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Organic rice–prawn farming yields 20 % higher revenues

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Abstract Rice–prawn farming in Asian countries is a sustainable practice using less fertilizers. Organic farming of rice and giant river prawns in rotational crops was tested in the water-logged paddy fields of Kuttanad, Kerala as part of the Indian Organic Aquaculture Project. Rice was cultivated during November to February, followed by a crop of freshwater prawns in the same field from March to September. Here, we study the production of four certified farms growing organic rice and organic prawns compared with four conventional farms growing rice and prawns in rotational crops. We evaluate the economic viability by cost–return and partial budgeting analysis. Our results show that farming rice organically reduced yields by 23 %, from 5,690 kg/ha in conventional farming compared to 4,376 kg/ha in organic farming. However, the organic prawn crop yield of 396 kg/ha was 10 % higher than the yield of the conventional system, of 360 kg/ha, although the differences were not significant. Furthermore, total investment for organic rice was approximately 20 % greater than for the non-organic rice crop. Total investment for organic prawns was 17 % greater than for the non-organic prawn crop. Net revenue was 11 % lower for organic rice than for conventional rice. Organic prawns realized 117 % higher net revenue than conventional prawns. Although organic rice farming realized lower returns than conventional, its combination with organic prawn farming

enhanced net revenue by 20 % over conventional rice/conventional prawn production.

Keywords Organic rice · Prawns · *Macrobrachium rosenbergii* · Organic aquaculture · Partial budgeting · Economics

1 Introduction

Organic agriculture is intended to produce high-quality, nutritious food by combining tradition, innovation, and science, and avoiding the use of fertilizers, pesticides, animal drugs, and food additives that would help enhance and sustain the health of ecosystems and organisms from the smallest in the soil to human beings (IFOAM 2008). Organic farming adopts a holistic approach to agriculture by promoting synergies among the natural environment, plants, and animals with due regard to the physiological and behavioral needs of the animals (Cottee and Petersen 2009). It protects the health of consumers and the environment by using organic management practices without the perceived adverse effects of conventional farm practices (Argyropoulos et al. 2013). Organic agriculture and allied activities (including aquaculture and other farm-related activities on non-agricultural land) are currently practiced in 162 countries, covering an area of 71.3 million ha (nearly 1.7 % of the total utilized agricultural area globally), involving 1.8 million producers, more than 80 % of them in Asia, Africa, and Latin America (Willer et al. 2013). These authors stated that the global market for organic products is currently valued at US\$ 62.8 billion, more than 90 % of which is shared by North America and Europe.

The standards for certifying organic aqua-products have relied mostly on those previously established for organic agriculture, but varied across geographies, species, markets, and certifying bodies. It is often difficult to adapt some species

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and aquaculture systems to an organic system, which is more akin to a traditional kind of farming. Total production of certified aquaculture products (~5,000 tons in the year 2000, primarily from European countries) was estimated to increase to 1.2 million tons by 2030 by Tacon and Brister (2002). This would be equivalent to 0.6 % of the total projected aquaculture production of 194 million tons in 2030. Organic aquaculture production has continued to increase globally, reaching 53,500 tons in 2008 with a market value of US\$ 300 million, dominated by salmon, shrimp, and common carp (Bergleiter et al. 2009). However, farming areas are mostly limited to Europe (46.7 %), Asia (35.5 %—more than two thirds of this comes from China), and Latin America (13.1 %) (Prein et al. 2012). Conversion to organic farming is still limited by several factors in the conversion process over time, which is usually an economically difficult period for farmers (Acs et al. 2007). There is also the risk that the higher product values associated with organic farming may be concomitant with lower production (Berentsen et al. 2012). Consumer perceptions about organic products are also greatly varied (New 2003).

Rice (*Oryza sativa* L.) is the staple food for over half of the world population. The total world production in 2011 was 722.8 million tons (FAOSTAT 2011). Ninety percent of the global production was grown in Asia, over 23 % of it in India. Rice is an integral part of agriculture in the southern Indian state of Kerala, and rice-based aquaculture systems follow traditional farming methods that could easily adopt organic farming practices. The giant river prawn (*Macrobrachium rosenbergii*) is indigenous to South and Southeast Asia, parts of Oceania, and some Pacific islands from where it has been transferred to other parts of the world for farming (New 2002). By 2009, the global production of all species of freshwater prawns had reached 444,000 tons valued at US\$ 2.2 billion (New and Nair 2012). Freshwater prawns have been grown as part of rice–fish integrated farming systems in many countries including Bangladesh, China, India, Indonesia, Philippines, Thailand, and Vietnam (Halwart and Gupta 2004). Such systems synergize the available resources and improve income from farming operations without increasing expenses, all of which could play an important role in food security, poverty alleviation, and socio-economic welfare of rural populations.

The Kuttanad wetland system is a flood plain of four rivers that confluence into the Vembanad Lake. It comprises low-lying (0.5 to 2.5 m below mean sea level) rice cultivation fields that extend to 1,100 km² and is known as the rice bowl of Kerala (Fig. 1). In most of the low-lying rice polders, from which water is removed by using high-capacity axial-flow pumps, rice cultivation begins in the northeast monsoon period (around November) and is harvested by February. Vembanad Lake and the adjoining wetlands in Kuttanad have native stocks of *M. rosenbergii*, and this species has been successfully integrated for farming with rice in rotational crops in wetlands over the past two decades (Nair and Salin 2012). Soon after the

harvest of paddy, these fields are stocked with giant freshwater prawns and fish, mostly carps, which are grown for over 6 months before the subsequent crop of rice. This practice has greatly reduced the use of inorganic fertilizers and other chemicals required for rice cultivation in rice–fish rotational crop fields. There are obvious advantages of integrating aquaculture, particularly with the stocking of weed-eating grass carp (*Ctenopharyngodon idella*) thus reducing the use of herbicides in fields before each rice crop (Zimmerman et al. 2010).

Organic aquaculture of freshwater prawns was introduced in Kuttanad as a joint effort by government (coordinated by the Marine Products Export Development Authority of India), non-governmental organizations, and Indian farmer groups. These collaborated with the State Secretariat for Economic Affairs (SECO), Switzerland and Naturland, Germany who made the framework based on the organic standards of the European Union (IFOAM 2010; Naturland 2012) with the support of a local inspection agency. A few farms adopted this strategy through a conversion process, certifying the paddy crop before becoming eligible to seek certification by Naturland as organically certified prawn farms (Fig. 1); the organic harvested produce were marketed by a certified processor who procured it at a premium price from the farm sites.

Despite its perceived environmental benefits, the profitability of organic freshwater prawn farming as an enterprise has yet to be exploited, particularly in respect to its integration in organic rice fields. Here, we evaluate the economic viability of the first organic rice–prawn integrated farming trials based on the production data collected from four certified organic rice–prawn farms in comparison with four non-organic farms. The yields of rice and prawns, and the costs and returns in respect of organic and conventional farms are compared with a view to evaluating the perceived economic advantage of organic farming. This may support the integration of organic farming of giant river prawns with organic rice cultivation as a sustainable farming model.

2 Materials and methods

Our study incorporates data collected during a crop of organic rice followed by one crop of organic giant river prawns cultured in four rice–prawn integrated farms (area 4.4, 4.0, 3.9, and 3.2 ha, respectively) in Kuttanad (9°17' to 9°40'N; 76°19' to 76°33'E), Kerala. For comparative analysis of production and economics, conventional farming data from non-organic rice and non-organic prawns was also collected during the same period from four farms (area 5.6, 4.9, 3.6, and 2.1 ha, respectively) situated adjacent to the organic farms. Farmer-owned conventional farms that were closely located and sourcing water from the same creek, part of the Vembanad Lake, were selected for the study. This choice reflected the need to keep in mind that tenancy often negatively influences farm output, as farmers are better motivated to invest scientific

Fig. 1 **a** Extensive rice–fish/prawn rotational farming fields in Kuttanad, Kerala, India are low-lying areas, 0.5–2.5 m below sea level. Fish and prawn are cultured in the submerged fields during March to October, before the subsequent crop of paddy. **b** View of the waterlogged field from which water is removed by using high-capacity pumps during November to February for the paddy crop. Organic paddy and prawns are grown alternately in the same field. **c** Prawn juveniles are stocked 1 month prior to paddy harvesting in a nursery pond formed at one corner of the rice–prawn rotational field and reared for 45–60 days. The juveniles are then released into the entire field by breaking the nursery bund on one side after the harvest of paddy. **d** View of the harvested organic prawns from rice–prawn fields

practices in their own farms (Mendoza 2002). The farmers maintained close contacts with each other, often sharing resources and inputs for efficient farm management; thus, similar farming practices in the case of both organic and conventional crops were adopted. Water quality and weather conditions were comparable among these locations and manpower costs were similar (though not equal), as revealed in a preliminary study for the selection of the farms. All these factors weighed in favor of selecting the conventional farms in the present study, while in the case of organic farms all four certified farms were selected.

2.1 Conventional and organic rice cultivation practices

In Kuttanad, a locally developed high-yielding variety *Uma MO.16* (Devika et al. 2004) is the predominant paddy cultivated during the months of November to February following the adapted farmers' practices, which were based on the protocol recommendations for the crop (KAU 2002).

In the conventional farms, paddy was cultivated without a nursery and the method of wet sowing was followed, in which the seed was kept soaked in water for 18 days and then held tight in jute bags for another 3–4 days when the seed started sprouting. For seeding, the entire field was prepared by removing weeds, mostly by manual means (chemical weed removal prior to rice sowing is not required in rice–fish integrated fields) followed by leveling, and the field was filled to ~5 cm of water, over which the sprouted seed were broadcast. Two days after sowing, the field was dewatered and kept

moderately wet for a week. As the paddy started growing, water was allowed to enter the field and a level of around 30–45 cm was maintained until final harvesting after 120 days. Three doses of NPK fertilizers were applied; the first application was done after 20–22 days of sowing at 155 kg ha^{-1} , followed by a second application at 40–45 days at the same dose and a third application before 60 days at 90 kg ha^{-1} . During the farming period, in addition to manual weeding, a selective herbicide such as 2,4-D (sodium salt of 2,4-dichlorophenoxyacetic acid) was applied at 1.25 kg ha^{-1} around 18–25 days after sowing. Emergency spraying of the pesticide Monocrotophos occurred twice at 750 mL ha^{-1} .

The farms practicing organic cultivation used seed of the same variety of paddy grown under organic protocol and followed similar farm practices to conventional paddy culture, but with the use of organic manure and specialized mixtures containing probiotic bacteria, and other bio-control methods in the field as outlined in Alexander et al. (2009). The use of the inorganic fertilizers and pesticides that were used in conventional rice farming in the area were completely dispensed with. Before sowing, the seed were soaked in a *Pseudomonas* culture preparation at 10 g kg^{-1} seed for 12–16 h. The first application of organic manure was carried out before sowing, followed by a second application before 30 days post-sowing. The composition of the organic manure mixture at each application (ha^{-1}) was as follows: organic manure (an equal mix of dried cattle manure and vermicompost)—100 kg; the biofertilizer, *Azospirillum*—1 L; phosphobacteria (*Bacillus* sp.)—250 mL; and potassium mobilizing bacteria (*Frateruria*

aurentia)—250 mL. Organic pest and insect control was achieved by three applications of *Tricho* (*Trichogramma japonica* and *Trichogramma chilonis*) egg ($5\text{ cm}^3\text{ ha}^{-1}$) cards as follows: first application before 20 days, second application before 45 days, and third application at 60–65 days post-sowing. In addition to organic manures, three applications of specialized probiotic mixtures containing 15 kg ha^{-1} of cow dung, 15 L ha^{-1} of cow urine, and 2 kg ha^{-1} each of jaggery (traditional, unrefined whole cane sugar), cereal flour, and mud from the field were also used. The first application was carried out before 20 days, the second application before 35 days, and the third application before 50 days post-sowing. During the whole period, one or two field applications of *Pseudomonas* at around 45 days and before 70 days after sowing were also made, either by foliar spray at a dose of 10 kg diluted to 500 L ha^{-1} or by soil application at 2.5 kg ha^{-1} mixed with 50 kg of dried cow dung and applied on the field after dewatering.

2.2 Conventional and organic farming of prawns in rice fields

Following rice cultivation, the same fields were used for prawn culture during the months of March to October. Prawn juveniles sourced from a hatchery were initially reared in a nursery pond prepared in one corner of the field by earthen embankments comprising about 10 % of the total farm area for 45 to 60 days. The prawn nursery was prepared and stocked 1 month prior to paddy harvesting (January); this ensured that the juveniles were ready to be released into the grow-out area immediately after paddy harvest and subsequent field preparation. The nursery pond was sundried well by pumping out the water and then refilled with water from the adjacent stream screened through sluice nets. Tea seed cake powder (100 kg ha^{-1}) was applied to remove predatory fish in the nursery pond, followed by the application of 500 kg ha^{-1} each of agricultural lime powder (CaCO_3) and dried cow dung. After 2 days, the water level was raised to 1.2 m and the pond kept ready for stocking juveniles within 5 days, when a healthy plankton bloom appeared. In the grow-out area, field preparation for the prawn crop was limited to twice flushing out the entire field after the harvest of paddy to clear any residues of the chemicals or fertilizers used in conventional paddy farming practice. After the second flushing, the entire field was filled with water and 1–2-month-old juveniles were then released into the entire field by breaking the nursery bund on one side after the harvest of paddy. At this time, a few fish, mostly advanced fingerlings of grass carp, were also stocked, primarily to control aquatic weeds and phytoplankton blooms in the grow-out area.

In the case of the farms practicing organic prawn farming, freshwater prawn postlarvae were sourced from a hatchery certified organic by Naturland. These were stocked into the nursery pond 45 days before release into the grow-out area of

the farm following the standard operating protocols framed by Naturland based on the organic standards. Compliance was ensured by maintenance of farm diaries and scrutiny by periodic farm inspection. The preparation and management of the nursery pond was similar to that followed in conventional prawn farming, except that the feed used was certified organic by Naturland (“Magnum” brand; The Waterbase Ltd, Chennai, India). The use of mahua oil cake or tea seed cake powder was permitted in the Indian Organic Aquaculture Project because it was absolutely essential for the crop, but it was used only in the nursery area, effectively ~10 % of the entire farm area.

2.3 Data collection and analyses

According to the Internal Control System framed as part of the Indian Organic Aquaculture Project, every farm to be certified as organic must keep a continuous record of farm data that is subject to periodic evaluation by the inspection agency under the standards stipulated by Naturland. Effective transition of the selected farms from conventional farming to organic farming for rice was achieved in the first phase followed by a transitional crop of prawns. The crops succeeding the successful transitional crops were certified as organic by Naturland according to the set standards. Although the transitional crops were similar to the organic crops in every respect, with a view to streamlining the analysis, these crops were not considered in our study. The data we used were recorded on the farm site and were not based on interviews with farmers in order to maintain as much accuracy as possible. The data recorded by farmers in their farm diaries as part of the Internal Control System for organic farming were also used in our analysis.

The cultivation schedules of both conventional and organic rice and prawn farms were closely monitored, and the costs of all the physical inputs and labor, together with the associated costs of operation, were recorded. During prawn culture, temperature, pH, and dissolved oxygen were recorded in the afternoon hours using a CyberScan Multiparameter portable meter (Eutech Instruments, Fisher Scientific, UK), and ammonia ($\text{NH}_3\text{-N}$) was determined using a test kit (Aquatic Ecosystems, USA). This was carried out in both organic and conventional prawn farms, every week during the entire nursery period, and thereafter fortnightly in the grow-out area.

At harvest, the crop yields of rice and prawns (including prawn size class data) and the revenue generated were recorded. The individual values obtained from the two sets (conventional rice and prawns; organic rice and prawns) of four farms were summarized. The mean values per hectare were used for analysis because of the inevitable variations in individual farm area. These mean values were compared by analysis of variance (ANOVA) after making suitable transformations wherever necessary using the software package SPSS version 16.

The water quality parameters tested were analyzed by three-way ANOVA and multiple comparisons of mean values were carried out using Tukey's post hoc test. Significant differences among treatments were determined at 5 % levels. The cost of production was estimated for each system and the economic feasibility of the four different modes of production evaluated by cost-return and partial budgeting analysis (Shang 1990).

3 Results and discussion

3.1 Yield from rice and prawn crops

Rice and prawns performed differently in conventional and organic systems, as evidenced by their yields, but differences in rice yield, prawn production, fish production, percentage survival, and the food conversion ratio of reared prawns were not significant. The terms “rice” and “paddy” are used here interchangeably to denote unmilled, wholegrain rice retaining its husk after threshing, and the yield (grain humidity at harvest was ~16 %) was measured from the entire area of the rice field. Rice yielded 23 % less in organic ($4,376 \pm 58 \text{ kg ha}^{-1}$) farms than in conventional farms ($5,690 \pm 116 \text{ kg ha}^{-1}$), while organic prawns had a higher mean yield ($396 \pm 6 \text{ kg ha}^{-1}$) than in the conventional farms ($360 \pm 13 \text{ kg ha}^{-1}$), an increase of 10 %. The mean sowing rates of rice in conventional and organic farms were 125 ± 1.6 and $126 \pm 1.4 \text{ kg ha}^{-1}$, and the mean prawn stocking densities were $28,607 \pm 743$ and $25,835 \pm 336$ postlarvae ha^{-1} , respectively. Additionally in the prawn grow-out areas, fingerlings of grass carp (*C. idella*) were stocked at 458 ± 20 and 398 ± 20 individuals ha^{-1} in conventional and organic farms, resulting in yields of 87 ± 6 and $60 \pm 4 \text{ kg ha}^{-1}$, respectively.

Farmer trials on organic farming had already begun in Kuttanad by 2004 in about 33 ha of rice fields with support from non-governmental organizations and a few private entrepreneurs generating much needed interest in organic farming in the region (see report—Anon 2005). However, there is no published report on the scales of production or economics to make a comparison with our study. Production from organic farming is often found to be low compared to conventional farming and the nutrient inputs are also low (Mäder et al. 2002), but yields equivalent to or better than conventional farming may be achieved, particularly in developing countries (Badgley et al. 2007), where low-input farming systems have already been in practice. The water-logged paddy fields of Kuttanad are one of the most productive areas for rice cultivation (Elizabeth et al. 1990). Yields of rice in the conventional farms we studied were comparable to the results of multi-locational variety trials of rice reported from Kerala, which ranged from 4,887 to 6,583 kg ha^{-1} (Devika et al. 2004), but the mean rice yield from organic farms was below this range.

The highest mean individual size of prawns obtained in both crops was similar: 119 g in organic and 116 g in conventional farms. Among the prawns harvested in conventional farms, 12.33, 20.37, 31.36, 26.17, and 9.76 % belonged to the size classes of >100, 70–100, 50–70, 30–50, and <30 g, respectively. In the case of the organic farms, the size class composition was as follows: 15.97, 21.01, 25.77, 30.14, and 7.11 % for the size classes of >100, 70–100, 50–70, 30–50, and <30 g, respectively. The disposition amongst these size classes was not significantly different between the two types of farms, except for that comprising 70–100 g prawns ($P < 0.05$). Mean prawn survival rate was higher in organic prawn farms (31.29 ± 2 %) compared to 27.45 ± 3 % in conventional farms, though not statistically significant.

Freshwater prawns (1.5 cm size) are usually stocked in integrated paddy fields at a density of three juveniles m^{-2} (Halwart and Gupta 2004). The stocking densities of prawn juveniles used in the organic farms we studied were not significantly lower than those in the conventional farms; if they had been so, it might have provided a justification for the greater production achieved in the organic farms. We need to examine these systems in a future trial to determine the best stocking density to achieve optimum production.

In the wetland rice fields in Kuttanad, the harvesting of rice is limited to cutting the panicles alone. The stubble and the straw remaining in the rice fields shortly after the harvest of rice are important sources of organic matter and nutrients (Dobermann and Witt 2000), which justifies the smaller quantities of organic manure used in the rice fields we studied, compared to those typically used in intensive rice cultivation practices. The organic manure used in organic rice farming might also be beneficial for prawns in the subsequent crop as natural productivity and added manure have great roles in improving the productivity of *M. rosenbergii* (MacLean et al. 1989). The apparent food conversion ratio was comparable in both crops ($1.40:1 \pm 0.04$ in organic compared to $1.42:1 \pm 0.09$ in conventional farms). Lower stocking density and good management associated with an appropriate diet and feeding technique play a great role in contributing to the welfare of reared animals in aquaculture systems (Ashley 2007), which is an important attribute of organic prawn farming. The quantity of supplementary feed to be used in organic prawn culture systems therefore needs to be moderated in future trials, considering the organic manure inputs as part of the organic rice crop in rotational fields.

The primary difference between organic and conventional farming systems of fish or prawns is the feed used and the set of organic standards followed in the former to facilitate certification. The organic standards adopted in Kuttanad were the first such standards for certification implemented in the case of giant river prawns. This led to the first successful marketing of “certified organic prawns” in the European Union markets since the earliest organic standards were formed in Austria for

certification of common carp, *Cyprinus carpio*, in 1994 (Bergleiter et al. 2009). Integrated rice fields are one of the best environments that could be readily adapted to the organic farming of rice and fish or prawns together or in rotation because of the low-input culture practices already prevailing. Out of the 44.5 million ha of land under rice cultivation in India, 20 million ha are suitable for rice–fish integration (Mohanty et al. 2009). The Naturland standards can be readily adopted in all similar systems and further streamlined for specific rearing situations.

The water quality parameters recorded in the conventional and organic farms were as follows: pH, 7.77 ± 0.14 and 7.94 ± 0.10 ; temperature, 28.75 ± 0.16 and 28.66 ± 0.17 °C; dissolved oxygen, 5.32 ± 0.12 and 5.13 ± 0.13 ppm; and ammonia, 0.36 ± 0.06 and 0.23 ± 0.04 ppm, respectively, which were within the normal limits suitable for prawn growth. However, statistical analysis revealed that, except for temperature, all of the water quality parameters tested, viz. pH and dissolved oxygen ($P < 0.01$) and ammonia ($P < 0.05$), varied significantly between conventional and organic farms, and across the rearing period from 1 to 36 weeks. Pairwise comparison of the data using Tukey's post hoc test did not help in inferring any distinct pattern of differences, except a general trend in which water quality in the first few weeks of rearing varied from the later stages of the crops nearing harvest. The significant reduction in the $\text{NH}_3\text{-N}$ levels in organic compared to conventional farms is particularly interesting. Further research on the water and soil quality interactions in organic and non-organic rice–prawn farming systems, with a focus on their microbial populations, would be useful. Gram-positive bacteria *Bacillus* spp. have known beneficial effects on reducing ammonia levels and increasing survival in fish and prawns (Cha et al. 2013; Mujeeb Rahiman et al. 2010). Inclusion of microbial supplements in the organic manure used in rice cultivation thus seems to have a positive role in improving water quality during the subsequent organic rice crop, a possible interaction that needs to be better understood.

Organic farming in wetlands also opens up a number of future research opportunities that will help us understand the major factors determining production in low-input, agri-aquaculture systems and also update the standards of organic farming in similar culture situations. In a study by Saha et al. (2007), organically grown rice compared well to rice produced from inorganically fertilized plots in respect of the nutritional and physico-chemical properties and cooking quality. It had a higher content of iron, but was lower in copper content than inorganically fertilized treatments. The type of rearing may also influence the nutritional value of prawn meat which is also dependent on the quality of the feed offered to the animal. The proportion of n-3 HUFAs was found to be three times higher in organically reared sea bass than conventionally reared fish (Trocino et al. 2012). Organic production systems such as the extensive rice–fish fields that use

relatively low stocking densities would provide a more “natural” environment for fish and prawns than smaller ponds or cages. They would also offer better welfare attributes to the reared animal than most other inland farming systems. This clearly establishes the potential of extensive rice fields in producing organic prawns. The energy consumption of conventional and organic rice–prawn systems is also an important aspect to be investigated with a view to compare the relative energy efficiency of organic and conventional farming systems as a measure of sustainability (Mendoza 2004; Rahman and Barmon 2012). This could be one of the most important criteria applied to organic farming systems worldwide to improve input use efficiency.

3.2 Operational costs

In general, organic rice and prawn crops were more capital-intensive operations in the four farm crops tested. Total fixed costs—mean values of the figures for four farms each—were Indian Rs. 7,910, Rs. 8,314, Rs. 9,189, and Rs. 9,757 (1 US\$ = approximately Rs. 50) in conventional rice, organic rice (Table 1), conventional prawn, and organic prawn (Table 2), respectively. Total fixed costs consisted of land lease and interest on operating costs (at the rate of 7 % per annum). Although all farmers evaluated in the present study owned their farms, for economic analysis the lease costs for the amount of the land as shared between rice and prawn crops was considered, based on the prevailing rates. In the fixed costs, however, permanent fixtures and consumables that have already been in existence as part of the farming system for years such as sluice gates, pumps, boats, etc. were not considered, as these have become common infrastructure in all the existing farms in Kuttanad. Similarly, the power subsidy granted to farmers by government towards pumping costs for dewatering, which is unique to the waterlogged paddy fields in Kuttanad, was also not factored into this analysis, except for the marginal costs towards pumping (costs for pumping in addition to the subsidy component). Opportunity costs for family labor were also not considered because farm owners had no other source of income apart from paddy farming; therefore, the total costs for operation were treated as the total cost of investment.

Total variable costs for organic rice (Rs. 29,490) and organic prawn (Rs. 50,094) crops were 24 % and 19 % greater than the non-organic rice (Rs. 23,708) and non-organic prawn (Rs. 41,991) crops. Total operating costs were greater for organic crops; Rs. 37,805 for the organic rice crop, which was ~20 % greater than the non-organic rice crop (Rs. 31,618); and Rs. 59,850 for the organic prawn crop, which was 17 % greater than the non-organic prawn crop (Rs. 51,180).

Variable costs accounted for 84 % of the total costs of the organic prawn crop, 82 % for the non-organic prawn, 78 % for organic rice, and 75 % for non-organic rice. Major variable

Table 1 Comparison of variable costs associated with conventional and organic rice cultivation in rotational rice fields (figures in parentheses are percentage of the totals; 1 US\$ = approximately Rs. 50)

Item	Conventional rice			Organic rice		
	Quantity (ha ⁻¹)	Unit rate (Rs)	Cost (Rs ha ⁻¹)	Quantity (ha ⁻¹)	Unit rate (Rs)	Cost (Rs ha ⁻¹)
Operating costs						
Variable costs						
A						
1	Seed	20	2,493 (10.52)	125.71 kg	20	2,514 (8.52)
2	<i>Pseudomonas</i> for soaking seed and field applications			5.26 kg		1,578 (5.35)
3	Herbicides	200	267 (1.13)			
4	Pesticides (2 emergency applications)		646 (2.72)			
5	Inorganic fertilizers (3 applications)		2,750 (11.6)			
6	Organic manure and microbial supplements					3,709 (12.58)
7	<i>Tricho</i> egg cards (3 applications)					1,275 (4.32)
8	Probiotics (3 applications)					375 (1.27)
9	Labor charges					
i	Field preparation and manual weeding (women)	127.50	1,608 (6.78)	12.5 man-days	136.25	1,703 (5.77)
ii	Repair of bunds and feeder canal (men)	235	1,714 (7.23)	7.53 man-days	237.50	1,788 (6.06)
iii	Sowing of seed	127.50	388 (1.64)	2.83 man-days	136.25	385 (1.31)
iv	Spraying of herbicides (18–25 days of sowing)	150	302 (1.27)			
v	Fertilizer application (3 times)	150	1,175 (4.96)			
vi	Emergency pesticide application (2 applications)	150	738 (3.11)			
vii	<i>Pseudomonas</i> application			2.5 man-days	136.25	341 (1.16)
viii	Application of <i>Tricho</i> cards (3 times)			2.1 man-days	136.25	283 (0.96)
ix	Organic manure application (2 times)			4.92 man-days	136.25	670 (2.27)
x	Probiotic application (3 times)			8.12 man-days	136.25	1,106 (3.75)
xi	Manual weeding and spreading of rice seedlings (women)	136.25	1,619 (6.83)	20 man-days	137.50	2,750 (9.33)
xii	Transportation	150	2,845 (12)	14.6 man-days	150	2,188 (7.42)
10	Marginal cost for pumping (field drain out)		863 (3.64)			725 (2.46)
11	Mechanical harvesting		6,300 (26.57)			6,100 (20.68)
12	Inspection and certification fee					2,000 (6.78)
	Total variable costs (TVC)		23,708 (100)			29,490 (100)
Fixed costs						
B						
1	Land lease		6,250 (79.01)			6,250 (75.2)
2	Interest on operating cost at 7 % per annum		1,660 (20.99)			2,064 (24.8)
	Total fixed costs (TFC)		7,910 (100)			8,314 (100)
C	Total cost (TVC + TFC)		31,618			37,805

US\$ United States dollars, Rs Indian rupees, ha hectare

Table 2 Comparison of variable costs associated with conventional and organic freshwater prawn farming (figures in parentheses are percentage of the totals; the unit rates for prawns and fish represent the cost for 1,000 postlarvae and fingerlings, respectively; 1 US\$ = approximately Rs. 50)

Item	Quantity (ha ⁻¹)		Unit rate (Rs)		Cost (Rs ha ⁻¹)	
	Conventional prawns	Organic prawns	Conventional prawns	Organic prawns	Conventional prawns	Organic prawns
Operating cost						
A Variable costs						
1 Seed						
i Prawns (postlarvae)	28,607	25,835	320	420	9,011 (21.46)	10,722 (21.40)
ii Fish (fingerlings)	458	398	700	700	320 (0.76)	278 (0.55)
2 Feed	512 kg	554 kg	39.85	44.97	20,398 (48.58)	24,898 (49.70)
3 Tea seed cake	47.82 kg	35 kg	50	50	2,391 (5.69)	1,750 (3.49)
4 Consumables					613 (1.46)	844 (1.69)
5 Pond preparation (labor)	8.34 man-days	7.61 man-days	235	241.25	1,960 (4.67)	1,835 (3.67)
6 Farm labor charges	14.36 man-days	14.30 man-days	235	241.25	3,375 (8.04)	3,450 (6.89)
7 Harvesting expenses (labor)	9.51 man-days	8.93 man-days	235	241.25	2,235 (5.32)	2,154 (4.30)
8 Pumping costs					1,688 (4.02)	1,588 (3.17)
9 Inspection and certification fee				2,575		2,575 (5.14)
Total variable costs (TVC)					41,991 (100)	50,094 (100)
B Fixed costs						
1 Land lease					6,250 (68.02)	6,250 (64.06)
2 Interest on operating cost at 7 % per annum					2,939 (31.98)	3,507 (35.94)
Total fixed costs (TFC)					9,189 (100)	9,757 (100)
C Total cost (TVC + TFC)					51,180	59,851

US\$ United States dollars, Rs Indian rupees, ha hectare

costs in conventional rice farming included labor charges (43.8 %); costs of seed (10.5 %), herbicides, and pesticides (3.9 %); inorganic fertilizers (11.6 %); and harvesting expenses (26.6 %). Labor charges in conventional farming were those towards field preparation (repair of embankments, feeder canal, etc.), sowing, spreading of seedlings, manual weeding, application of herbicides, pesticides and fertilizers, and transportation for marketing the harvested produce (Table 1). In the case of organic paddy cultivation, variable costs included labor charges (38 %); costs of seed (8.5 %), organic manure (12.6 %), biofungicides (5.4 %), probiotic bacterial emulsions (1.3 %), and organic pest control methods (4.3 %); harvesting expenses (20.7 %); and the annual inspection and certification fee (6.8 %) that was shared between the organic rice and prawn crops. Labor charges in organic rice farming consisted of the activities of field preparation, sowing, spreading of seedlings, manual weeding, application of organic manure, application of biofungicides and *Tricho* egg cards, and transportation to market.

In the case of prawn farming, supplementary feed (48.6 % in conventional and 49.7 % in organic crops) formed the major component of total variable costs, followed by seed (approximately 22 % in both crops), labor, including harvesting expenses (18 % in conventional and 15 % in

organic), field preparation and farm consumables (7.2 % in conventional and 5.2 % in organic), and certification costs (5.14 %) in the case of the organic crop (Table 2). In our analysis, the annual cost of certification was shared between the organic rice and prawn crops from the same farm, which in total was less than 6 % of the total annual operating costs for organic rice and prawn crops combined.

In a study on the adoption of sustainable farming practices in Kuttanad, Bonny and Vijayaragavan (2001) found that a sizeable group (43 %) of rice farmers were adopting low-input farming practices with high, positive farmer sustainability indices. Even though these were combined with a few conventional farming strategies, it highlighted the potential that organic farming could be readily adopted by many of these farmers. The adoption of sustainable practices, particularly integrated pest management strategies, has the potential to significantly reduce the use of pesticides and increase crop yields (Birch et al. 2011). Further, integrated rice–fish farming system has the inherent advantage of reducing the cost of paddy cultivation and the use of inorganic chemicals, particularly in weeding and land preparation, while improving income. The impact of the inclusion of a rotational prawn crop in the rice fields of Kuttanad is revealed by our results; pesticides, herbicides, and inorganic fertilizers formed only

about 15 % of the total variable costs in conventional farming. In comparison, fertilizers and pesticides formed as much as 83 % of the total cost in conventional paddy farming in the Philippines (Mendoza 2004).

The operational costs in our study were higher in organic crops for both rice and prawns. In the Philippines, organic rice farming required 33 % less capital investment than that required for conventional farming, but needed more labor (Mendoza 2004). In the farms we studied, labor was one of the major components of the total operating costs for rice cultivation. The organic rice crop demanded more labor, generating 75 man-days ha^{-1} than the conventional rice crop (69 man-days ha^{-1}). The higher labor requirement for organic farming was mostly because of the application of organic manure and pest control methods. These were more frequent and labor-intensive activities compared to broadcasting inorganic fertilizers and spraying pesticides in conventional farming. The ratio of male–female labor was 64:36 for conventional rice and 57:43 for organic rice. The contribution of female labor in prawn farming was negligible; women were engaged only during harvest and post-harvest operations.

3.3 Partial budgeting analysis

For the paddy reared in Kuttanad fields, there is a government minimum support price system; every farmer gets a fixed price for their produce. The conventional rice produced in the farms we studied all received the same farm gate price (Rs. 11 kg^{-1}) for their harvest. Organic paddy and prawn farmers also received fixed premium prices for their produce, i.e., Rs. 15 kg^{-1} and Rs. 190 kg^{-1} , which were 36 % and 23 % greater than the prices for conventional rice and prawn, respectively. However, price inconsistencies were more common in the conventional prawn farming in the paddy fields of Kuttanad; there was no support price from government and the farmers received an average of Rs. 155 kg^{-1} , with the marketing system besieged by intermediaries who often do not pay a fair price to producers. Our results also show that the organic prawns achieved higher prices for every individual size class (counts) of prawn as shown in Table 3.

The cost–return and partial budgeting analysis per hectare per crop basis is provided in Table 4. Of all the four crops studied, the organic prawn crop returned the highest gross revenue followed by organic rice. Gross revenue from conventional rice was greater than conventional prawns. Gross revenue from organic rice (Rs. 65,646 ha^{-1}) was nearly 5 % greater than non-organic rice (Rs. 62,592 ha^{-1}), while organic prawns realized almost 33 % higher gross revenue (Rs. 80,781 ha^{-1}) than non-organic prawns (Rs. 60,807 ha^{-1}). Net revenue was highest for conventional rice among all the crops tested (Rs. 30,974 ha^{-1}), which was 11 % more than the organic rice crop (Rs 27,841 ha^{-1}). In contrast, the organic prawn crops fared far better, providing 117 % higher net revenue (Rs. 20,930 ha^{-1}) than the Rs. 9,627 ha^{-1} for the non-organic crop. Lan et al. (2008) found that prawn yields ranged from 412 to 584 kg ha^{-1} from rotational rice fields in Vietnam, but the yield was greatest at higher prawn stocking densities (6 postlarvae compared to 2 ha^{-1}). However, the investment cost significantly increased from US\$ 1,033 ha^{-1} at the lower stocking density to US\$ 1,844 ha^{-1} at higher density. Net profit was also significantly reduced from US\$ 591 ha^{-1} at 2 postlarvae ha^{-1} to US\$ 53 ha^{-1} at 6 postlarvae ha^{-1} .

The data from our study showed that all four crops were profitable with the highest return on investment (ROI) being for conventional rice (98 %) followed by organic rice (74 %). The ROI was greater for organic prawns (35 %) than for conventional prawns (19 %). Although the yield of organic rice was 23 % less than conventional rice, this was partly compensated by the 36 % extra price it fetched. However, the net revenue obtained was still greater in conventional rice. In contrast, in the organic rice trials reported from the Philippines, organic farms earned higher net revenue than conventional rice farms despite having about 8 % lower yields (Mendoza 2004).

The costs of producing 1 kg of rice and prawns on various major inputs, and the various indices of economic efficiency such as productivity of seed, feed, labor etc. in all the four crops tested, were also evaluated in our study (Table 4). We also compared the cost of using inorganic fertilizers together with pesticides and herbicides in conventional rice production with that of the use of organic manures and

Table 3 Premium prices (Rs kg^{-1}) obtained for individual size classes of prawns harvested from organic, compared to conventional farming (1 US\$ = approximately Rs. 50)

	Price obtained for the produce		
	Conventional prawns (Rs kg^{-1})	Organic prawns (Rs kg^{-1})	Enhanced price obtained for organic prawns (%)
>100 g	197.5	240	21.52
70–100 g	187.5	230	22.67
50–70 g	175	200	14.29
30–50 g	147.5	180	22.03
<30 g	65	100	53.85
Mean	154.50	190.00	22.98

US\$ United States dollars,
Rs Indian rupees

Table 4 Cost-return and partial budgeting analysis (ha^{-1}) of conventional rice, organic rice, conventional prawns, and organic prawns farmed in rotational crops (gross revenue in the case of prawns also includes that from fish—Rs. 2,644 in conventional and Rs. 1,797 in organic, but the

yield of fish was not considered while calculating the contribution margin; productivity of seed in the case of prawns, thousand-postlarvae $^{-1}$; 1 US\$ = approximately Rs. 50)

Particulars	Conventional rice	Organic rice	Conventional prawns	Organic prawns
1 Total production (kg)	5,690	4,376	360	396
2 Price kg^{-1} (Rs)	11	15	155	190
3 Gross revenue (Rs)	62,592	65,646	60,807	80,781
4 Total cost (Rs) (from Tables 1 and 2)	31,618	37,805	51,180	59,850
5 Net revenue (Rs)	30,974	27,841	9,627	20,930
6 Return on investment (ROI)	97.97	73.64	18.81	34.97
7 Productivity of seed (kg)	45.65 kg^{-1}	34.81 kg^{-1}	12.57	15.33
8 Productivity of feed (kg^{-1})			0.70	0.72
9 FCR			1.42	1.40
10 Productivity of labor (kg^{-1})	82.91	58.33	11.17	12.84
11 Employment generated (man-days ha^{-1})	68.63	75.03	32.21	30.84
12 Cost of production on seed (Rs kg^{-1})	0.44	0.57	25.06	27.07
13 Cost of production on feed (Rs kg^{-1})			56.72	62.86
14 Cost of production on labor (Rs kg^{-1})	1.82	2.56	21.04	18.77
15 Cost of production on fertilizers, pesticides, etc. (Rs kg^{-1})	0.64			
16 Cost of production on organic manures, biofungicides, etc. (Rs kg^{-1})		1.59		
17 Incremental benefit (Rs)	3,133			11,303
18 Incremental cost (Rs)	6,187			8,670
19 Net benefit (Rs)	9,320			2,633
20 Contribution margin kg^{-1} (Rs)	6.83	8.26	52.32	77.48

US\$ United States dollars, Rs Indian rupees, ha hectare

biocontrol methods in organic rice production. The cost of these applications for organic rice (Rs. 1.6 kg^{-1}) was greater than for the corresponding inputs in conventional rice production (Rs. 0.6 kg^{-1}).

Our study provides the first report that evaluates the production and economic efficiency of certified organic rice and freshwater prawn production in rotational rice fields.

Economic analysis revealed that although organic rice farming realized lower returns than conventional farming, the net revenue (Fig. 2) from a combination of organic rice with organic prawn farming (Rs. 48,771 ha^{-1}) was 20 % greater than the conventional rice–conventional prawn combination (Rs. 40,601 ha^{-1}). A combination of organic rice and organic prawn in rotational crops could be a feasible strategy for

Fig. 2 Comparison of the combined costs and returns from conventional rice–conventional prawn and organic rice–organic prawn rotational crops. The net revenue from the combination of organic rice with organic prawn farming is 20 % greater than the conventional rice–conventional prawn combination, despite higher (~18 %) operational costs for the former combination. The greater net revenue was realized by the premium price obtained for the harvested organic rice and prawns. Rs Indian rupees

augmenting the income of rural farmers, while supplying safe and nutritious food for the emerging markets, and protecting the environment.

4 Conclusions

Rice and giant river prawn production represent an ideal combination for rotational farming in wetlands where they complement each other. They effectively utilize the available resources and perhaps mitigate many adverse crop conditions for both forms of activity. The benefits of such integration seem to be better for the rice crop than are perceivable for prawns. However, further investigations are necessary to determine the possible interactions of rice and prawn crops, particularly in optimizing water quality for prawns as evidenced by the reduction of unionized ammonia in water during prawn grow-out in the organic farming environment.

The challenge before any organic aquaculture certification program is to make the recommended farm practices adhere strictly to the accepted standards in place and to adapt to the rearing conditions for particular species, thus reasonably balancing farm outputs and market demands. Rice–prawn rotational farm fields in our study presented an ideal situation for organic certification because of the inherent low-intensity culture practices. The farming protocol followed, even in conventional farming, had minimal use of pesticides and herbicides before and during rice production. The transitional crop before organic certification further ensured that any traces of inorganic residues had been washed off. The presence of fish and prawns in the aquaculture phase ensured a naturally leveled field for direct sowing of rice without the application of any herbicides, which would otherwise have formed a major cost component, apart from savings on labor.

Our results for organic rice yield were similar to the many published reports in showing a reduction in output, compared to conventional production, but these differences were not significant. The difference in yield between conventional and organic prawn crops was also not significant. Despite the low levels of organic manure used, the rice stubbles and straw remaining in the fields after the harvest of rice return most of the nutrients and organic matter and may help to conserve the soil nutrient status in the rice–prawn fields in the long term. Therefore, it can be assumed that over a few crops, these differences would level off and the organic crops would tend to yield as much as non-organic crops or even more in the fertile rice–prawn rotational fields. The prawn farming practices prevailing in Kuttanad are more or less similar to a “modified extensive” system with the provision of supplementary feed. Unlike organic rice cultivation where large-scale replacement of inorganic fertilizers, pesticides, and herbicides by organic manure, probiotics, and bio-pest control measures was necessary to ensure a comparable crop of

organic rice, there was no additional input in organic prawn production other than the certified organic feed supplement. However, further studies are recommended to determine the nutrient dynamics in the soil and water phases of rice–prawn fields. These may show that substantial reductions in the input of organic feed in prawn farming are feasible since the prawns would be able to utilize organic manure and other inputs used in the previous crop of organic rice. This would considerably reduce the operational costs of organic prawn farming as supplementary feed forms approximately 50 % of the total variable costs.

Government support in the form of power subsidies and minimum support prices for the produce are the two major factors affecting profitability of rice cultivation in Kuttanad. The value of rice production as a profitable enterprise was revealed by our analysis. Price fluctuations and problems with seed quality and water conditions have been major issues for prawn farming in the rotational fields of Kuttanad. These are largely overcome by organic farming, which guarantees premium prices for the harvested produce without intermediaries, ensures the quality of seed by certification, and improves water quality.

In our study, we could not assess the quality of the organic produce. Detailed research, not limited to organoleptic evaluation, is recommended for evaluating the grain quality of rice and meat quality of prawns hypothesizing some quality advantage in the organic produce. Further, the energy use efficiency of rotational rice–prawn farming systems should also be compared to understand the relative differences between organic and conventional farming methods. The pumping of water from the paddy polders is an energy-intensive operation (although this is not adding to the operational cost as it is almost fully subsidized by government), but this is inevitable to carry out any kind of farming in the waterlogged fields of Kuttanad.

Further questions will also arise in streamlining the farming protocol and the standards used for organic prawn farming, particularly with regard to the use of tea seed cake or mahua oil cake in eradicating predatory and weed fishes, although this is only practiced in about 10 % of the total prawn grow-out area (i.e., the nursery area). At present, this is inevitable in order to obtain a balanced crop of prawns; screening of intake water can do little to prevent extraneous fish entering into prawn nursery. In the grow-out field, there is no effective control other than screened sluice gates over the entry of other fish, and the prawns virtually grow in an extensive natural environment. This is one of the best scenarios for organic farming.

To our knowledge, this is the first report of successful production of certified organic rice and organic freshwater prawn from rotational crops in rice fields. We believe that our results indicate that there is great potential for expansion in suitable areas. The novelty of organic rice–prawn rotational

farming practice lies in the manner in which both rice and prawn crops are synergized in producing safe and nutritious food. In our study, combining organic rice with organic freshwater prawn production in paddy fields as rotational crops achieved 20 % more net revenue than the combination of conventional rice–conventional prawn production. This is an important outcome and demonstrates the potential for adapting rotational rice–prawn farming practices to organic farming.

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