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POTENTIAL FOR DIVERSIFYING CROPS ON RICE MONOCULTURE LAND AFFECTED BY SALINITY INTRUSION IN THE MEKONG DELTA

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ABSTRACT

This study was conducted to evaluate the potential for crop diversification on rice monoculture land affected by salinity intrusion in the Mekong Delta. Data on current cropping practices were collected through interviews with over 204 households in Soc Trang Province during the 2022 dry season. Field experiments were carried out to assess the adaptability of selected cash crops such as beetroot, maize, and watermelon to drought and salinity conditions, as well as to evaluate their economic viability when cultivated as alternatives to rice in Long Phu and Tran De districts during the 2021–2023 dry seasons. The results indicated that in saline and drought-affected areas, more than 31 types of vegetables could potentially replace rice in the dry season. All three tested crops, beetroot, maize, and watermelon, demonstrated favorable adaptability and economic efficiency under saline and drought-affected conditions. Among them, beetroot yielded the highest economic returns, surpassing maize, watermelon, and traditional rice. These findings provide a scientific basic for local authorities and farmers to make informed decisions regarding the adoption of suitable cropping models to cope with regional drought and salinity challenges.

Keywords: Upland crops, drought and salinity, salinity intrusion, Soc Trang.

1. INTRODUCTION

Salinity intrusion has become a major challenge for agricultural production and the livelihoods of people in Vietnam's coastal areas, particularly during the dry season in the Mekong Delta (MD). From January to June annually, the freshwater supply from upstream declines, allowing saline

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water to intrude deeply inland. This significantly impacts irrigation sources, alters soil characteristics, and reduces crop yields, especially for rice and vegetables (Guong et al., 2010).

Since the mid-2010s, salinity intrusion in the MD has intensified due to El Nino-related droughts, reduced Mekong River flows, and sea level rise. The 2015–2016 event was the most severe in over 60 years, with saltwater penetrating up to 90 km inland and causing widespread agricultural and water supply damage. Similar events in 2019–2020 and 2023–2024 extended intrusion up to 110 km, damaging over 240,000 ha of rice and affecting thousands of households. Hydro-meteorological data showed increasing frequency, severity, and inland reach of salinity events, now recurring approximately every four years and posing growing socio-economic and environmental risks (Lavane et al., 2023).

Soc Trang Province, located at the downstream end of the Hau River with 72 km of coastline and three major river mouths, is a key rice-producing region with an annual output of over 2 million tons. Coastal districts such as Tran De and Long Phu, where rice is cultivated two to three times per year, were severely impacted by salinity intrusion (Be et al., 2017). Rice is known to have low salinity tolerance, less than 3‰ (Hoang et al., 2016), and is highly susceptible to saline irrigation, which causes stunted growth, high proportion of unfilled grains, and significant yield reductions (Hai et al., 2021).

In response to this situation, Soc Trang province has implemented structural measures such as constructing reservoirs, diverting freshwater, and installing salinity-control sluices. At the same time, local authorities have encouraged farmers to adjust cropping calendars, adopt salt-tolerant rice varieties, introduce alternative upland crops, and improve soil conditions (Khong et al., 2020). Nonetheless, the salinity tolerance of these alternative crops has not been comprehensively assessed.

Building on this context, this study was conducted in Long Phu and Tran De districts from 2021 to 2023 to analyze the adaptability and economic performance of selected alternative crops in comparison to conventional rice farming systems. The study aimed to: (i) assess the current status and limitations of cash crop cultivation on salinity-affected soil; and (ii) propose solutions to improve resilience and promote sustainable agricultural development under climate change conditions.

2. RESEARCH METHODS

The study was conducted in Tran De and Long Phu districts, Soc Trang province, situated at geographic coordinates 9.3000° N, 105.9500° E (Figure 1). This region has predominantly implemented specialized rice cultivation systems, comprising three principal models: triple rice cropping (accounting for 30.3% of the natural land area), double rice cropping (21.2%), and rice-

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shrimp farming (4.3%), as reported by Diep et al. (2017). The area is markedly affected by salinity intrusion during the dry season, which substantially undermines both the yield and economic performance of traditional rice production systems.

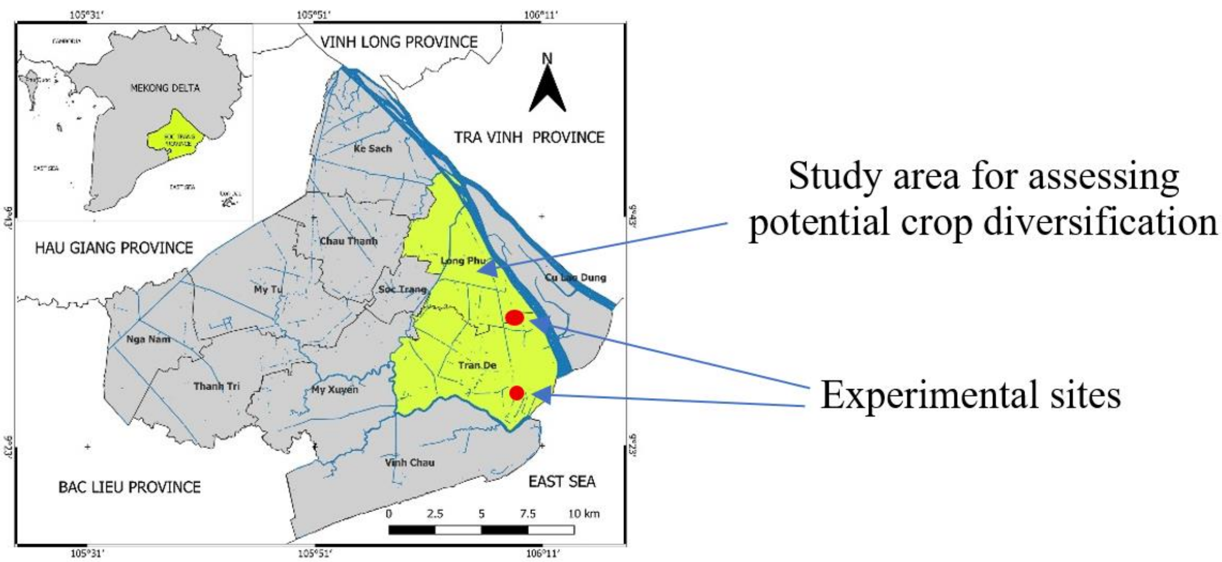

Figure 1: Map of the study site

2.1. Primary Data Collection via Household Surveys

Household surveys were conducted at the end of the 2022 dry season to evaluate the economic efficiency of various crops under salinity stress conditions. The survey encompassed demographic information, cultivated land area, adaptation strategies to salinity intrusion, and the household evaluation about the potential vegetable crops.

The sample size was determined based on Slovin's formula (1960):

$$n = \frac{N}{(1 + N * \sigma^2)}$$

Where:

- n is the sample size.
- N is the total number of households in Tran De and Long Phu districts (N = 42,384 + 36,118 = 78,953).
- The allowable margin of error, σ, is 7%.

Therefore, the total sample size for the survey was determined as follows:

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$$n = \frac{78.953}{1 + 78.953 * (0{,}07)^2} = 204$$

2.2. Field Experiments

Field experiments were conducted during the dry seasons from 2021 to 2023, focusing on three selected crops: beetroot, maize, and watermelon. Beetroot is recognized as a salt-tolerant crop and is considered a potential crop for diversification within the agricultural systems of the MD. The inclusion of this crop aimed to assess its agronomic adaptability under region-specific edaphic and climatic conditions. Additionally, maize and watermelon, which had been widely cultivated in the region, were selected as comparative species. Notably, watermelon, characterized by its relative sensitivity to abiotic stresses, was employed as a control crop to facilitate comparative analysis of differential stress tolerance and adaptive performance among the selected species. The cropping calendar was developed in accordance with local climatic conditions (Table 1).

Table 1: The cropping calendar for the tested crops

Month (Gregorian)	1	2	3	4	5	6	7	8	9	10	11	12
Beetroot												
Maize												
Watermelon												

The crops information in the experiment were in Table 2.

Table 2: The crops information

Crops (Scientific name)	Harvest period (days)	Planting density (kg/ha)	Potential yield (tons/ha)
Beetroot (*Beta vulgaris*)	60–75	0.5	18–25
Maize (*Zea mays*)	65–90	10-12	12–15
Watermelon (*Citrullus lanatus*)	60–95	0.5–0.6	34–36

The field experiments were arranged in a completely randomized design (CRD), comprising: 3 crop types × 4 treatments × 3 replications = 36 experimental plots. The treatments involved different levels of straw mulch application as follows: no straw mulch, 3.5 tons/ha of straw mulch, 7.0 tons/ha of straw mulch, and 10.5 tons/ha of straw mulch. Each experimental plot measured 25 m² (5 × 5 m), with a planting density of beetroot was 0.25 x 0.25 m, maize was 0.30 x 0.70 m, watermelon was 0.30 x 4,5 m. Irrigation was provided through a sprinkler system using water sourced from the local canals. The objective of the experiment was to identify the correlations between straw mulch levels and the yields of upland crops, and the treatment with the highest benefit-cost (B/C) ratio, to inform recommendations for scaling up the cropping systems that are suitable to drought and salinity intrusion conditions.

2.3. Economic Efficiency Assessment of Upland Crop Cultivation

Economic efficiency was assessed through a four-step process:

1. **Total revenue (T)** = Yield × Selling price
2. **Total cost (C)** = Cash expenditures + Input value of family labor
3. **Profit (B)** = T − C
4. **Benefit-cost ratio (B/C)** = B/C

Cost components included seeds, fertilizers, pesticides, hired labor, and the input cost of family labor. Selling prices were obtained from local markets at the time of harvest.

The applied fertilizers consisted of Urea (46% N), DAP (18% N, 46% P_2O_5), KCl (60% K_2O), and NPK compound fertilizer (16-16-8).

2.4. Statistical Analysis and Data Processing

Data were processed using Microsoft Excel for descriptive statistics (means and standard deviations) and SPSS version 19.0+ for analysis of variance (ANOVA). Duncan's multiple range test at a significance level of $\alpha = 0.05$ was employed to determine statistical differences among treatments. The correlation between straw mulch levels and yield was identified by the formula $y = ax + b$.

3. RESULTS AND DISCUSSION

3.1. Current status of Crop Cultivation on Salinity-Affected Rice Land in Soc Trang Province

Current Status of Irrigation Water Resources for Agricultural Production

Canals serve as the primary source of irrigation water for agriculture in the study area, utilized by 61% of households, followed by rainwater at 27%. Water retained in fields and groundwater from wells account for the remaining 12%.

Survey results indicated that 71% of households had adequate irrigation water, whereas 29% experienced water shortages; notably, 28% faced severe irrigation water deficits, and only 1% were self-reliant with alternative water sources.

Water scarcity during the dry season is pronounced, with merely 20% of households having access to water of acceptable quality, while 80% relied on polluted water, significantly impairing

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agricultural productivity in the region. Agricultural production in the region was also risky by salinity intrusion that accelerates water scarcity for irrigation in the dry season.

Challenges Affecting Crop Yields

High salinity levels in irrigation water, reported by 70.6% of farmers, and freshwater scarcity during the dry season, identified by 57.4% of farmers, constituted the two major challenges directly affecting crop yields. Labor shortages were also highlighted by 44.6% of farmers. Other difficulties, including limited access to agricultural inputs, markets, and credit, were considered less severe, with each factor cited by fewer than 20% of farmers as significant constraints. These findings are consistent with the study by Thuan et al. (2020), which affirmed that coastal communities were predominantly impacted by climate change-related factors, such as salinity intrusion and drought, rather than financial constraints.

The results from the household interviews about the current status of vegetable cultivation during the dry season on salinity-affected rice land were shown in Table 3. Generally, the vegetable cultivation models in the study area are predominantly small-scale (≤ 0.37 ha). The five models with the highest capital efficiency are in orders: water celery grown outside the dike (B/C = 16.3, area = 0.07 ha), okra grown outside the dike (10.8, 0.05 ha), mustard greens grown outside the dike (9.96, 0.05 ha), chili grown inside the dike (5.47, 0.25 ha), and brassica juncea grown inside the dike (4.64, 0.2 ha).

The survey revealed a relatively diverse cropping system, with 31 upland crops, most of which were well-adapted to local conditions. While some models demonstrated high economic efficiency, they remained small-scale and largely spontaneous. Capital efficiency ranged widely from -0.48 to 16.3, indicating that vegetable cultivation in the area remained unstable and had yet to provide a reliable source of income for local farmers.

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Table 3: Current status of vegetable cultivation during the dry season on salinity-affected rice land

Upland crop	Average Area (ha)				Benefit-Cost Ratio (B/C)			
	Area of upland crops cultivation (ha)				B/C ratio			
	Long Phu		Tran De		Long Phu		Tran De	
	Inside the dike	Outside the dike	Inside the dike	Outside the dike	Inside the dike	Outside the dike	Inside the dike	Outside the dike
Maize	0.20±0.01	0.11±0.02	0.09±0.02	0.20±0.01	1.04	1.84	0.75	2.40
Watermelon	0.35±0.18	0.10±0.01	0.27±0.08	0.12±0.02	2.78	0.33	1.07	0.48
Bitter melon	-	0.08±0.01	0.26±0.01	0.17±0.09	-	0.24	0.14	1.47
Cucumber	0.27±0.11	0.17±0.08	0.16±0.08	0.12±0.08	0.13	0.60	0.88	1.86
Eggplant	0.10±0.01	-	-	-	0.14	-	-	-
Bottle gourd	0.18±0.04	-	-	-	0.35	-	-	-
Chili	0.24±0.09	0.18±0.15	0.25±0.01	0.14±0.11	1.33	5.05	5.47	3.66
Tomato	-	-	-	0.05±0.01	-	-	-	3.59
Luffa	-	-	-	0.10±0.01	-	-	-	2.22
Yardlong bean	-	0.10±0.01	-	-	-	0.54	-	-
Winged bean	0.21±0.10	0.10±0.01	-	-	2.12	0.53	-	-
Pumpkin	0.20±0.01	0.05±0.01	0.09±0.04	0.37±0.31	0.06	-0.27	0.55	1.38
Wax gourd	0.32±0.12	0.15±0.01	0.18±0.11	0.10±0.05	-0.15	0.34	0.18	1.57
Green bean	-	-	0.13±0.01	0.08±0.04	-	-	0.15	2.49
Okra	-	0.15±0.13	0.10±0.01	0.05±0.01	-	0,18	0.13	10.8
Mung bean	0.10±0.01	0.07±0.01	-	-	0.38	2	-	-
Lotus	0.35±0.07	-	-	-	0.85	-	-	-
Water celery	-	-	0.20±0.01	0.07±0.01	-	-	1.5	16.3

Upland crop	Average Area (ha)				Benefit-Cost Ratio (B/C)			
	Area of upland crops cultivation (ha)				B/C ratio			
	Long Phu		Tran De		Long Phu		Tran De	
	Inside the dike	Outside the dike	Inside the dike	Outside the dike	Inside the dike	Outside the dike	Inside the dike	Outside the dike
Shallot	-	-	-	0.10±0.01	-	-		1.09
Green onion	-	-	0.18±0.09	0.12±0.16	-	-	0.14	0.96
Water spinach	0.10±0.01	-	0.15±0.01	-	1.96	-	1.97	-
Mustard greens	-	-	-	0.05±0.01	-	-	-	9.96
Chinese mustard greens	-	0.05±0.01	-	0.05±0.01	-	3.03	-	0.31
Lettuce	-	-	0.05±0.01	0.05±0.01	-	-	0.6	3.23
Pak choi	0.20±0.01	-	-	0.05±0.01	4.64	-	-	1.39
Cabbage	-	-	-	0.20±0.01	-	-	-	0.21
Straw mushroom	-	-	-	0.04±0.01	-			2.13
Cassava root	-	-	0.20±0.01	-	-	-	3.33	-
Daikon radish	-	-	-	0.13±0.11		-	-	3.75
Water taro	0.20±0.01	-	-	-	-0.43	-	-	-
Beetroot	0.02±0.01	-	-	-	0.56	-	-	-

"-": value equals zero; "-number": negative capital efficiency; "±": standard errors; B: profit; C: total cost.

3.2. Correlation between Straw Mulch Levels and the Adaptability of Upland Crops

The results presented in the Figure 2 indicate that the four levels of straw mulch application (0, 3.5, 7.0, and 10.5 tons/ha) are strongly correlated with the yields of three upland crops (beetroot, maize, and watermelon), with all correlation coefficients (R^2) exceeding 0.9. Among these, the treatment on beetroot exhibited the highest correlation ($R^2 = 0.95$), followed by maize ($R^2 = 0.92$) and watermelon ($R^2 = 0.93$).

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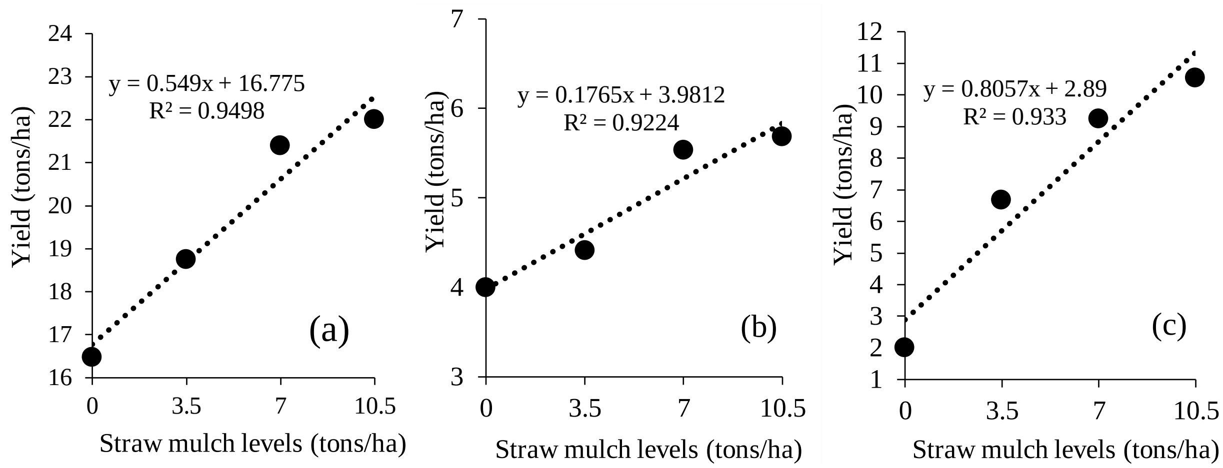

Figure 2: Correlation between straw mulching levels and crop yields in the experimental trials with beetroot (a), maize (b) and watermelon (c) grown in Long Phu district, Soc Trang Province

Similar to the findings from the Long Phu field trials, the results presented in the Figure 3 show that the four levels of straw mulch application (0, 3.5, 7.0, and 10.5 tons/ha) are strongly correlated with the yield of two upland crops (beetroot and maize) cultivated in Tran De district. Among these, the treatment on beetroot exhibited a lower correlation coefficient compared to maize (R^2 = 0.84 and R^2 = 0.95, respectively).

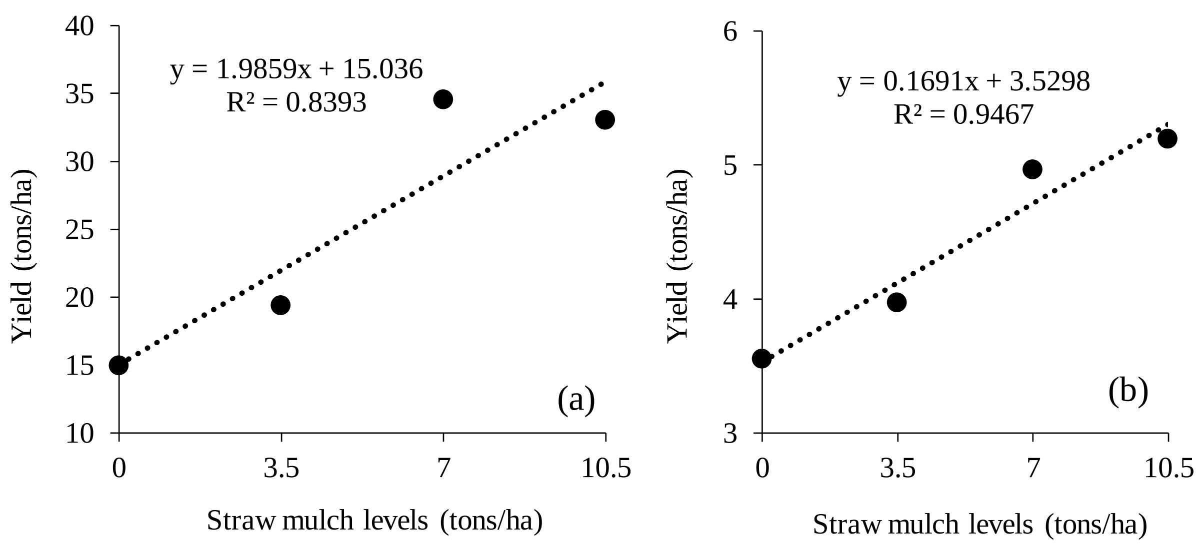

Figure 3: Correlation between crop yield and straw mulching levels in experimental trials with beetroot (a) and maize (b) grown in Tran De district, Soc Trang province

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The results from the two experimental sites in Long Phu and Tran De districts confirmed a strong positive correlation between straw mulch levels and the yield of upland crops. Specifically, higher straw mulch application rates were associated with increased crop yields. These findings are consistent with the studies of Ba et al. (2004), which reported that mulching with straw not only enhances water-use efficiency but also promotes the growth and yield of upland crops in the MD.

3.3. Results of the Experimental Model Evaluating the Efficiency of Crop Cultivation as a Replacement for Rice in the Dry Season

Based on the obtained results of different treatments, the mulching treatments that yielded the highest capital use efficiency for each type of vegetable crop were selected for comparison with rice cultivation practiced by local farmers in the same region and cropping season. Accordingly, maize consistently demonstrated the highest capital use efficiency under the 7.0 tons/ha straw mulching treatment, whereas beetroot and watermelon achieved the highest efficiency under both the 7.0 and 10.5 tons/ha mulching treatments. The results of the comparison of capital efficiency between beetroot, maize, watermelon, and rice cultivated in Long Phu district are indicated in Figure 4 and beetroot, maize, and rice in Tran De district are indicated in Figure 5.

In the Figure 4, in 2021 and 2022, the capital efficiency of beetroot significantly outperformed that of rice, reaching a peak of 5.60 in 2021, 3.2 times higher than rice (1.80). In the same year, maize and watermelon showed comparable capital efficiencies (about 1.5), both remained below that of rice. In 2022, watermelon ranked highest at 1.75, surpassing beetroot (0.75), while maize and rice were similarly low (about 0.5). In 2023, beetroot's efficiency dropped sharply to -1.00, maize reached 1.00, and both were outperformed by rice (1.50). Watermelon was not cultivated in 2023 due to unfavorable weather conditions, which caused plant mortality and reduced yield.

These results suggested that while beetroot, maize, and watermelon demonstrated good adaptability to salinity stress, they were less tolerant of drought and elevated temperatures. Nevertheless, beetroot and watermelon continued to exhibit superior economic performance compared to rice and maize.

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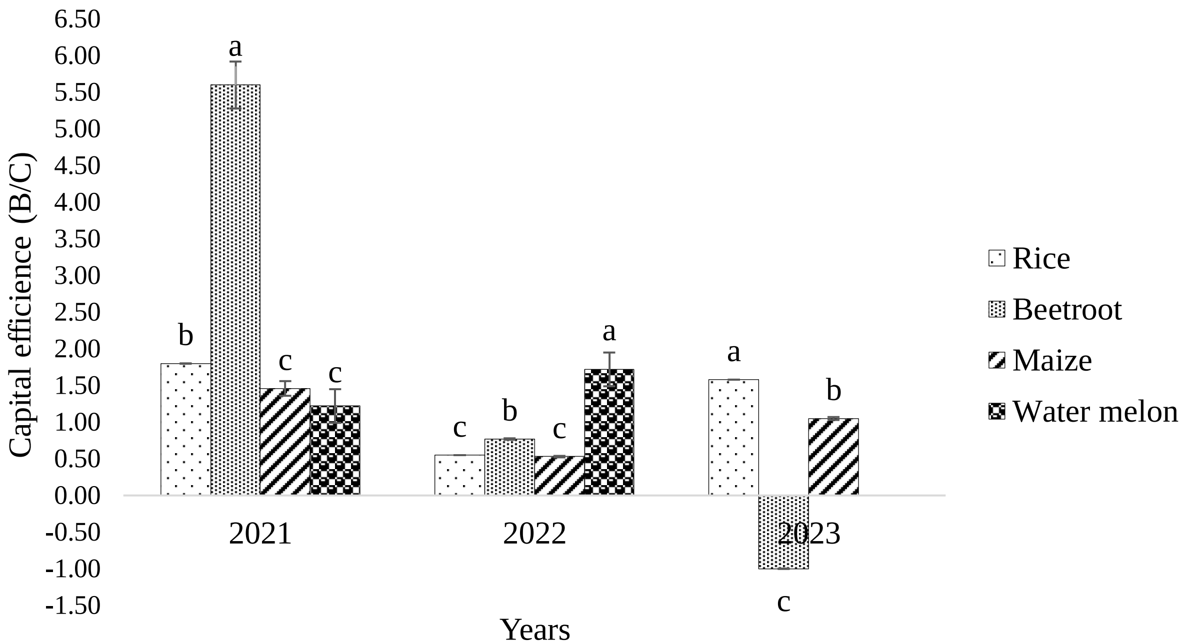

Figure 4: Comparison of capital efficiency between beetroot, maize, watermelon and rice cultivated in Long Phu district, Soc Trang province during the dry seasons of 2021, 2022, and 2023

In the Figure 5, beetroot demonstrated the highest capital efficiency, consistently outperforming rice and maize across all three study years. In 2021, the B/C ratio for beetroot reached 5.60, 3.1 times higher than rice (1.80) and 4.6 times higher than maize (1.20). In 2022, although its efficiency declined to 3.00, it was still 2.4 times higher than rice (1.25) and 6 times higher than maize (0.50). In 2023, beetroot achieved a B/C ratio of 3.50, approximately 2.5 times higher than that of rice (1.50) and maize (1.40).

These findings suggested that beetroot offers the highest and most stable economic returns under saline and drought-prone conditions in Long Phu and Tran De districts, making it a promising candidate for dry-season expansion. Rice ranks second, maintaining its primary role, while maize and watermelon exhibit lower or comparable economic efficiency to rice.

These results were consistent with earlier studies (Linh et al 2021; Tan et al 2014), which confirmed that rice-vegetable crop rotation, particularly involving beetroot, not only increased income during the dry season but also enhanced soil fertility and rice yields in subsequent cropping seasons (Guong et al 2010; Nghi 2022). However, shifting from rice to upland crops may presents several socio-economic challenges for local farmers, including susceptibility to market

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fluctuations, constraints arising from labor shortages, the burden of elevated initial investment requirements, and insufficient technical expertise related to the cultivation of new crop varieties.

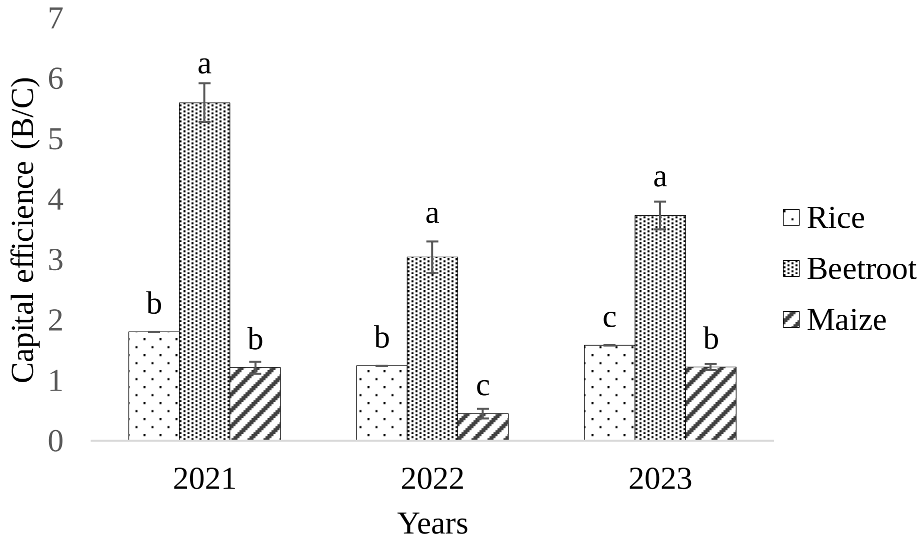

Figure 5: Comparison of capital efficiency of beetroot and maize with rice cultivated in Tran De district during the dry seasons of 2021, 2022, and 2023

3.4. Proposed Adaptation Solutions

Farmer interviews in the study area identified two main challenges in dry-season agriculture: (1) worsening climatic change conditions, including water scarcity and salinity intrusion; and (2) unstable markets for vegetable and cash crops. Based on the study's outcomes, the following adaptation strategies are proposed.

Crop diversification during the dry season. Instead of leaving land fallow or continuing rice cultivation with the risk of yield failure due to unpredictable drought and salinity intrusion, farmers can shift to cultivating upland crops that require less water and offer better economic returns.

Application of mulching techniques. Mulching enhances plant growth and yield, thereby improving household income. Maize responds well to mulching with 7.0 tons of straw per hectare, while beetroot and watermelon benefit from 7.0 to 10.5 tons of straw per hectare.

Adjustment of planting calendars. The early growth stage following seed germination is highly sensitive to weather fluctuations. Therefore, aligning planting schedules with the periods of available irrigation, particularly water shared from upstream sources, can help crops thrive and achieve better yields.

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Rational land-use planning. Although upland crops showed strong potential for climate change adaptation and improvement of household income, they cannot replace rice in terms of ensuring national food security. Additionally, markets for upland crops remain unstable. Strategic zoning of upland crop production on salt-affected rice land, with appropriate scale, location, and supply chain planning, is thus essential.

Establishment of early warning systems. An information system and tools for early monitoring and warning of drought and salinity are needed in coastal agricultural areas to help farmers proactively plan cropping seasons and select suitable crops.

4. CONCLUSION AND RECOMMENDATIONS

Based on the survey and experimental results, several vegetable crops have been identified as well adapted to saline-affected rice land. Among them, beetroot, maize, and watermelon have emerged as promising alternatives to rice for dry-season cultivation in the study area. For a sustainable long-term agricultural development strategy in coastal regions, it is essential to create spatial-temporal maps of salt-affected soil zones to guide localized cultivation practices and optimize land-use management.

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