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Research

Evaluation of Environmental Parameters and Economic Efficiency of Integrated Farming System on Acidic Soil and Saltwater Intrusion in The Coastal Area: A Case Study of Mekong Delta, Vietnam

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ABSTRACT

The shift to growing sedge plants, combining raising snails and tilapia in coastal areas could improve the soil nutritional environment, income, and land use efficiency compared to rice monoculture. This study aims to evaluate soil and water environmental factors and to compare the financial efficiency of integrated farming with rice monoculture farming. These experiments were arranged on field land affected by drought and saltwater intrusion in two ecological regions of Kien Giang province. The research found the adaptation of crops (rice, sedge) and aquatic species (snails, tilapia) to the characteristics of acidic and saline soils in coastal areas. The results showed that an integrated farming system reduced soil salinity, but increased soil pH, nitrogen, phosphorus, potassium, and organic matter content more than rice monoculture farming. In addition, this system improved pH, reducing salinity, temperature, and TDS of water more than rice monoculture farming. Acidity and salinity factors affect the rice yield of Winter-Spring crops. The sedge grass (*Cyperus malaccensis*) grew well under the pH and salinity conditions, but the sedge yield in the dry season was higher than in the rainy season. The weight gain of tilapia *(Oreochromis niloticus*) was from 0.45 to 0.96 g/day, but fish yield was still low (226 - 541 kg/ha); due to low survival rate (30-36%). Snails (*Pila gracilis*) adapted well to experimental conditions and the survival rate reached 53-79%. The data analysis of financial efficiency showed that the profit of integrated farming was higher than rice monoculture farming (10,905 to 11,146 USD compared to 904-1,672 USD/ha/year). Therefore, diversified land use in coastal areas to grow sedge grass combined with snails and tilapia increased household income in these study sites.

Key words: Diversified land use, financial efficiency, integrated farming, rice monoculture farming, sedge grass

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INTRODUCTION

The transformation of integrated farming systems (combining crops, livestock, & fisheries) at the household level in rural areas of Asia regions was an issue of current concern. Small-scale households can diversify production activities to increase family food sources or sell for additional income (Dung *et al*., 2017; Ha, 2020). The Mekong Delta (MD) of Vietnam was a rice production region and rice export output, which activities were help Vietnam to rank in the top 5 of rice export in the world (De, 2006). However, rice monoculture farming used a lot of fertilizers and chemicals, which has negatively impacted the agricultural ecological environment and affected biodiversity (Nhan, 2009; Toan, 2013). Kien Giang province located in the MD region, which had the largest area of rice farming and affected by factors such as: drought, saline water intrusion, natural disasters and degradation of productive land due to increasingly serious impacts of climate change (Tuan, 2012). Rice plants was sensitized to environmental salinity (soil & water), so salinity of 3 ppt reduces grain weight (Khuong, Khanh & Hung, 2018). Therefore, rice monoculture farming did not improve the agricultural ecological environment, but also directly impacts the livelihoods of farmers and affects the sustainable development of the MD of Vietnam.

There were many studies applying methods of rotating rice with other crops and aquatic species in the coastal areas of the MD to improve the characteristics of rice fields (Guong, Dong & Khoi, 2010; Long & Phuong, 2010), but intensive farming and increasing the number of crops/year caused more soil salinity (Tri, Guong & Kiet, 2009). Furthermore, the overused chemicals in treating aquatic diseases and industrial food residues cause environmental pollution increasingly (Long, Sinh & Hao, 2010; Mai, Ni & Hai, 2014). Some coastal areas are no longer favorable for shrimp and fish farming as before, due to organic matter in pond bottom mud and length of fish/shrimp farming time (Son *et al.*, 2014). Meanwhile, there were not many studies on the application of crop species (such as vetiver grass, sedge grass, water hyacinth, & duckweed) to treat polluted water sources (Loc *et al.*, 2015). Specifically, the sedge grass (*Cyperus malaccensis*) grew well in wetlands, acidic soils, and saline soils of 4 - 8 ppt (Ngot, Nhan & Son, 2014; Hang *et al.*, 2022), and could improve wastewater containing NH^{4+} and PO_4^{3-} (Cuong, 2012). A potential aquatic species is Nile tilapia (*Oreochromis niloticus*) which can be cultured in saline areas for up to 20 ppt (Toan, Sang & Khuyen, 2012), or polyculture with other fish species in rice fields (Nico, 2002). Meanwhile, snails (*Pila gracilis*) can live in many different types of water bodies (Shamita *et al.*, 2014; Thao & Binh, 2017), and are very diverse in ecosystems with salinity 3 ppt (Ting *et al.*, 2020); However, this snail species has not been studied much (Joshi *et al.*, 2017; Piyaruk, 2017) and there is little information about the factors affecting the distribution of snails in the MD (Tu, 2015; Sang & Thinh, 2017). Therefore, integrated farming systems research is needed to protect native aquatic species and contribute to increasing income for farmers in the MD of Vietnam.

At present, there have not been many studies on integrated farming systems (sedge grass-fresh water snail-nile tilapia) based on environmental aspects and economic efficiency. Therefore, this study aims to evaluate soil and water environmental factors, crop productivity, and aquaculture species in coastal areas of Kien Giang province. This research also meets the needs of transition in agriculture and copes with the negative impacts of climate change.

MATERIALS AND METHODS

Research subjects

The objects studied are rice, sedge grass (*C. malaccensis*), snail (*P. gracilis*), and Nile tilapia (*O. niloticus*). These subjects were tested on farmer's fields cultivated with 2 rice crops/year, in 2 ecological regions: Southwest Song Hau (site 1) and Long Xuyen Quadrangle (site 2) in the coastal area of Kien Giang province. These ecological regions had acidic soil, and saline water and have been affected by climate change (such as drought, lack of fresh water, flooding & saltwater intrusion, making it unfavorable for rice farming).

Trials in farmer's fields

Location of site 1 was in Chau Thanh district (Latitude 950' to 10°5'; and Longitude 105°7' to 105°17'), in the southwest region of Hau River of Kien Giang province. This location was a lowland area and flooded in the rainy season for 15 days (the flood level was 0.5-0.7m). In the dry season affected by saltwater intrusion. According to the soil profile description alluvial soil at a depth of 55 cm was the alum layer (pH 3.7-4.5) and salinity 2.5 ppt.

The location of site 2 is in Hon Dat district (Latitude 9°48'27''; & Longitude 103°23'), in the Long Xuyen Quadrangle of Kien Giang province. This was a land that gradually lowered towards the West Sea; The rainy season flooded for 20 days, with a flood level of 0.3 m. The dry season was affected by salt water. According to the soil profile description alluvial soil had a high proportion of clay. At a depth of 50 cm the alum layer (pH from 3.2 to 4.2), salinity from 2.5 to 2.8 ppt.

The experiment was arranged in farmers' fields and indicators were evaluated for one year (from April 2022 to April 2023). The experimental design was completely randomized in two treatments including an integrated farming system (sedge-snail-tilapia) and rice monoculture farming (two crops/year) such as a control treatment, and three times repeated. The area of each lot was 150 m^2 (10 m x 15 m), with surrounding area of dikes and canals (accounting for 15%); The canal was a shelter for snails and fish when there was a lack of water in the sedge field, and the dike managed water between experimental plots (the dike was 0.6 m high, the canal was 0.6 m deep and 0.8 m wide).

Materials and methods for rice farming

The summer-autumn crop was from April to September and the winter-spring crop was from October to April of the following year. Rice variety ST24 was used with a seeding rate of 80 kg/ha. The fertilizer formula was adapted well for rice farming at each crop; 100 Nitrogen (N)-50 Phosphorus (P_2O_5)-30 Potassium (K_2O). This fertilizer formula was applied 3 times (10, 25 & 45 days after sowing). The water level in rice fields was kept from 5-10 cm and pest prevention according to IPM (Integrated Pest Management). At harvest time, the height stem and number of rice stems were measured and counted in a 0.5 m x 0.5 m sample frame. In each sampling frame, 100 panicles were randomly collected to analyze yield components (grain weight and moisture); The remaining part was separated from the seeds (dried at 40-45°C), weighed, and measured for moisture (14%) to convert to yield (tons/ha).

Materials and methods for sedge farming

The crop was planted in the Summer-Autumn crop (April) and the first harvest was in October. The second crop was harvested in the winter-spring (April of the following year). The brown cotton sedge variety was used in the experiment with a planting density of 25 cm x 30 cm. The fertilizer formula for sedge farming at each recycle harvesting; is 240 Nitrogen (N)-32 Phosphorus (P_2O_5)-150 Potassium (K_2O). This fertilizer formula was applied at 5 days, 30 days after planting, and 30 days before harvest. Keeping the field moist until 20 days after planting and then increasing the water level in the field to 15-30 cm throughout the growing period. Collecting agronomic indicators of sedge grass included: height (cm); stem diameter (mm), and total number of stems/m^2. Fresh yield, collected 1 m^2/lot then weighed (kg/m^2), dried then weighed (kg/m^2), calculated dry/fresh ratio (%), and yield tons/ha.

Materials and methods for fish farming

Nile tilapia fingerlings (weight 7-8 g/fish) were released into sedge fields that had been planted for 20 days, at a density of 1 fish/m^2 of water surface. Raising fish was not supplemented with food to evaluate the ability to use natural food sources in the field. The time to harvest fish was after harvesting sedge and rice; The form of harvesting fish of commercial value for sale (size & weight). Small fish continued to be raised and cared for in the next farming season. Fish collection criteria included: weight at stocking, weight at harvest, growth rate (g/day), survival rate (%), and productivity (kg/ha).

Materials and methods for snail farming

The snail variety (weight 6 g/snail) was released into the sedge field that had been planted for 10 days, with a density of 10 snails/m^2 of water surface. Raising snails did not add additional food to evaluate their ability to use natural food sources in the field. The time to harvest snails was after harvesting sedges and rice; The form of collection was large snails, reaching commercial value for sale (size & weight). Small snails are continued to be raised and cared for in the next farming season. Collect snail indicators included: size (mm), weight (g), growth rate (g/day), survival rate (%), and productivity (kg/ha).

Data collection and analysis

Soil analysis was performed 2 times (before & after the experiment) with the following method: soil profile description and recording the current state of cultivation in the field. Soil analysis in the laboratory included indicators: pH, EC, salinity, nitrogen (%), phosphorus (%), potassium (%), and organic material (%). During the experiment, water parameters were sampled every 2 weeks with the following criteria: pH, salinity (ppt), temperature (°C), total dissolved solids-TDS (ppm), and water transparency (cm) by using a Secchi disk. Sample collection time was measured directly in the afternoon (3:00 PM) with a handheld water tester, and the measurement method was 30 cm above the water surface.

Recording all of the cost inputs for the farming systems included: labor, expenditure on materials, fuel, and equipment rental. Total income from crops, fish, and snail; and products output at market price. All data were analyzed statistically (mean value, standard deviation, error) in a completely randomized arrangement. In particular, using the ANOVA analysis of variance method and T-*Test's* significance compared the difference between the average values.

RESULTS AND DISCUSSION

Soil analysis

The trials' fields were affected in saline and acidic soil, but they had high nutrition. The results of soil analysis before setting up the experiment (site 1) showed a soil pH of 3.7 and salinity of 2.5 ppt (Table 1). This soil had high fertilizer such as total nitrogen from 0.16-0.28%, total phosphorus 0.13-0.15%, exchangeable potassium 0.58-0.61%, and high organic content (2.86-5.27%). Similarly, soil analysis at site 2 showed that the pH from 3.2 to 4.2 and salinity from 2.5 to 2.8 ppt. The soil had total nitrogen of 0.16-0.17%, total phosphorus of 0.27-0.33%, exchangeable potassium of 0.36-0.93%, and organic content was quite high (6.03-8.82%). In general, this soil was suitable for arranging experimental models.

Table 1. Characterization of soil on the rice fields (before and after trials) for integrated farming and rice monoculture farming system by experimental sites at the sampling dates

Items	(1) Chau Thanh site				(2) Hon Dat site			
	Integrated farming		Rice monoculture		Integrated farming		Rice monoculture	
	Before (2022)	After (2023)	Before (2022)	After (2023)	Before (2022)	After (2023)	Before (2022)	After (2023)
pH	3.70	3.66	3.81	4.17	3.63	4.07	3.28	4.17
EC(ms/cm)	3.99	1.71	3.86	3.74	4.44	1.38	3.96	3.50
Salinity (ppt)	2.55	1.10	2.47	2.39	2.84	0.88	2.53	2.60
Nitrogen (%)	0.16	0.24	0.28	0.24	0.17	0.22	0.16	0.20
Phosphorus (%)	0.13	0.26	0.15	0.22	0.27	0.21	0.33	0.20
Potassium (%)	0.58	0.87	0.61	0.77	0.36	0.68	0.93	0.24
Organic material (%)	2.86	8.62	5.27	7.36	6.03	8.14	8.82	4.19

Results of soil analysis after 1 year of farm experience in both sites showed that the trials' fields were improved. The soil nutritional indicators in integrated farming were better than in rice monoculture farming (Table 1). Specifically, the salinity in the integrated farming decreased in both locations; It was from 2.5 ppt to 1.1 ppt (site 1) and from 2.8 ppt to 0.88 ppt (site 2). It was better than when compared to rice monoculture at both sites (remaining about 2.4 to 2.6 ppt). However, the levels of pH in the soil at both sites of integrated farming were increased. In addition, the nitrogen content (%), phosphorus, and potassium increased when compared to rice monoculture farming. In particular, organic matter increased more (from 2.86% to 8%). The results also showed that integrated farming had potassium content (from 0.58 to 0.87%) and organic matter (from 2.86 to 8.62%) in site 1 increased higher than in site 2 (from 0.36 to 0.68% and 6.03 to 8.18%, respectively). The results were similar to Simpson *et al*. (2011), *C. malaccensis* was important in wetland environments and ecosystem services in improving water quality (e.g., salinity, total nitrogen content) and absorption capacity of heavy metals (such as Pb, Zn & Fe^{2+}) in the stem root system (Zhang, Cui & Zhang, 2011). Based on bioaccumulation factors, it showed that integrated farming not only retains salinity and pH in the soil but also improves nutrients better than rice fields.

Water analysis

The results of water analysis showed that integrated farming improved water pH better than rice monoculture farming. Beginning of the season at site 1, the water pH in the rice field was lower than in the sedge field (4.5 vs 5.6). From October 30 onwards, the water pH increased. However, the pH in rice fields was always lower than in sedge fields (6.7 vs. 7.7), and then the difference was not statistically significant (Figure 1). Similarly, at the beginning of the season at site 2, the water pH in the rice field was higher than in the sedge field (6.70 vs. 4.91), and after that, the pH fluctuations did not differ between the two systems. However, on February 15, the water pH in the rice field was lower than in the sedge field (4.47 vs. 6.50). Figure 1 also showed that the water pH at site 1 was high level and maintained stability compared to site 2. This result showed that integrated farming improves pH better than rice monoculture farming (Zhang, Cui & Zhang, 2011), and this water pH was suitable for the crops, fish, and snails in this experiment.

The data analysis of water salinity at both sites showed that the integrated farming was lower than the rice monoculture farming (Figure 2). Specifically, site 1 showed that rice monoculture farming was always higher than integrated farming. Beginning of the season (June 30) at site 2, the water salinity in the rice field was lower than in the sedge field (1.7 vs. 3.0), but on August 30 the salinity in the rice field was higher than in the sedge field (2.0 vs. 1.0). The fluctuation of water salinity in rice fields from October 15 to December 30 was always higher than in sedge fields. Figure 2 also showed that the water salinity at site 1 was low level and maintained stability in comparison to site 2. This result indicated that integrated farming stabilized water salinity more than in rice monoculture farming; because sedge grass reduces water salinity (Lee & Shih., 2004). The water salinity in the experiment was within the range for crops, fish, and snails.

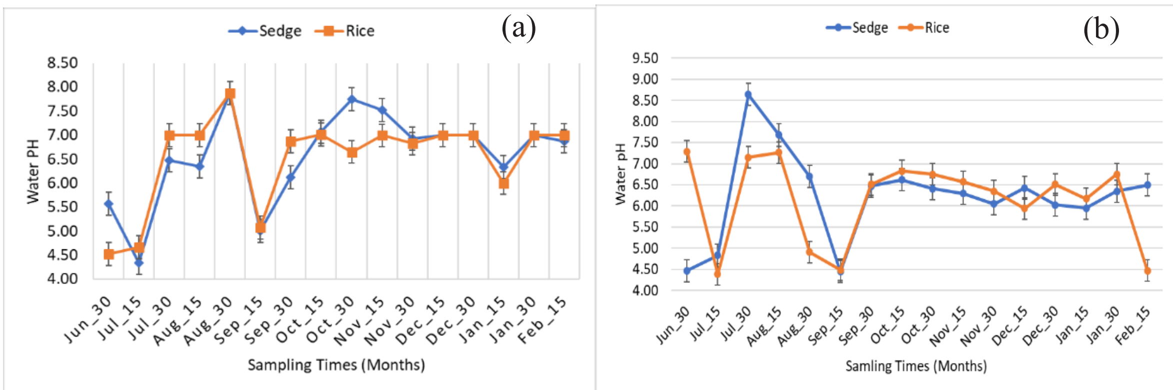

Fig. 1. Water pH in rice fields by experimental sites (a) Chau Thanh and (b) Hon Dat at the sampling dates.

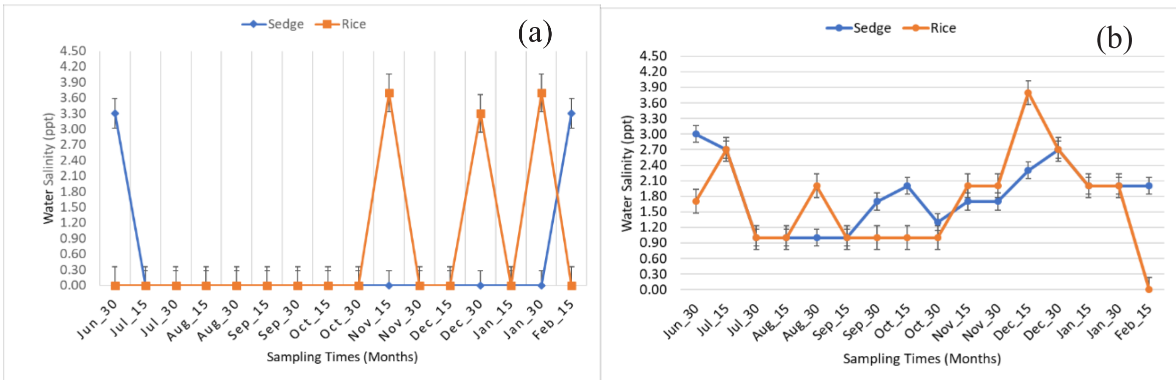

Fig. 2. Water salinity (‰) in rice fields by experimental sites (a) Chau Thanh and (b) Hon Dat at the sampling dates.

Evaluation of water temperature changes showed that the integrated farming was lower than the rice monoculture farming (Figure 3). The low water temperature was because the water level in the sedge field was always kept higher (20 cm) and the height of the sedge plant was also higher than the rice plant. The early season at site 1 showed that the water temperature fluctuated around 26 to 33°C, and there was no difference between the two systems. From September 30 to November 30, the water temperature in the monoculture rice farming fluctuated higher than in the integrated farming, because the rice plants had just been sown (about 40 days old), so the rice leaves had not yet covered all of the water surface in the field. From December 15 onwards, the water temperature in integrated farming was always lower than that in monoculture rice farming. Similarly, the early season at site 2 also showed that the water temperature in the rice field was lower than in the sedge field (28 vs. 33°C). From September 30 to December 15, the water temperature in rice fields was higher than in sedge fields (from 31-33 vs. 30-32°C; respectively), because the rice plants had just been sown (about 40 days old), so the rice leaves had not yet covered all of the water surfaces in the field. Therefore, the water temperature conditions were stable at about 25-35°C during the experiment, so it was very suitable for crops, fish, and snails.

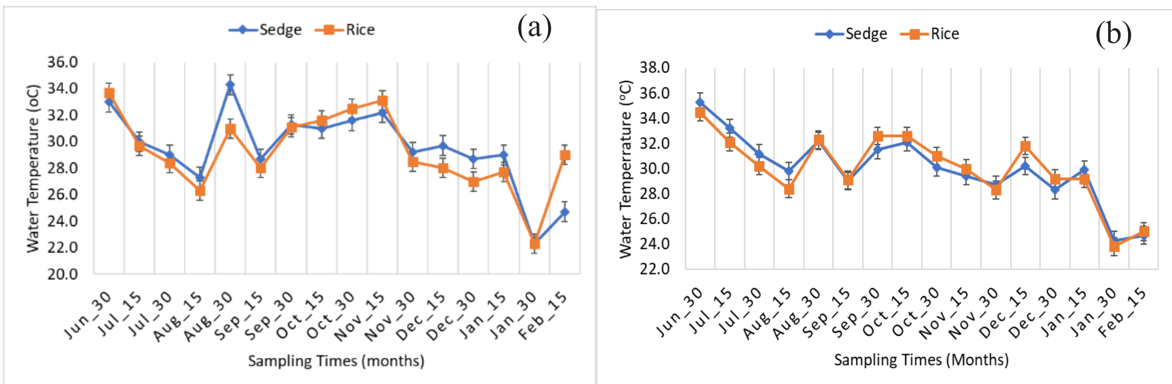

Fig. 3. Water temperature (°C) in rice fields by experimental sites (a) Chau Thanh and (b) Hon Dat at the sampling dates.

The results of assessing TDS (total dissolved solids) content at both sites were high, and in the rice field was higher than in the sedge field (Figure 4). Specifically, in the early stages of the crop at site 1, TDS ranged from 427 to 553 ppm. From September 30 to November 30, TDS in the rice field was higher than in the sedge field (636-1007 vs. 417-513 ppm). From December 15 to December 30, the TDS of the rice field was higher than that of the sedge field (535-903 vs. 472-598 ppm). Similarly, the results of water TDS content at site 2 showed that in the early stage, the difference was not statistically significant (ranging from about 114 to 147 ppm). From December 15 to January 15, TDS in the rice field was higher than in the sedge field (636-1007 vs. 417-513 ppm). Figure 4 also shows that the TDS level at site 1 was high and maintained stability compared to site 2. This TDS difference was not only affected by the water pH level but also by the water salinity at site 1 was low level and maintained stability in comparison to site 2; as discussed in the above sections (Figures 1 & 2). Additionally, fertilizer use could significantly influence changes in pH, salinity, and TDS values. This result indicates that *C. malaccensis* could improve water quality (Chayapan *et al*., 2015), and that the variation of TDS content in rice fields was higher than in sedge fields.

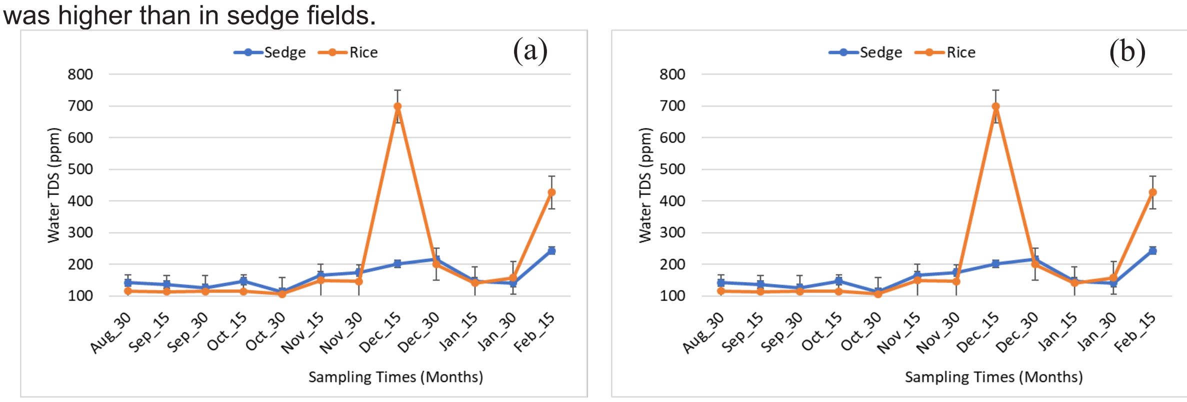

Fig. 4. Water TDS (ppm) in rice fields by experimental sites (a) Chau Thanh and (b) Hon Dat at the sampling dates.

The results of the water purity assessment in integrated farming were lower than in rice monoculture farming. The early season at site 1 showed that water transparency in the rice field was higher than in the sedge field (18 vs. 12 cm). During these later times, water transparency in rice fields fluctuated more than in sedge fields (Figure 5). The water transparency at the beginning of the season at site 2 was lower in the rice field than in the sedge field (18 vs 30 cm). At later times, fluctuations in water transparency in rice fields were lower than in sedge fields. This result indicated that the presence of fish and snails in integrated farming caused water transparency to be lower than in rice monoculture farming.

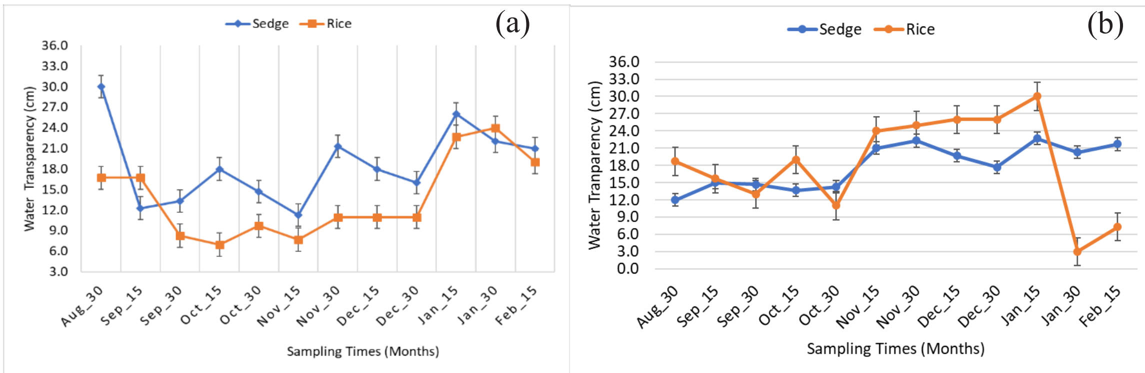

Fig. 5. Water transparency (cm) in rice field by experimental sites (a) Chau Thanh and (b) Hon Dat at the sampling dates

Evaluation of agronomic indicators

Agronomic indicators of rice farming

The results in the Summer-Autumn showed that there was no difference (P>0.5) in rice plant height and rice yield components (Table 2), but there were differences in the Winter-Spring rice crop. Stem height at site 1 was lower than at site 2 (104 compared to 117 cm) and the number of panicles/m^2 was also lower (303 compared to 459 panicles). The grain weight of 100 panicles was not different, so the rice yield at site 1 was lower than at site 2 (5.10 compared to 7.63 tons/ha). Rice yield in this experiment was similar to the results of Vu *et al*. (2020), and the results indicated that the rice yield components at site 1 were lower than at site 2.

Table 2. Comparison of agronomic indicators of Summer-Autumn and Winter-Spring rice crops in 2 experimental locations

Items	(1) Chau Thanh site	(2) Hon Dat site	Significance
1) Summer-Autumn crop			
- Stem height (cm)	112.7 ± 1.8	115.7 ± 2.6	ns
- Number of panicles/m^2	407.7 ± 14.3	368.3 ± 25.9	ns
- 100 panicles grain weight (g)	118.5 ± 6.8	126.3 ± 4.5	ns
- Rice yield (ton/ha)	4.83 ± 0.33	4.63 ± 0.19	ns
2) Winter-spring crop			
- Stem height (cm)	104.0 ± 0.6	117.4 ± 3.5	*
- Number of panicles/m^2	303.0 ± 12.5	458.7 ± 9.3	**
- 100 panicles grain weight (g)	168.8 ± 5.6	166.5 ± 4.2	ns
- Rice yield (ton/ha)	5.10 ± 0.06	7.63 ± 0.19	**

Note: P-value for T-Test's significance comparison; ns (not significant), *(p<0.05), ** (p<0.01), *** (p<0.001).

Agronomic indicators of sedge farming

The results of the analysis of agricultural indicators for the first cycle of sedge grass (Table 3) showed no difference in stem height (145-146 cm), fresh weight (8,922 vs. 11,793 g/m^2), dry weight (2,489 vs. with 2,333 g/m^2) and total dry biomass (24.9 versus 23.2 tons/ha) between the two experimental sites. However, there was a difference in stem width (site 1) was larger than site 2 (3.47 vs. 2.84 mm); The dry/fresh ratio (%) was also higher (28 compared to 20%). This result indicated that the size of sedge grass at site 1 was larger than at site 2, so the sedge yield was also higher (24.9 compared to 23.2 tons/ha).

Table 3. Comparison of agronomic indicators of sedge farming (*Cyperus malaccensis)* at 2 experimental locations

Items	First crop			Second crop		
	(1) Chau Thanh site	(2) Hon Dat site	Significance	(1) Chau Thanh site	(2) Hon Dat site	Significance
Stem height (cm)	145.6 ± 7.3	144.7 ± 4.4	ns	182.1± 2.3	169.3 ± 4.9	*
Stem weight (cm)	3.47 ± 0.13	2.84 ± 0.42	*	4.25± 0.20	3.18± 0.29	*
Number of stems/m^2	783 ± 67	1.321 ± 98	**	458 ± 49	661 ± 50	*
Fresh weight (g/m^2)	8.922±1.415	11.793 ± 818	ns	10.153±1.148	8.187±337	ns
Dry weight (g/m^2)	2.489 ± 321	2.322 ± 159	ns	1.328 ± 148	1.693±139	ns
Ratio (%) dry/fresh	28.2 ± 1.1	19.7 ± 0.4	**	13.2 ± 1.2	20.7 ± 1.3	**
Sedge yield (ton/ha)	24.89 ± 3.21	23.22 ± 1.59	ns	13.28 ± 1.48	16.93±1.39	ns

Note: P-value for T-Test's significance comparison; ns (not significant), *(p<0.05), ** (p<0.01), *** (p<0.001).

The results of the analysis of the second cycle of sedge grass showed that the size of the sedge at site 1 was larger than at site 2; although stem density/m^2 was the opposite. Specifically, the stem height of the sedge at site 1 was higher than at site 2 (182 vs. 169 cm), the stem width was also higher (4.3 vs. 3.2 mm), but the number of stems/m^2 was lower (458 compared to 661 stems). Fresh and dry weights were not statistically different (10,153 vs. 8,187 g/m2; and 1,328 vs. 1,693 g/m2, respectively). The dry/fresh ratio (%) at site 1 was lower than at site 2 (13.2 vs. 20.7%), and total dry biomass was not different (13.3 vs. 16.9 tons/ha). The result would indicate that integrated farming had potassium content (from 0.58 to 0.87%) and organic matter (from 2.86 to 8.62%) in site 1 higher than in site 2 (from 0.36 to 0.68% and 6.03 to 8.18%, respectively). This result was equivalent to a sedge yield of 20.6 tons/ha/crop (Anh & Canh, 2015), and similar to sedge farming in Cang Long district - Vinh Long province (Hue, 2019; Ung *et al*., 2020). This data again indicated that sedge grass at site 1 was larger than at site 2; Large-sized sedges would have higher economic value when used as materials in handicraft industries such as: getting yarn, weaving mats, and other weaving materials.

Evaluation indicators of fish farming

The results in Table 4 showed that Nile tilapia raised at site 1 grew better than at site 2. Fish density, weight fingerling, and farming time were similar, but the weight of harvested fish at site 1 was higher than at site 2 (150 g vs. 76 g/fish), fish size was larger (20 cm vs. 17 cm), and fish growth rates was higher (0.96 vs. 0.45 g/day). Therefore, fish productivity at site 1 was higher than at site 2 (541 versus 226 kg/ha); due to the higher survival rate of fish (36 versus 30%). This result correlated that the water quality at site 1 was better than at site 2; as discussed in the above sections. Although the Nile tilapia growth rate in this experiment was lower than 1.09 ± 0.33 g/day (Shoko *et al*., 2015; Binh & Thao, 2020), the fish grew well in saltwater environment.

Table 4. Comparing of weight, size, survival rate, and productivity of fish (*Nile tilapia*) at 2 experimental sites

Items	(1) Chau Thanh site	(2) Hon Dat site	Significance
Stocking density (fish/m^2)	1.0	1.0	ns
Initial weight (g/fish)	7.0 ± 0.2	8.0 ± 0.1	ns
Rearing period (days)	150	150	ns
Harvesting weight (g/fish)	150.3 ± 20.5	76.0 ± 1.5	*
Harvesting length (cm)	20.0 ± 0.6	16.8 ± 0.3	*
Growth rates (g/day)	0.96 ± 0.13	0.45 ± 0.01	*
Survival rate (%)	36.4 ± 1.5	29.7 ± 1.1	*
Gross fish yield (kg/ha)	541.4 ± 52.1	226.1 ± 10.7	*

Note: P-value for T-Test's significance comparison; ns (not significant), *(p<0.05), ** (p<0.01), *** (p<0.001).

Evaluation indicators of snail farming

The data analysis in Table 5 showed that the size, weight, and growth rate of snails raised in the two experimental locations were not different. The weight of snails when stocked was 6 g/snail. After 150 days of farming, the average harvested weight was 13 g/snail, with a growth rate of about 0.05 g/day. The survival rate at site 1 was higher than at site 2 (79% compared to 53%), so snail productivity was also higher (1,020 compared to 647 kg/ha). These results also indicated that the water quality at site 1 was better than at site 2; as discussed in the above sections. Snail growth in this experiment was low (Binh & Thao, 2017) because the snails did not supplement food to take advantage of the natural food sources available in the sedge field. The survival rate of snails in this experiment was also low (53-79%), so the productivity achieved was low.

Table 5. Comparing of weight, size, survival rate, and productivity of snails (*Pila gracilis)* at 2 experimental sites

Items	(1) Chau Thanh site	(2) Hon Dat site	Significance
Stocking density (snail/m^2)	10	10	ns
Initial weight (g/snail)	6.00 ± 0.2	6.33 ± 0.1	ns
Rearing period (days)	150	150	
Harvesting weight (g/snail)	12.67 ± 0.67	12.67 ± 1.67	ns
Shell length of snail (mm)	32.57 ± 0.22	33.67 ± 0.88	ns
Shell width of snail (mm)	24.80 ± 0.11	24.30 ± 0.67	ns
Growth rates (g/day)	0.05 ± 0.01	0.04 ± 0.01	ns
Survival rate (%)	78.5 ± 10.5	52.8 ± 7.1	*
Gross snail yield (kg/ha)	1.020 ± 92.9	647 ± 53.2	*

Note: P-value for T-Test's significance comparison; ns (not significant), *(p<0.05), ** (p<0.01), *** (p<0.001).

Analysis of economic efficiency

The overall data analysis at two experimental locations showed that integrated farming systems had higher economic efficiency than rice monoculture farming. The results in Table 6 showed that the profit of integrated farming (site 1) was higher than rice monoculture farming (11,146 compared to 904 USD/ha); due to higher total income (18,052 vs. 3,001 USD/ha), despite total production costs higher (6,906 vs. 2,078 USD/ha). Similarly, site 2 also showed that integrated farming was more profitable than rice monoculture farming (10,905 compared to 1,672 USD/ha); due to higher total income (17,884 vs. 3,782 USD/ha), and higher total production costs (6,979 vs. 2,110 USD/ha). The BCR ratio (benefit-cost ratio) was higher than in rice monoculture farming. This result showed that integrated farming on acid soil and salt water was more economically effective than rice monoculture farming. These results also indicated that the profit of integrated farming (site 1) was higher than site 2. However, rice monoculture farming at site 1 had less economic efficiency than rice monoculture farming at site 2.

Shortly, this result reinforced that the diversified use of wetlands (for fish, snail & sedge farming) contributes to increasing the annual income of local households (Juffe & Darwall, 2012; Jana, Das & Puste, 2015; Ha, Di & Phuoc, 2023). Furthermore, sedge farming played an important role in providing food, animal feed, and medicinal fuel, along with raw materials for construction, carpet weaving, and perfume making in Africa and Asia (Benazir, Manimekalai & Ravichandram, 2010). As such, integrated farming systems research should focus on transforming rice fields to reduce production risks, reorganize the hierarchy of agricultural ecosystems, and include sustainable livelihood frameworks for future farmers.

Table 6. Comparing of financial efficiency of an integrated farming system with rice monoculture farming in 2 experimental sites (Unit: USD/ha/year)

Items	(1) Chau Thanh site			(2) Hon Dat site		
	Integrated farming	Rice monoculture	Sig.	Integrated farming	Rice monoculture	Sig.
1) Total costs	6.906 ± 120	2.078 ± 24	***	6.979 ± 108	2.110 ± 70	***
- Material inputs	2.188 ± 0	1.193 ± 0	**	2.188 ± 0	1.193 ± 0	***
- Labour inputs	3.531 ± 51	313 ± 10	***	3.542 ± 37	313 ± 30	***
- Machine inputs	1.188 ± 69	592 ± 14	***	1.250 ± 75	604 ± 40	**
2) Gross income	18.052 ± 1.710	3.001 ± 116	***	17.884 ± 1.126	3.782 ± 114	***
3) Gross margin	11.146 ± 1.592	904 ± 91	**	10.905 ± 1.019	1.672 ± 55	**
4) BCR	1.61 ± 0.20	0.43 ± 0.04	*	1.56 ± 0.12	0.79 ± 0.02	**

Note: P-value for T-Test's significance comparison; ns (not significant), *(p<0.05), ** (p<0.01), *** (p<0.001), Sig. - Significance

CONCLUSION

Sedge grass in the integrated farming system not only reduced soil salinity, but also increased soil pH, nitrogen, phosphorus, potassium, and organic matter content compared to rice monoculture farming. In addition, this integrated farming system improved water quality such as increasing pH, and reducing salinity, temperature, and TDS compared to rice monoculture farming.

The levels of acidity and salinity at two experimental sites affected rice yield in the Winter-Spring crop (dry season), and rice yield at site 1 was more effects than at site 2 (5.10 compared to 7.63 tons/ha). However, sedge grass farming at site 1 was larger than at site 2 (stem height & stem weight). The size of Nile tilapia raised at site 1 was also higher than at site 2 (weight 150 g/fish vs. 76 g/fish; size 20 cm vs. 17 cm; weight gain 0.96 g/day vs. 0. 45 g/day). Fish productivity at site 1 was still higher than at site 2 (541 versus 226 kg/ha), due to a higher fish survival rate (36 versus 30%). Snails raised at site 1 had a higher survival rate than at site 2 (79% vs. 53%), so the total productivity of snails was also higher (1,020 vs. 647 kg/ha).

Integrated farming systems practiced on acidic and saline soils got more economic efficiency compared to rice monoculture farming. At site 1, Integrated farming profits were higher than rice monoculture farming (11,146 versus 904 USD/ha). Similarly, at site 2, integrated farming was more profitable than rice monoculture farming (10,905 compared to 1,672 USD/ha).

Recommendation: It should diversify the use of coastal wetland resources to raise fish, combined with snails and aquatic plants (such as sedge grass) to increase the annual income of households in these study areas. However, it is necessary to further research and evaluate water and soil indicators in the following years to provide data to evaluate the sustainability of this farming system in the next time.

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ETHICAL STATEMENT

Not applicable

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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