table 2: The total revenue breakdown between rice and prawns for both farmers

Farmer	Rice Revenue (USD)	Prawn Revenue (USD)	Total Revenue (USD)
Nara	159	4,752	4,911
Yon	175	2,496	2,671

4.4 Rice and Vegetable Yields

As shown in Table 3, Nara's rice yield was 1.67 t/ha (0.17 kg/m²) from 635 kg over 3,801 m². Yon's yield was 3.89 t/ha (0.39 kg/m²) from 700 kg over 1,800 m². Both farmers planted different types of vegetables on the field bunds, using canal water to irrigate the vegetables. Compared with the baseline system, which relied solely on rice, this integrated that provided for additional crops.

Table 3: Rice and Vegetable Performance

Farmer	Harvest (kg)	Area (m²)	Rice Yield (t/ha)	Rice Yield (kg/m²)
Nara	635	3,801	1.67	0.17
Yon	700	1,800	3.89	0.39

4.5 Juvenile Growth and Daily Gain

After 45 days of culture (sampling on 13 November 2025), juvenile prawns showed steady growth from 450 heads/kg (equivalent to 2.22 g/head), with Nara's averaging 22.32 g/head and Yon's 20.44 g/head, corresponding to daily growth rates of 0.50 and 0.45 g/day, respectively.

Table 4: Growth Performance of Juvenile Prawns over 45 Days

Farmer	Stocked Juveniles	Sample Size	Avg Weight (g/head)	Total Weight (g)	Total Length (cm)	Avg Growth/day (g/day)
Nara	9,900	50	22.32	1,116.2	951	0.50
Yon	5,200	30	20.44	613.3	482.5	0.45

Figure 5: Growth Performance of Juvenile Prawns over 45 Days

5. Discussion

5.1 Interpretation of Findings

Early growth monitoring at 45 days confirmed that prawns adapted well to the integrated rice-prawn-vegetable system. Average weights of 22.32 g for Nara and 20.44 g for Yon, along with an estimated 52% survival, indicate that rice fields can provide a suitable habitat for prawns. During the first 45 days of culture, prawns were fed a mixed diet of commercial feed supplemented with locally sourced golden apple snails, offering a natural protein supplement that supported early growth.

Figure 6: Golden Apple Snail and Feeding Tray for Prawn

Rice yields varied between farmers: Nara produced 1.67 t/ha (0.17 kg/m²), while Yon achieved 3.89 t/ha (0.39 kg/m²). Importantly, integrating prawns and vegetables did not reduce rice yield, indicating that the system can support multiple production components simultaneously. Differences in yield likely reflect the use of short and medium rice varieties. Both farmers planted vegetables on the field bunds in this early dry season, irrigating from canals. Prawn farming is expected to be the main income source, with a projected gross margin of USD 5.89/kg for Nara and USD 3.75/kg for Yon. Cost-benefit analysis of these preliminary results indicates substantial potential profit gains compared with rice-only systems.

Under the baseline rice monoculture, production costs and profits per unit area were relatively low, with costs ranging from USD 0.056-0.057/m² and profits from USD 0.005-0.015/m².

- Nara: Net profit is expected to increase 25-fold (USD 2,334 vs. USD 92.88)
- Yon: Net profit is expected to increase 36-fold (USD 779 vs. USD 21.75)

These findings demonstrate that the integrated rice-prawn-vegetable approach is both technically feasible and economically advantageous for smallholder farmers in rainfed lowland systems.

5.2 Growth Performance and Projection

Early growth rates observed during the first 45 days after stocking indicate that juvenile prawns in the integrated rice-prawn system developed steadily, consistent with patterns reported in other small-scale aquaculture systems where balanced diets (25-35% protein) and regular water management support prawn growth (New, 2002; Valenti et al., 2010).

To estimate potential productivity over a full production cycle, growth was extrapolated to 150 days, which is sufficient for prawns to reach marketable size 8-12 prawns/kg (New, 2002; Lam et al., 2006). While growth typically slows as prawns approach larger sizes, the projection was adjusted using observed patterns from the neighboring Seng Hong's Farm and literature of comparable integrated systems, which report moderate final weights and survival under field conditions (Lam et al., 2006; Valenti et al., 2010).

Under these assumptions, prawns are projected to reach an average weight of 77 g per individual (13 prawns/kg) with an overall survival of 52%, resulting in a total projected biomass of 396 kg for Nara's farm and 208 kg for Yon's farm.

These growth projections provide insight into the economic potential of the system. Assuming a market price of USD 12.00/kg, the projected revenue and gross margins are substantial (Table 5). Nara's farm is expected to generate a gross margin of approximately USD 4,172 (USD 5.89/kg), while Yon's farm could achieve USD 2,066 (USD 3.75/kg).

Overall, these projections highlight that integrating prawns into rice fields can provide significant supplementary income while maintaining rice productivity, demonstrating both the biological feasibility and economic benefits of this integrated farming approach.

Table 5. Projected prawn biomass and gross margin under integrated rice-prawn farming

Farm	Projected Biomass (kg)	Avg. Weight (g/head)	Sale Price (USD/kg)	Gross Revenue (USD)	Total Cost (USD)	Gross Margin (USD)	Gross Margin per kg (USD/kg)
Nara	396	77	12.0	4911	2,577	4,172	5.89
Yon	208	77	12.0	2671	1,892	2,066	3.75

5.3 Comparison with Previous Studies

Traditional rice monoculture in Cambodia relies on chemical input, applying 140-220 kg/ha of fertilizer for yields of 2.7 to 4.3 t/ha (CDRI, 2021). Production costs are high, averaging USD 925-1,020 per hectare (MDPI, 2022).

In contrast, integrated rice-prawn-vegetable systems offer a more sustainable and profitable alternative. They improve resilience without expanding land area, while prawn growth and survival in this study matched successful practices observed at Seng Hong's farm.

5.4 Challenges and Limitations

Managing rice, prawns, and vegetables is labor-intensive and requires careful coordination. Farmers must regulate water exchange, control predators such as birds and snakes, and optimize feeding to minimize losses. In this study, the production cycle started in August, later than the optimal May-June rainy season, which is likely to affect synchronization of rice and prawn growth. Limited access to high-quality input materials, mainly sourced from Phnom Penh, added further management challenges.

6. Practical Recommendations

Based on findings from the first production cycle, the following practical measures are recommended:

1. Timing: Start the production cycle in May-June to align with the rainy season for optimal rice and prawn growth.
2. Stocking: Use healthy juveniles at a density of 2 prawns/m².
3. Feed Management: Prioritize local feeds, e.g., snails and pumpkin to reduce costs, supplemented with commercial pellets as needed.
4. Infrastructure: Maintain water depths of 15-25 cm in rice paddies and 120-150 cm in refuge canals for prawn survival.
5. Capacity Building: Expand farmer training on disease diagnosis, organic fertilization, and best practices through demos and exchange visits.
6. Promotion of Integrated Farming: Scale rice–prawn–vegetable systems in similar lowland areas to increase income and reduce risks. Improve feed and water management and monitoring of prawn survival.

7. Future Research: Include more farmers, extend trials into the dry season, and collect detailed data on prawn growth, survival, and economic returns to support scaling.

7. Conclusions

The integrated rice-prawn-vegetable system is a high-return and resilient alternative to rice monoculture in rainfed lowland areas. It generated 25-36 times higher net profits while maintaining or improving rice yields, showing that the system is both technically feasible and economically viable for smallholder farmers.

The system also supports Good Agricultural Practices by reducing the use of chemical pesticides. Farmers collected Golden Apple snails and other natural feeds from the fields, which helped control pests and reduced the need for chemical inputs. This practice should support the agroecosystem, including soil health, water quality, and beneficial organisms in rice fields. By combining rice, prawns, and vegetables, the system diversifies household income, uses land and water more efficiently, and improves farm resilience. Overall, the results show strong potential for scaling up this integrated farming approach across rainfed lowland rice areas in Cambodia.

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Annex

Annex 1. Integrated Production Practices for Rice-Prawn-Vegetable Farming

Component	Farmer	Details / Variety / Planting	Inputs / Feed / Seed	FCR / Crop Management	Production Cycle / Timing	Notes
Prawns	Nara	Stocked 28 Sept 2025: 9,900 juveniles	80 kg commercial feed (USD 1.30/kg) + 2,745 kg Golden Apple Snails (USD 0.13/kg)	FCR 8.95; regular monitoring and biosecurity	5 months (Sept 2025-Feb 2026)	Integrated with rice paddies; shared water with rice canals
Prawns	Yon	Stocked 28 Sept 2025: 5,200 juveniles	80 kg commercial feed + 3,661 kg Golden Apple Snails	FCR 12.84; regular monitoring and biosecurity	5 months (Sept 2025-Feb 2026)	Integrated with rice paddies; shared water with rice canals
Rice	Nara	Variety: Phka Romdol	38 kg seed; minimal chemicals; irrigation shared with prawn canals	Standard wet season crop management	Wet season 2025 (5-6 months)	Rice-Prawn integration
Rice	Yon	Variety: Chom Pei Sar	18 kg seed; minimal chemicals; irrigation shared with prawn canals	Standard wet season crop management	Wet season 2025 (5-6 months)	Rice-Prawn integration
Vegetables	Both	Planted Nov 2025 along raised dykes	Local seeds; minimal chemicals	Routine maintenance, weeding, irrigation	5 months (Nov 2025-Mar 2026)	Harvest pending; utilizes residual moisture along dykes

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