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Comparison Environmental Conditions and Economic Efficiency Between Organic and Non-Organic Integrated Mangrove – Shrimp Farming Systems in Ca Mau Province, Vietnam

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ABSTRACT

Mangrove forest protection is an essential solution for mitigating the impacts of natural disasters in coastal zones and climate change. Integrated mangrove-shrimp farming (IMSF) system has been promoted as a sustainable livelihood that can provide income for farmers and protect mangrove forests. However, the productivity of shrimp is limited. Therefore, to enhance the revenue for farmers, improving the value of shrimp products is a good option. Organic shrimp farming practices following the EU aquaculture organic standards have been previously applied in some areas of the Mekong delta. This study was conducted to compare technical, financial characteristics and environmental parameters between the applied (i.e., organic farms) and non-applied (i.e., non-organic farms) standards of Naturland, aiming to support the development of ecological shrimp farming and contribute towards green development. The study was carried out in Nhung Mien mangrove forest, Ngoc Hien district, Ca Mau province, Vietnam. Fifty organic farms and 50 non-organic farms were directly interviewed using structured questionnaires. And then, three farms in each system were selected for monitoring water quality. Results showed that the average mangrove coverage was 54.1% in the organic IMSF system and significantly different from the non-organic IMSF system ($p<0.05$). Total shrimp yield, total income and total profits tended to increase in organic IMSF system and the selling shrimp price increased by 10% compared to the conventional price. The study showed that following organic farming methods could provide higher income for farmers and a better chance to mitigate natural disasters and climate change impacts.

Keywords: integrated mangrove-shrimp farming system; organic and non-organic IMSF systems; Natural certificate; Ca Mau province.

INTRODUCTION

Mangrove forest plays a vital role in mitigating the impacts of natural disasters in coastal zones (Rabindra et al., 2009). Mangroves are natural barriers to storms, shoreline erosion and sea-level rise (Truong and Do, 2018). Therefore, reservation mangroves at the coastlines are essential. The IMSF system has been promoted as a sustainable livelihood in mangrove reserves in the Mekong Delta, especially in Ca Mau province. Ca Mau has the most prominent and wealthiest mangrove ecosystem in Vietnam (Veettil et al., 2019). However, the mangrove forest area was decreased by the shrimp aquaculture expansion. On the other hand, the shrimp productivity in the IMSF system also was limited by several factors such as low quality and quantity of shrimp seed, poor pond management, poor water quality (Clough et al., 2002; Hai and Yakupitiyage, 2005), leaf litter-fall and decomposition, shrimp survival rate and predators affecting shrimp yield in the system (Bosma et al., 2016; Viet and Hai, 2016). Therefore, to enhance the income for farmers, improving the value of shrimp products is a good option. The Vietnam Association of Seafood Exporters and Producers initiated the development of organic certification in Ca Mau province (Ha et., 2012). By 2010, the German organic certification scheme Naturland has been applying to 1000 farms in IMSF systems (Ha et al., 2012; Omoto, 2012). The organic certificate has improved the revenue for households through the selling price of shrimp in the organic IMSF system was increased by 10% (Angus and Richard, 2015). Therefore, the Naturland certificate has been demonstrated as one of the promising solutions to improve household income and encourage reserving mangrove areas (Ha et al., 2012; Angus and Richard, 2015). Besides, it also contributed to green development and promoted ecological shrimp farming practices. The objective was to encourage the households to reserve mangrove areas in the coastal regions. This study was carried out to compare the economic benefits and environmental quality between two IMSF systems, which applied and non-applied standards of Naturland.

MATERIALS AND METHODS

Identified the study site and interviewed households

This study was carried out at Nhung Mien mangrove forest, Vien An Dong commune, Ngoc Hien district, Ca Mau province, Vietnam (Fig. 1). Here a total of 2.683 households applied IMSF system, in which more than 1.000 households have been applied the German organic certification scheme Naturland (i.e., Naturland standard).

Data collection and analysis

Farming practices and economic efficiency

The Nhung Mien Mangrove Forest Management Board, Ca Mau province provided a list of households with detailed information including applied and non-applied organic certificates. Besides that, mangrove area and mangrove forest production were demonstrated. Based on the primary data, 50 organic IMSF farms and 50 non-organic IMSF farms (i.e., applied and non-applied the organic certification to the Naturland standard) were selected and interviewed by using structured questionnaires. Concerning information during interview and environmental conditions are summarized in Table 1.

Water quality and pond bottom sediment characteristics

Based on the result of survey research, the study selected six farms for collecting water and sediment samples (Fig. 1). In which, three farms were obtained the Naturland certificate (e.g., organic IMSF system) and three farms cultivated the conventional farming (e.g., non-organic IMSF system). Water samples were collected from 20–30 cm below the surface (Johnston et al., 2002) with three replicates at each sampling point, then mixed to get a representative sample. Water samples were stored in an ice chest and taken to the laboratory where they were kept at 4^{o}C in a refrigerator prior to analysis. The temperature, pH, DO and salinity of water samples were measured at sampling time by using the corresponding portable meters. All water quality parameters were analyzed by the Standard method (APHA, 1998).

Statistical analysis

Statistical analyses were performed in Statistical Package for Social Sciences (SPSS) version 26.0 (SPSS Inc., Chicago, IL, USA). Analysis of variance was performed to compare characteristics between organic and non-organic IMSF systems. Water quality parameters were compared with the Vietnamese standard level for brackish shrimp water quality (MARD, 2014) and for the protection of aquatic life (MONRE, 2008; 2011). All computations and the figures were prepared in Origin 2019 software (OriginLab, Northampton, MA, USA). All differences were compared at the 5% level of significance.

Table 1. The group of quantitative and qualitative variables used in the questionnaires

Variables	Components
Farming practices	Area: farm area, mangrove coverage, mangrove age. Farm characteristics: sediment height after dredging. Shrimp: total stocking density, total shrimp yield. Economic: total initial cost, total income and total profit.
Water quality parameters	Water samples: temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), salinity, alkalinity, ammonium (NH_4-N), nitrate (NO_3-N) and nitrite (NO_2-N).

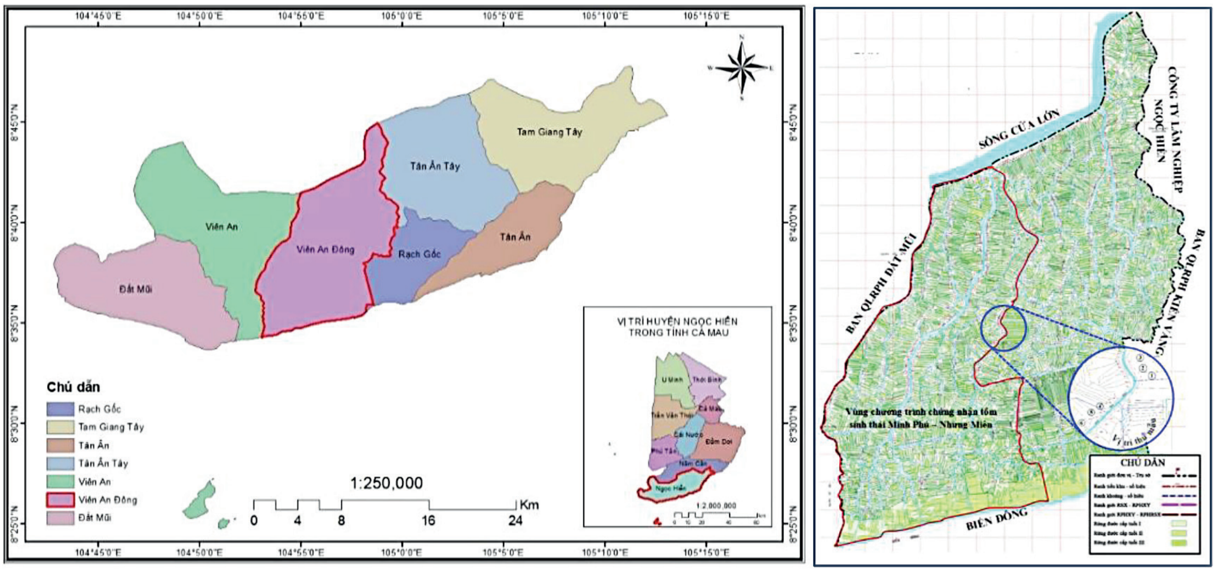

Figure 1. Map of Ngoc Hien district (a) and sampling sites (b) for collecting all samples

RESULTS AND DISCUSSIONS

Technical characteristics and financial efficiency of organic and non-organic mangrove-shrimp farming systems

The mangrove coverage and total stocking density were higher in organic IMSF systems than non-organic IMSF systems and showed significant difference (Table 2; $p<0.05$). Here, mangrove coverage in organic IMSF system was 54.1% and non-organic IMSF system was 47.1%. According to the Naturland standard, the mangrove coverage should be at least 50% of total area of IMSF system. Meanwhile, the Vietnamese government regulation requires a ratio of 40:60 pond to forest area for farms smaller than 3 ha (Decision No. 186/2006/QĐ-TTg). The mangrove coverage in the present study shows a result comparative to the Naturland standard, yet lower than the value in the government decision. Previous studies on the IMSF system in Ca Mau province indicated the percentage of mangrove-shrimp forest in the organic farming system was 50.2% in coastal areas (Sinh and Chanh, 2009) and 50.8% in Lam Ngu Truong (Xuyen, 2011; Phan, 2013). In addition, the research of Truong and Do (2018) analyzed data from integrated shrimp ponds in Ngoc Hien District and found that ponds with mangrove coverage of 30–50% have the highest return and confirmed an optimal mangrove coverage of 30–50% (Bosma et al., 2014). In general, the mangrove coverage in the present study of interviewed households was within the range area reported by the above authorities. Total stocking

Table 2. Technical farming characteristics and financial efficiency in organic and non-organic IMSF systems of 100 households (calculated for one ha per year)

VariableS	Organic IMS farming system	Non-organic IMS farming system
Farm area (ha)	3.71 ± 1.2^{b}	4.68 ± 2.97^{a}
Mangrove coverage (%)	54.1 ± 6.49^{a}	47.1 ± 6.43^{b}
Mangrove age (year)	7.45 ± 2.5^{6}a	7.59 ± 2.81^{a}
Sediment height after dredging (cm)	32.1 ± 10.2^{a}	34.2 ± 8.83^{a}
Total stocking density (shrimp/m^2)	25.2 ± 9.69^{a}	20.2 ± 7.5^{b}
Total shrimp yield (kg/ha/year)	88.0 ± 27.2^{a}	90.4 ± 31.0^{a}
Total initial cost (mill VND/ha/year)	17.7 ± 6.9^{a}	15.7 ± 5.36^{a}
Total income (mill VND/ha/year)	38.4 ± 13.2^{a}	36.2 ± 10.5^{a}
Total profit (mill VND/ha/year)	22.7 ± 9.66^{a}	20.9 ± 8.04^{a}

Note: The value was presented by mean ± standard deviation; Different letters within the same row indicate significant difference at $p<0.05$ by Independent sample T-test.

density in organic IMSF system was higher than non-organic system and showed significantly different (Table 2; $p<0.05$). In addition, the total initial cost was higher in organic IMSF system (17.7 million VND/ha/year) than non-organic IMSF system (15.7 million VND/ha/year). This can be explained by the stocking density and the number of shrimp stocking in organic IMSF system (4–6 times per year) was higher than in non-organic IMSF system (3–4 times per year). However, the shrimp yield was not significantly different between organic and non-organic IMSF systems, with the value of each system recorded 88 and 90.4 kg/ha/year for total shrimp yield, respectively. Some previous studies showed that the shrimp yield in the IMSF system fluctuated 79.1–97.4 kg/ha/year (Sinh and Chanh, 2009; Xuyen, 2011; Huynh, 2015). The shrimp yield in the present study was within the range of previous studies. The average value was recorded as 38.4 and 36.2 million VND/ha/year for total household income and 22.8 and 20.9 million VND/ha/year for total profit, respectively. Although, the total household income and profit tended to increase in organic IMSF system but not significantly different from non-organic IMSF system (Table 2; $p>0.05$). When households applied for the organic standard by Naturland, Minh Phu seafood processing company committed to increasing shrimp price they paid the farmers by 10% compared to the conventional price or even the shrimp price in organic IMSF system could increase 20% (Ha et al., 2012). In this study, the shrimp price in organic IMSF system was sold higher 10% compared to non-organic IMSF system and this cause could increase the total income and total profit in organic IMSF system. In general, if the mangrove-shrimp systems had achieved the organic certification by Naturland standards, they improved household profits and cause fewer negative effects on the environment such as water pollution as well as the destruction of mangrove forest ecosystems. Moreover, the organic IMSF system positively impacts on natural resources and mangrove ecosystems. Besides, it also contributes to the green sustainable development in the integrated mangrove-shrimp farming system (Brunner, 2014). Futhermore, the IMSF system can increase environmental quality and socio-economic sustainability through species diversification (Thomas et al., 2021).

Water quality in organic and non-organic IMSF systems

The temperature (Fig. 2A) and pH value (Fig. 2B) of water samples in the shrimp ponds of the two systems showed not significantly different ($p>0.05$). The temperature in organic IMSF system ranged between 26.5°C and 30.1°C, while the non-organic IMSF system fluctuated from 26.2°C to 30.2°C. pH values showed stability at the five sampling times and did not differ significantly ($p>0.05$). Organic and non-organic IMSF systems were recorded from 7.2 to 7.4 and 7.1 to 7.4. The results are very similar to those of Binh et al. (1997), who assessed water quality in mangrove-shrimp ponds on the East and the West coasts of Ngoc Hien district, Ca Mau province. The average values of physicochemical parameters in pond water were pH (7.4–7.5) and temperature (27.7–28.3°C), and these values in the present study are consistent with the research of Andrew (2007).The measured concentration of DO and BOD_5^{20} in the shrimp ponds was presented in Figure 3. The results did not differ significantly in DO and BOD_5 parameters between organic and non-organic IMSF systems ($p>0.05$).

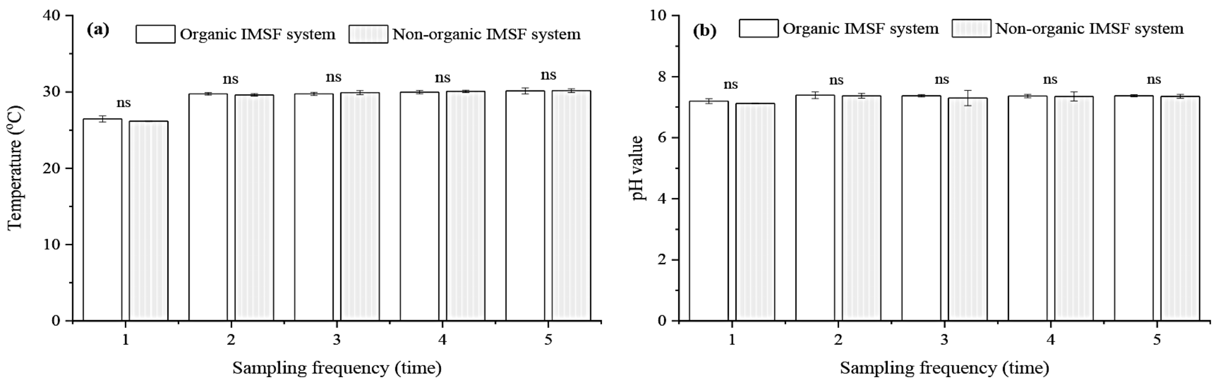

Figure 2. Temperature (a) and pH (b) in shrimp pond water of two IMSF systems

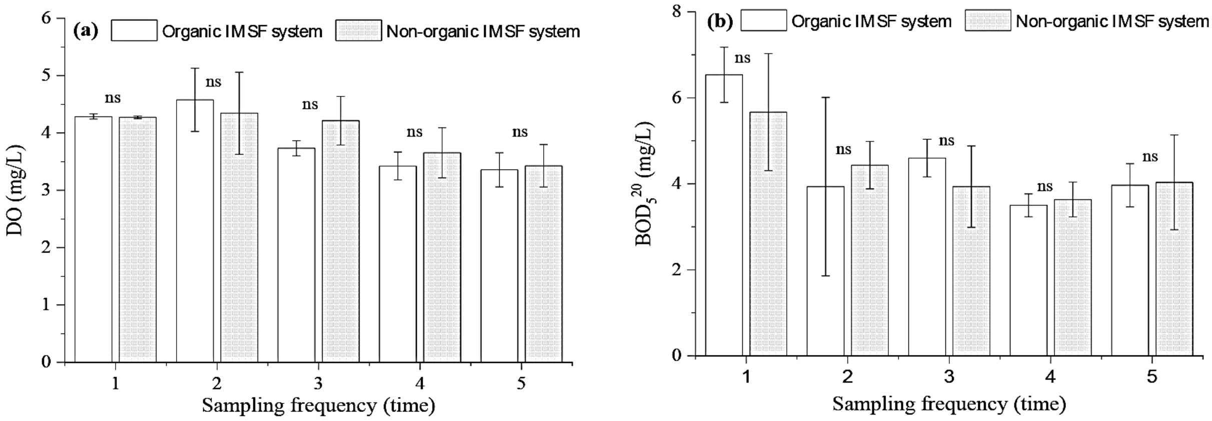

Figure 3. DO (a) and BOD_5^{20} (b) parameters in shrimp pond water of two IMSF systems

The DO concentration (Fig. 3A) ranged from 3.4 to 4.6 mg/L in organic IMSF system and from 3.4 to 4.3 mg/L in non-organic IMSF system. While the BOD_5 concentration (Fig. 3B) ranged from 3.5–6.5 mg/L in organic IMSF system and from 3.6–5.7 mg/L in non-organic IMSF system. The TSS and alkalinity concentrations were not significantly different between organic IMSF system and non-organic IMSF system ($p>0.05$). Figure 4A showed that TSS concentration ranged from 28.4 to 46.1 mg/L in organic IMSF system and 35.5 to 53.3 mg/L in non-organic IMSF system. The alkalinity concentration in organic and non-organic IMSF systems (Fig. 4B) were ranged from 61.9 to 99.8 mg/L and 62.8 to 99.0 mg/L, respectively. According to Ferreira et al. (2011), the alkalinity concentrations in the shrimp ponds should not exceed 140 mg/L. The average alkalinity concentration in the present study complied with the Vietnamese standard for brackish shrimp water quality requirement of 60–180 mg$CaCO_3$/L (MARD, 2014) and was acceptable compared to reported by Ferreira et al. (2011). Salinity, NH_4-N, NO_3-N and NO_2-N concentrations were not significantly different (Table 3; $p>0.05$) between organic IMSF system and non-organic IMSF system. Furthermore, comparison of the temperature, pH, TSS and NH_4-N parameters in shrimp ponds water all were within the Vietnamese standards (MONRE, 2008), the national technical regulation on coastal water quality, with the limit value of temperature (30°C), pH (6.5–8.5), TSS (50 mg/L), and NH_4-N (0.1 mg/L).

Meanwhile, the concentration of DO in both ponds ranged from 3.4 to 4.6 mg/L and this value was also lower than the threshold specified by MONRE (2008) (DO ≥ 5 mg/L). The cause can be explained by the impact of fallen mangrove leaves, leading to the decomposition and consumption of oxygen content in the ponds. Besides, the NO_2-N and NO_3-N are two important parameters in the IMSF systems. The NO_3-N parameter is the non-toxic form the aquaculture organisms, and it is final product of the nitrification process.

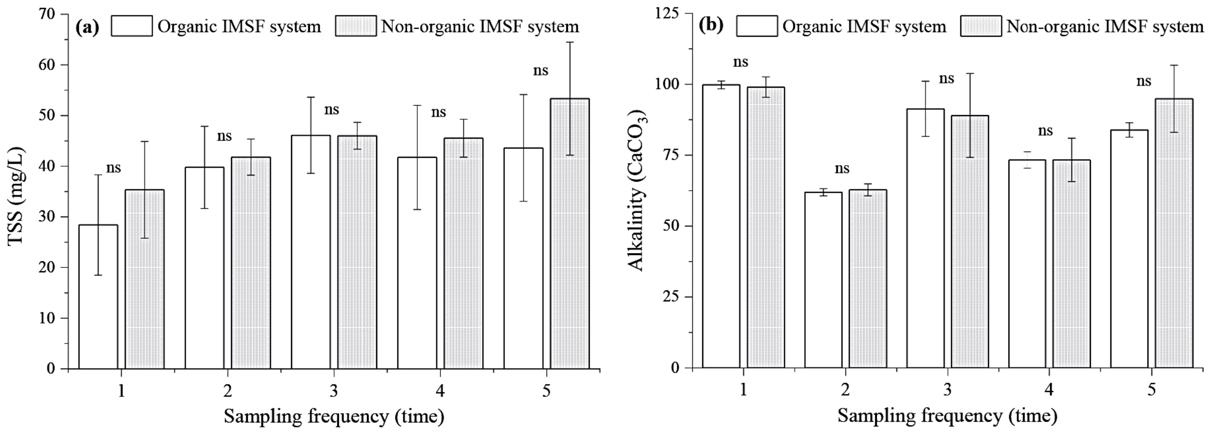

Figure 4. TSS (a) and Alkalinity (b) parameters in shrimp pond water of two IMSF systems

Table 3. Salinity, NH_4-N, NO_3-N and NO_2-N concentrations

Parameters	Integrated mangrove-shrimp system	Sampling frequency (time)				
		1	2	3	4	5
Salinity (‰)	Organic system	29.0	30.0	30.0	32.0	32.0
	Non-organic system	28.7	30.0	30.0	31.7	32.0
NH_4-N (mg/L)	Organic system	0.009	<0.01	0.085	<0.01	0.021
	Non-organic system	0.028	0.02	0.095	<0.01	0.009
NO_2-N (mg/L)	Organic system	0.012	<0.006	<0.006	<0.006	<0.006
	Non-organic system	0.008	<0.006	<0.006	<0.006	<0.006
NO_3-N (mg/L)	Organic system	0.028	0.019	0.105	0.051	0.176
	Non-organic system	0.034	0.013	0.046	0.090	0.101

In the present study, the NO_2-N and NO_3-N concentrations were low ranged from <0.006 to 0.012 mg/L and 0.013 to 0.176 mg/L, respectively. Comparison with the Vietnamese standard shows that the values of NO_2-N and NO_3-N were within the National technical regulation on surface water quality for the protection of aquatic life for tiger shrimp and white leg shrimp growth in IMSF system (MONRE, 2011), with the limit value of NO_2-N (0.02 mg/L) and NO_3-N (5 mg/L). However, the results in this study were lower than those reported in previous studies (Whetston et al., 2002; Yusoff et al., 2010; Furtado et al., 2014). In particular, the NO_2-N concentration in shrimp ponds should be ideally < 0.23 mg/L (Whetston et al., 2002) and the NO_3-N concentration in brackish aquaculture should be ideally below 20 mg/L. When this value increases up to excessive levels it slows the growth of aquatic organisms and increases disease sensitivity, low survival rates and reduces reproductivity (Yusoff et al., 2010). In the present study, the NO_2-N and NO_3-N concentrations were lower than the results of previous studies, this might be due to the low stocking density of shrimp, or no feeding supplementation associated with high frequent water exchange during the growth cycle.

CONCLUSIONS

The shrimp yields, total income and total profits were showed higher in organic IMSF system than non-organic IMSF system. While the selling shrimp price increased at least 10% compared with the conventional price at harvest. Therefore, the government and local authorities in Ca Mau province should encourage farmers, to apply the Naturland standard. Water quality and sediment characteristics in two IMSF systems showed not significantly different and were within the Vietnamese standards for water quality requirements for shrimp growth. Although, the concentration of DO was reached low values in both systems. Therefore, farms should increase the oxygen content in the IMSF system.

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