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Article

Saltwater Intrusion and Agricultural Land Use Change in Nga Nam, Soc Trang, Vietnam

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Abstract: Under the effects of saltwater intrusion from rising sea water levels, climate change, and socioeconomic issues, the Nga Nam district in Vietnam has suffered damage to its agriculture and changes in agricultural land use. This study aimed to investigate the factors that influenced land use changes and to propose approaches to limit the changes in agricultural land use. The damage caused by saltwater intrusion on agricultural production was evaluated via the use of secondary data collected from the Department of Infrastructure Economics of the Nga Nam district in the period of 2010–2021. The results show that during the 2010–2015 period, agricultural production areas were affected in 2010, 2012, and 2015. In the period of 2015–2021, the trend of saltwater intrusion along the damaged area remarkably decreased due to the work of saltwater-preventing structures. In this period, the area of annual plants increased, while that of fruit trees decreased. In the area comprising annual plants, the area using the triple rice land use type converted into an area using the double rice and double rice–fish ones. Lands for fruit trees transitioned from mixed farming to specialized farming to raise the economic efficiency for farmers. These changes were affected by four main factors: the physical factor, the economy, society, and the environment. The environmental and economic factors were seen to play the most important role as drivers of changes in land use. The factors of saltwater intrusion and acid-sulfate-contaminated soil, consumer markets, floods, drought, profit, and investments were noted to be significant drivers in agricultural land use change. Thus, both structural and non-structural approaches are suggested to inhibit the safeguard changes in the future.

Keywords: agriculture; land use change; affecting factors; multi-criteria evaluation; Soc Trang province—Vietnam

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1. Introduction

Land use change is the shift in the surface layer of land and is inevitable in the course of national socioeconomic development [1,2]. Typically, the alteration of land use modifies the purpose of land to be most suitable for human activity [1,3,4]. Typical factors that alter land use are socioeconomic activities and population growth [5,6], natural resources [7–9], and the effects of structures [3,5,6,10,11], land policy [12,13], and modernization [14,15]. Land use changes in functions, structures, and environmental conditions by modernization become increasingly extensive to adapt to population growth [16–20]. Additionally, land use change also has a reverse effect on natural or semi-natural ecosystems. For instance, the changes in the surface layer also alter the habitat of different organisms [19,21–23]. Thus, this could pose a risk to the sustainable development of the agricultural ecosystem; in other words, agricultural land use change is a global concern [10,24–26]. Besides the above issues, some studies also unveiled that the development of tourism also alters agricultural land use [27] because tourism brings profits to local farmers [28–31]. However, this change can cause contradictory effects in agricultural production and tourism, because the development of tourism can result in the shift from agricultural soils to soils for commercial uses and service, as well as a lack of support from state policies [27,32,33].

The Mekong Delta is such an important agricultural producing region in Vietnam that sustains national and international food security [34]. However, in the past few years, the Mekong Delta has been considered to be a region that is heavily affected by saltwater intrusion due to climate change [35–40]. The Mekong Delta is particularly impacted by both sea level rise and saltwater intrusion [34,38,41,42]. Due to the complex mix of freshwater, brackish, and salty water conditions in Soc Trang Province, changes in agricultural land use are needed [43,44]. Here and in other coastal provinces, the uncertain process of saltwater intrusion is a reason for changing the agricultural land use by farmers in the Mekong Delta [45,46].

Therefore, in Nga Nam district, Soc Trang province, the recent land use changes have recently caused many difficulties in the management and orientation towards agricultural land use. To understand the specific factors leading to the adjustments made by farmers as a basis to establish restrictive measures, as well as to raise the efficiency in agricultural land use and to enhance the household economy for farmers' lives, we undertook this present study.

Our research's findings identify barriers and offer workarounds to give local governments a solid scientific foundation for guiding wise land use decisions and crafting development-oriented policies. Changes in land usage and saline intrusion have an impact on socioeconomic development. This finding provides a solid scientific foundation for Mekong Delta regions and other coastal provinces in the Mekong Delta with similar conditions to take the initiative to support decision making and create suitable policies to mitigate the risk of saltwater intrusion in their respective situations.

2. Materials and Methods

2.1. Study Area

Nga Nam is a district in Soc Trang province, Vietnam (Figure 1). Its economic development depends on agriculture, with different rice farming models, such as triple rice, double rice, and double rice-fish. However, the Nga Nam district belongs to the lowest lowland area of Soc Trang province; therefore, it is heavily affected by climate change and rising seawater levels. Its low-lying terrain leads to poor drainage, resulting in more flooding that lasts a long time during the rainy season. On the contrary, this place also lacks water for agriculture in the dry season due to its location on the border between the sea and the freshwater zone. Moreover, the soil in this district is also contaminated by acid sulfate matter at the beginning of the rainy season. Heavy rain in this season also causes pests and diseases that lead to difficulties in agricultural production, which is the main source of livelihood and routine of the locals. The hydrological regime of Nga Nam district is affected by the Quan lo Phung Hiep canal system and the Ca Mau peninsula freshening system. In addition, the district is affected by the semi-diurnal tidal regime of the East Sea, and saltwater intrusion also changes the ecological environment, influencing the changes in the agricultural land use of the local farmers.

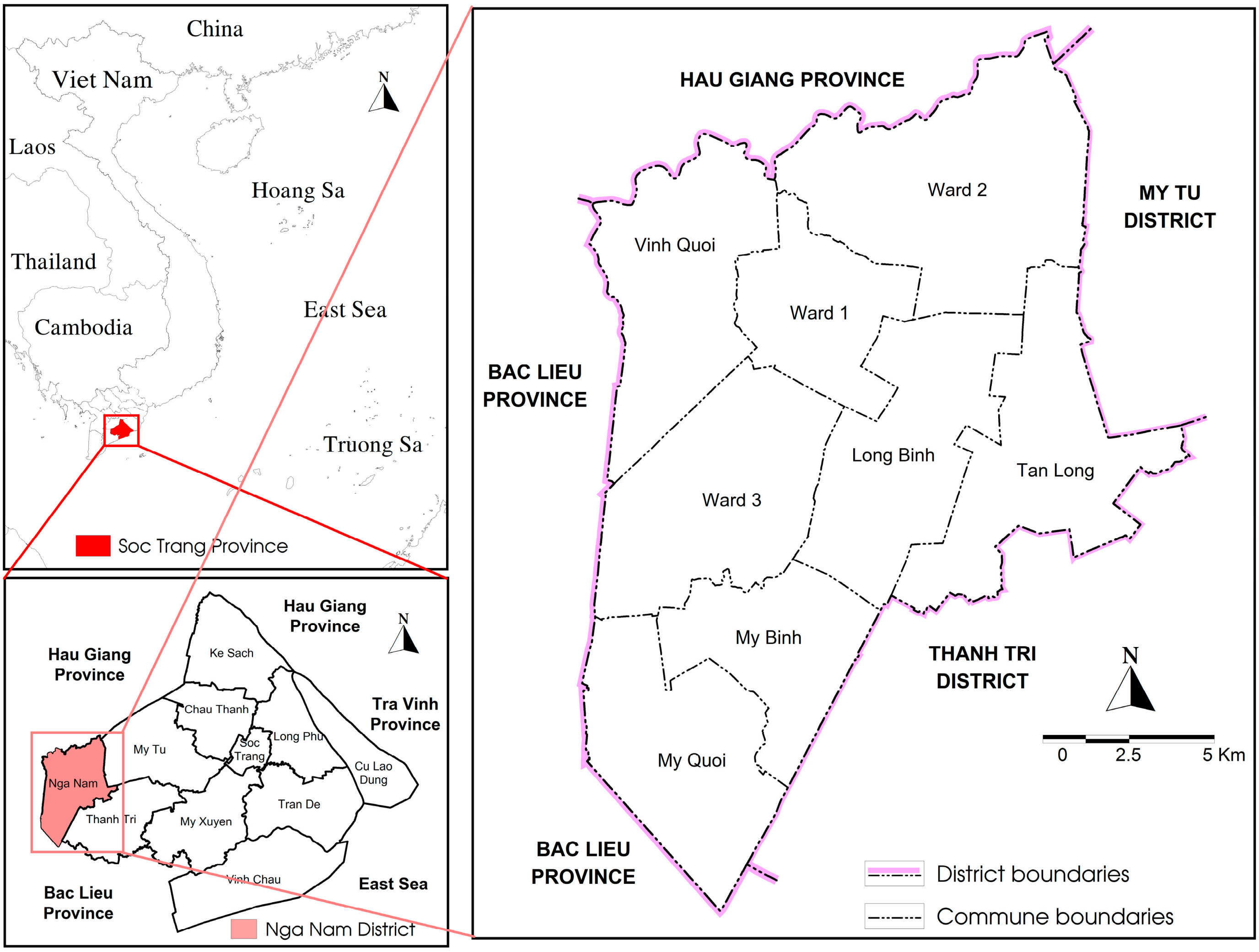

Figure 1. Location of Nga Nam district, Soc Trang province, Vietnam.

2.2. Land Use Change Analysis

Data, figures, reports, and maps on the status of agricultural land use in the Nga Nam district were collected to evaluate land use changes in the period from 2010 to 2021. These data were collected from the People's Committee of Nga Nam district. Subsequently, the changes were gathered and analyzed through statistics and a comparison of the area of land use change from 2010 to 2021 using descriptive statistical methods (charts and comparison tables). The assessment of change was also processed spatially by using data maps of the agricultural land use in 2010 and in 2021 in the Nga Nam district. The ArcGIS 10.6 tool was used to overlay the identification of varying regions of land use (Figure 2). The drivers and dates of changing land use were analyzed by interviewing people who were directly involved in agricultural production and agricultural management officers within commune-level administrative units.

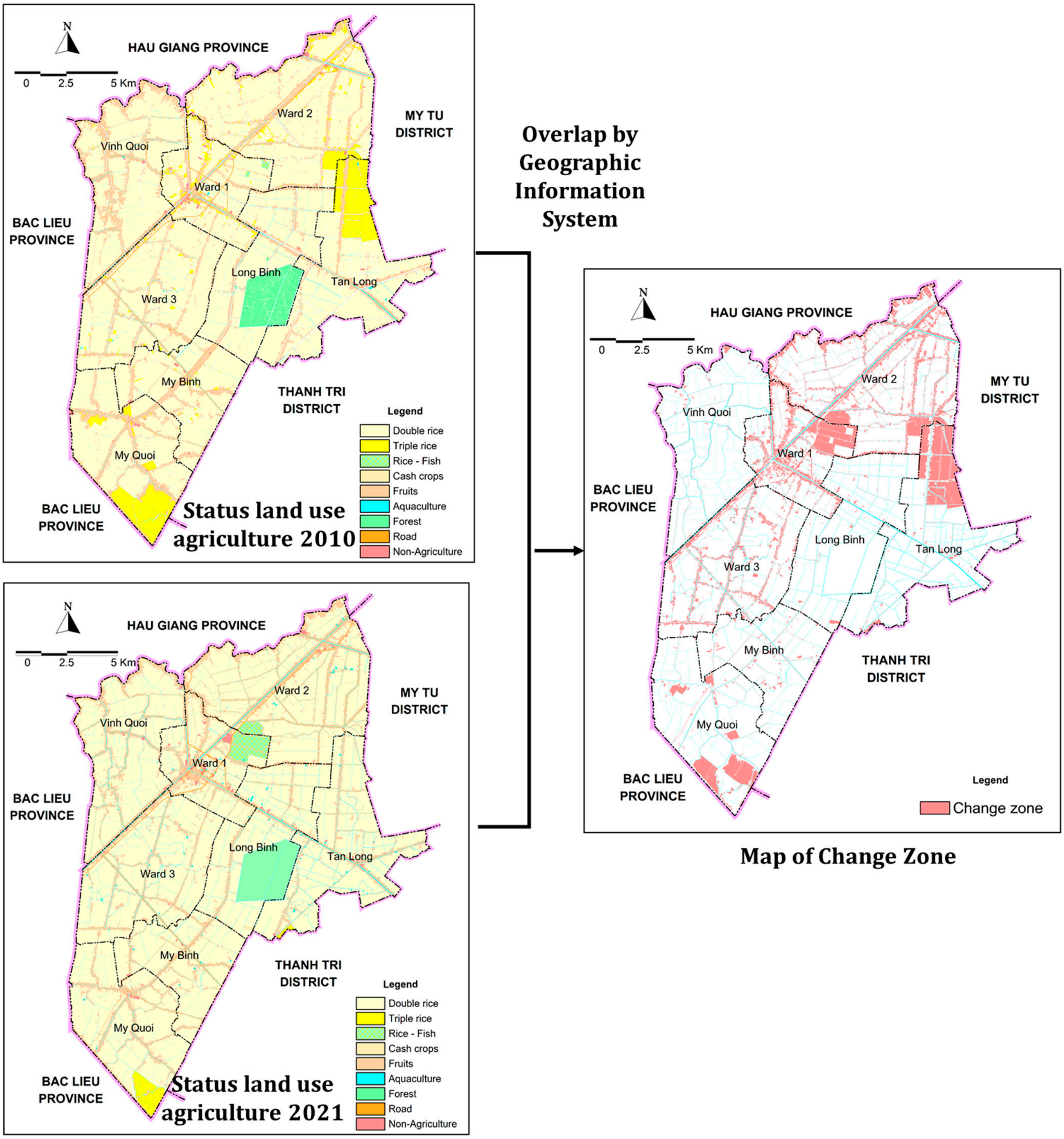

Figure 2. The overlap diagram determines the land use change area for the period 2010 to 2021 with the GIS tool.

2.3. Determination of Factors Affecting Agricultural Land Use Change

In this study, we conducted in-depth interviews with agricultural management officers within commune and town-level administrative units (09 experts) to investigate the reasons and factors that changed agricultural land use. Furthermore, in this study, we also directly interviewed 160 farming households (32 farmers/land use type) who directly conducted agricultural production in Nga Nam district to document and determine difficulties during the farming processes of the people and the reasons people switched to a new farming model. Based on the assessment of the experts and farmers, the factors transforming farming models of the people during 2010–2021 were determined.

2.4. Analysis of the Influencing Level of Factors on Agricultural Land Use Change

Based on the determination of factors changing the land use of farmers, comparison tables were built between pairs of factors (primary and secondary). Experts' opinions were also consulted. In the current study, the 45 experts who were familiar with the impacts of agricultural land use change towards farmers in Nga Nam district included managing officers and farmers who were directly engaged in farming so as to determine the level of influence (Table 1) of each pair of factors that change people's land use.

Table 1. Basic scale for the pairwise comparisons.

Number of Value	Verbal Scale
1	
3	Moderately more important, likely, or preferred
5	Strongly more important, likely, or preferred
7	Very strongly more important, likely, or preferred
9	Extremely more important, likely, or preferred
2, 4, 6, 8	Intermediate values to reflect compromise

Source: The basic scale of classification based on the previous research [42].

Subsequently, in this study, we used the method for evaluating the criteria by Saaty [46,47] to determine the level of influence of factors on the changes of agriculture land use in Nga Nam district, Soc Trang province. This method was performed following 3 basic steps: (1) determining influencing factors and building a pair-wise comparison table, (2) calculating the weight (1) (Figure 3a), and (3) determining the consistency ratio (CR) (2) (Figure 3b).

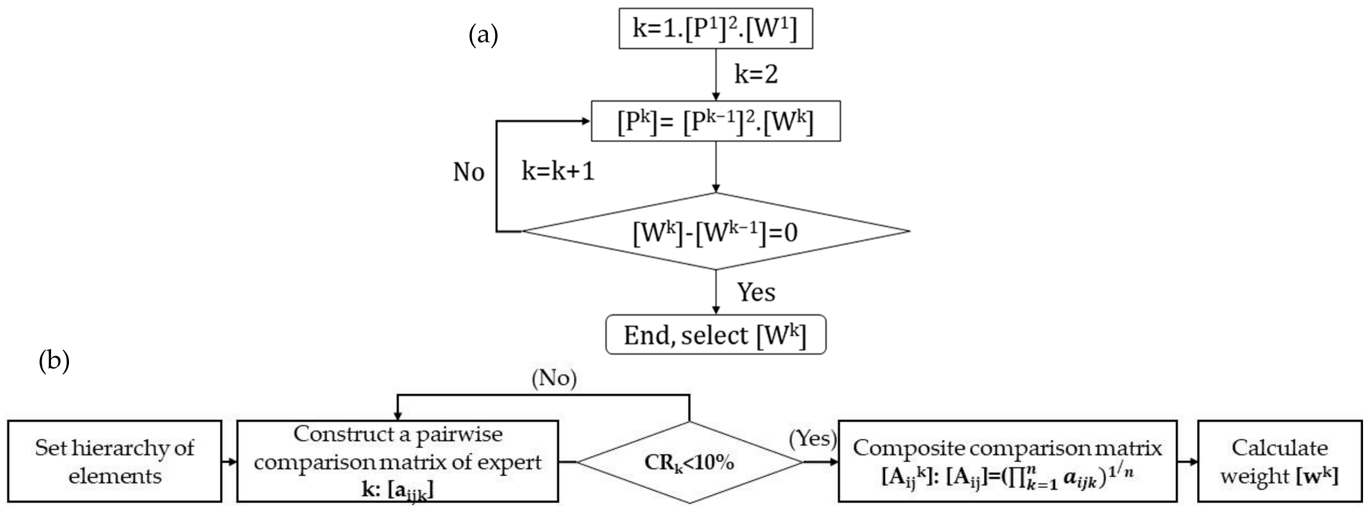

Figure 3. Weight calculation (**a**) and AHP-GDM in determining the weights of factors (**b**).

In this, the weight was determined by Formula (1):

$$w_1^k = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n} \cdot \sum_{j=1}^{n} a_{ij}}, \text{ sum row } \sum_{j=1}^{n} a_{ij} (i = 1,\ 2, \ldots, n) \quad (1)$$

and the vector was determined: $\left[W^k\right] = [w_1^k.w_2^k \ldots .w_n^k]^t$.

The consistency ratio (CR) is recommended to be accepted if and only if CR ≤ 0.10 (or 10%) [48,49]. A higher than such value means the pair-wise comparisons for the criteria are highly inconsistent in terms of preferences; hence, there is a need to revise the pair-wise comparisons.

The formula for the CR [48,49] was:

$$CR = CI/RI \tag{2}$$

in which:

CI is the consistency index.
RI is the random index (RI).

CI (3) was calculated according to:

$$CI = \frac{\lambda max - n}{n - 1} \tag{3}$$

in which:

n is the number of criteria;
λmax is the mean of the consistency vector (4).

In addition,

$$\lambda max = \frac{C_1 + C_2 + \cdots + C_n}{n}, \; with\ vector\ [C] = [C_1\ C_2\ \ldots C_n]^t \tag{4}$$

The RI (Table 2) depends on the number of criteria to be compared.

Table 2. The random index.

n	3	4	5	6	7	8	9
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.46

Source: The random index for calculate the CR [47].

After calculating the levels of primary and secondary factors, to determine the overall level of the factors, the weights of the two types of factors were multiplied with each other as follows:

$$W_{overall} = W_{primary\ factors} \times W_{secondary\ factors}$$

The results of determining the weights of each factor were the basis to recommend approaches that need to be prioritized in order to enhance the efficiency of agricultural land use in Nga Nam district in the future.

2.5. Suggesting Approaches to Limit Agricultural Land Use Change

It was based on the evaluation and analysis for causes, and factors influencing the changes of farming model of farmers combined with the socioe-conomic orientation of the district and the consumer market of the agricultural productions. Hence, the study suggests practically structural and non-structural approaches so as to prohibit the shifting of land use models of farmers, to improve land use efficiency, and to sustainably manage land resources to cope with saltwater intrusion and climate change.

3. Results and Discussion

3.1. The Change in Agricultural Land Use during 2010–2021 in Nga Nam District, Soc Trang Province

(a) The status of saltwater intrusion during 2010–2022 in Nga Nam district

The occurrence of saltwater intrusion in Nga Nam district was perplexing from 2010 to 2022. The intrusion went deeper into the inland fields from 2010 to 2015. Noticeably, in the years 2010, 2012, 2015, and 2018, the salinity substantially increased with long duration in the measuring stations of Nam Kieu and Nga Nam center (Figure 4), whereas, from 2016 to 2022, the salinity decreased. This is the direct result of the saltwater prevention structural systems in the Phung Hiep canal and Au Thuyen Ninh Quoi of Bac Lieu province and sluices in Nga Nam district. Furthermore, due to the effects of saltwater on agricultural production, the local government arranged and built many closed dike systems. Therefore, the saltwater intrusion was controlled by the end of the assessment period.

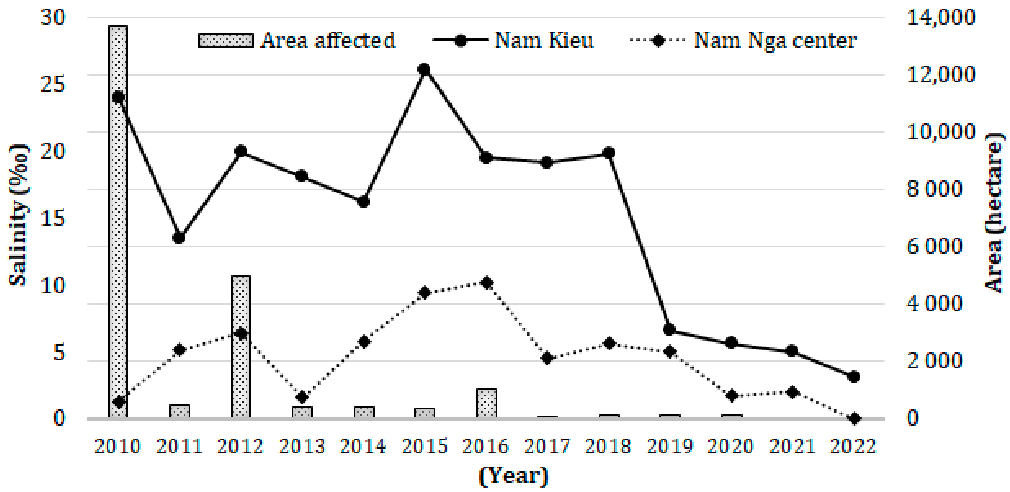

Figure 4. Changes in water salinity at the Nam Kieu station and the Nga Nam Center station and the area of agricultural land damaged during 2010–2022 in the Nga Nam district, Soc Trang province.

Figure 4 illustrated that the shifting of saltwater intrusion also directly affected crops, such as yield reduction, and crop loss. In 2010 and 2012, the salinity dramatically increased at the two stations, which significantly damaged the cropping area. However, at the beginning of 2015, although the salinity was still high, the area of land damaged by salinity decreased. This was because there were prior prevention activities undertaken against saltwater intrusion in previous years. The local government conducted salinity measurement and prediction at the beginning of the season so that the farmers had time to plan and cope with the saltwater intrusion. Therefore, farmers changed to another suitable crop for the saltwater intruding condition or changed the cropping schedule in order to limit the effects of saltwater intrusion. The operation of saltwater preventing structures is the key factor reducing the influences of saltwater intrusion in Nga Nam district. The progression of saltwater intrusion in the period of 2010–2022 illustrates that regions affected by saltwater in Nga Nam district are divided into three specific regions. The region that was heavily affected and high inland salinity was mainly in Ward 3, My Binh and My Quoi communes, while the Long Binh and Vinh Quoi communes, Ward 1 of Nga Nam district were partially affected (Figure 5). The region that was less affected by saltwater intrusion was in the Tan Long, Long Binh, Vinh Quoi communes and Ward 1. The remaining areas were almost unaffected by saltwater intrusion.

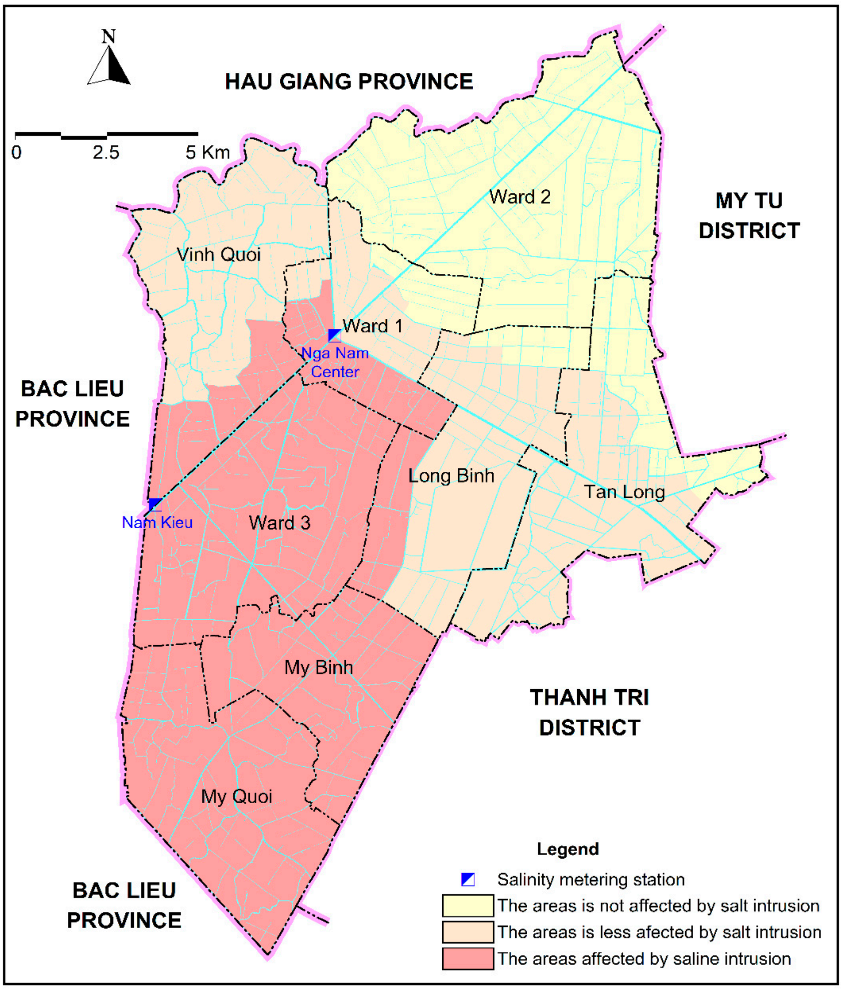

Figure 5. Map of saltwater intrusion influence in Nga Nam district.

(b) Changes in agricultural land during 2010–2021 in Nga Nam district

From 2010 to 2021, the area of agricultural land in Nga Nam district showed a downtrend along with the increase in non-agricultural land area (Figure 6). This was because there was a shift from agricultural land to non-agricultural land to adapt the need for developing infrastructure under the common socio-economic pattern of Nga Nam district [50].

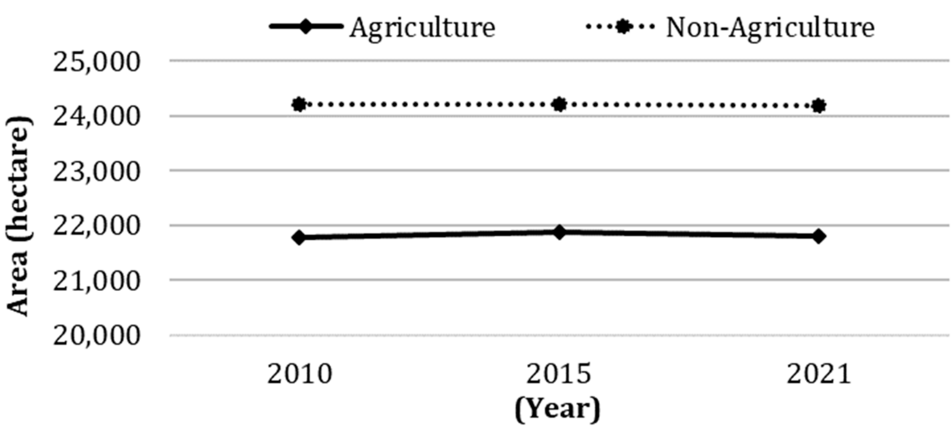

Figure 6. Changes in land use from 2010 to 2021 in Nga Nam district.

In the period from 2010 to 2021, agricultural land for annual plants increased from 18,215.6 ha to 18,611.3 ha. This increase happened mainly during the period of 2010–2015, and from 2015 to 2021, the trend decreased (Figure 7). The increase in land area for annual plants was because of the change from low-efficiency cultivation of perennial plants to lands for rice crops to cash crops because the saltwater-preventing structures at the beginning stage were not completed, which led to an increase in saltwater intrusion damaging plant viability. The mixed cultivation did not bring high economic efficiency to farmers (Figure 8).

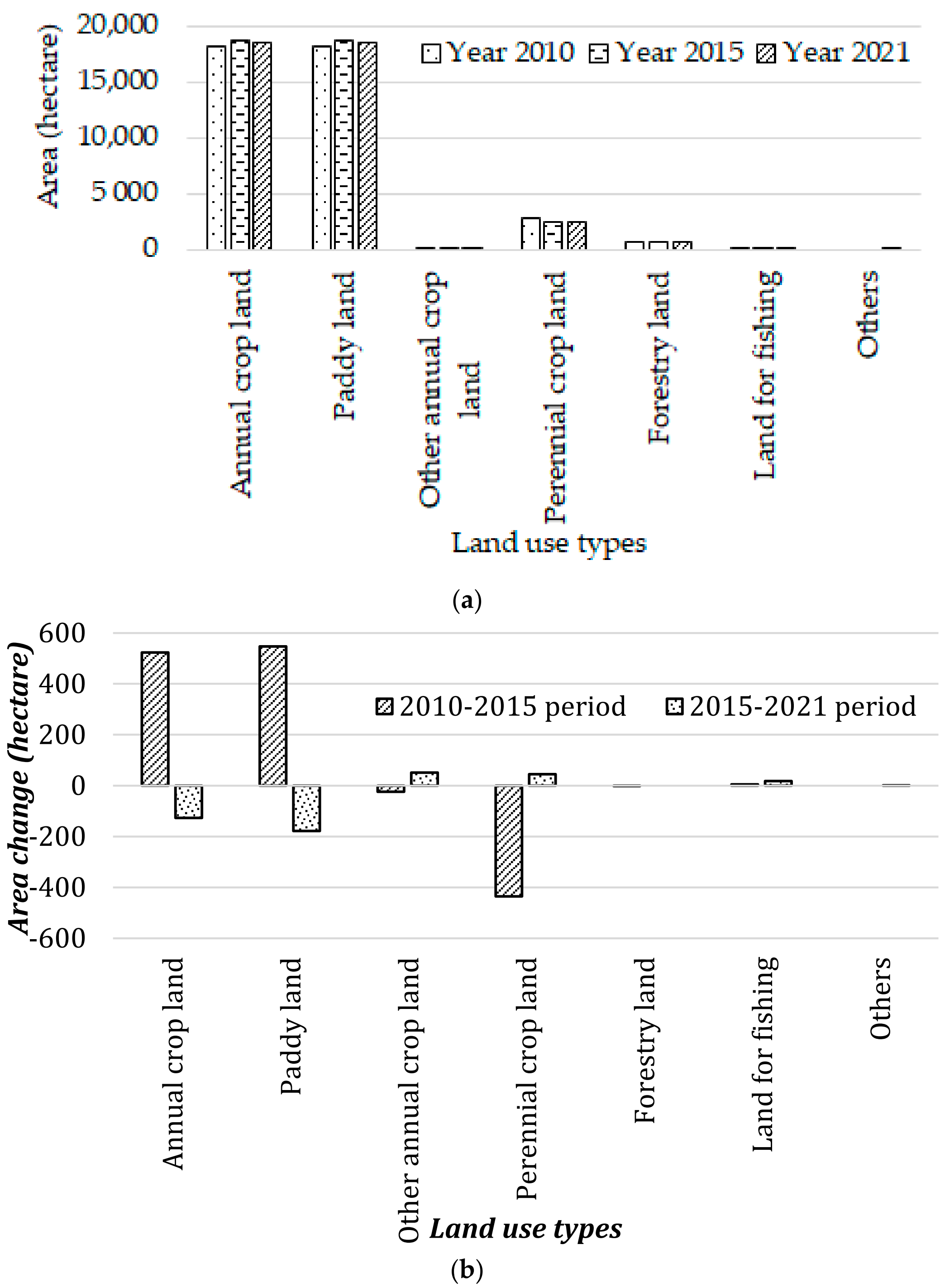

Figure 7. Areas of lands in 2010, 2015, and 2021 (**a**) and the changing area during 2010–2015 and 2015–2021 (**b**) in Nga Nam district, Soc Trang province.

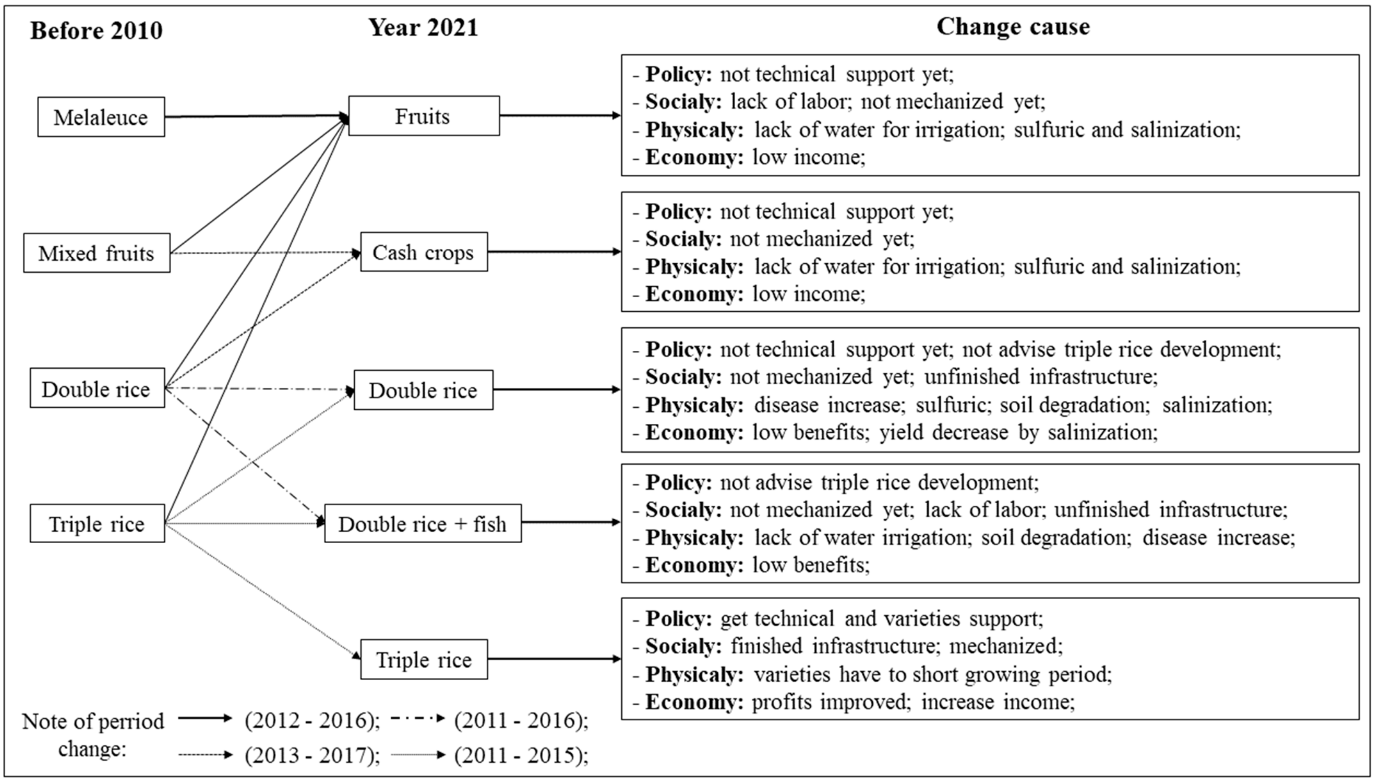

Figure 8. Reported reasons for changing farming models during 2010–2021 in Nga Nam district, Soc Trang province.

Figures 7 and 8 show that the area for rice cultivation increased by 547 ha between 2010 to 2015, but during the late stage (2015–2021), the area decreased by 178 ha. The types of rice land use in Nga Nam district are mainly for double rice and triple rice crops. In addition, some rice–fish integrated systems occurred in order to improve the income of farmers to raise their economy. The causes for the changes in paddy land were mainly because of the lack of irrigation source during dry seasons because of inland saltwater intrusion. Therefore, the farmers mainly in ward 3, My Quoi, and My Binh commune changed land for triple rice into double crops (Figure 9), as well as changed into different farming systems to bring about greater economic efficiency, such as cash crops and the rice–fish system. These systems are suitable in the physical environment and local governmental support.

On the contrary, land for cash crops and perennial plants during 2010–2015 went on a downwards trend because the cash crop farming was not efficient and was affected by saltwater intrusion, leading to crop loss. At same time, the dyke system was not in operation, so the regions were vulnerable to tides leading to local floods during wet seasons, which affected the productivity of cash crops. For fruit trees, because of the farmers' farming traditions, the development of mixed farms during this period was not efficient, with low economy. Therefore, the farmers replaced mixed farms with another system that gained more economic efficiency. In the period of 2015 to 2021, the area of these two types of lands was increased by being transferred from low-efficacy paddy land by farmers. This was because the economic values of these lands increased and lands for fruit trees were also developed to enhance the economy of farms cultivating soursop, guava, and pomelo. In addition, the infrastructure system was becoming more and more complete and could inhibit saltwater intrusion during the dry season and floods during wet seasons.

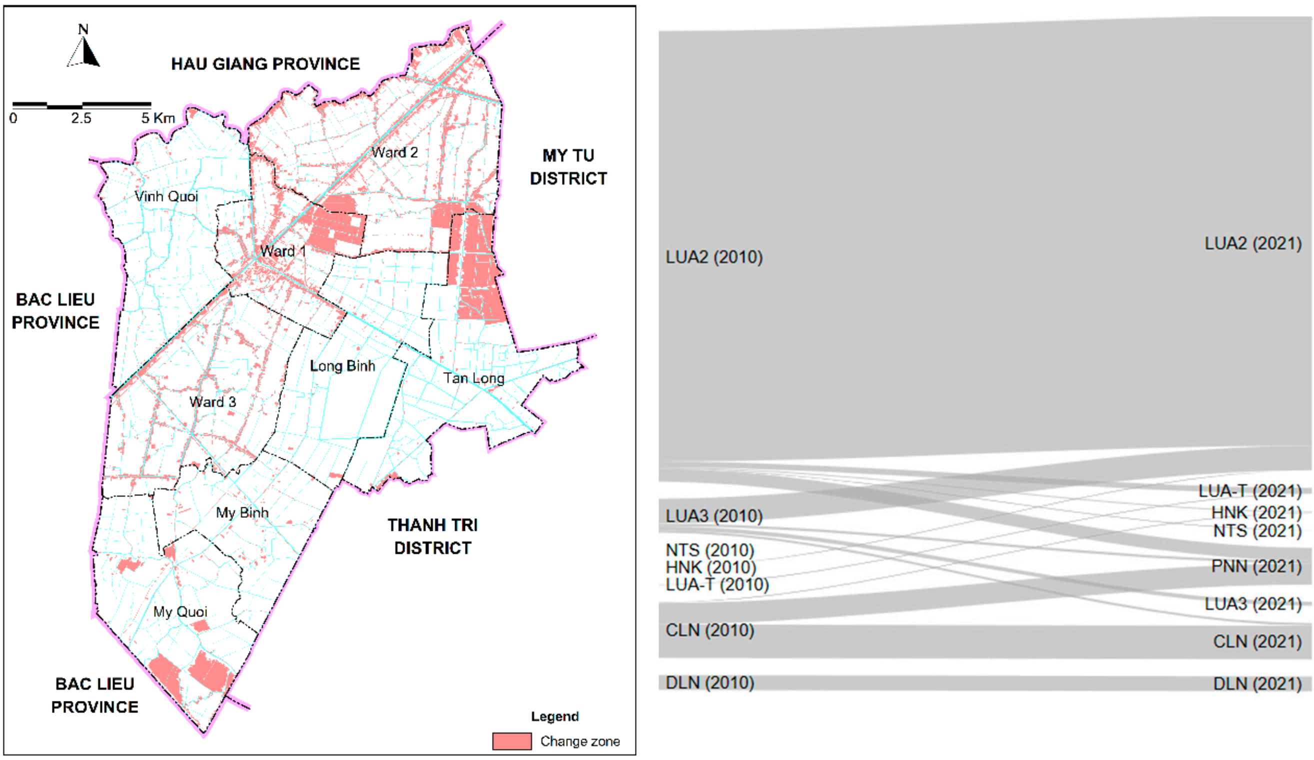

Figure 9. Map of agricultural land use change during 2010–2021 in Nga Nam district, Soc Trang. (Note: double rice (LUA2), triple rice (LUA3), aquaculture (NTS), rice–fish (LUA-T), fruit trees (CLN, *farms mixed with different types of fruits*), other annual crop land (HNK), and forestry (DLN).

Other types of land such as forest land, aquaculture land, and other agricultural land did not change significantly. The area of aquaculture land increased during the entire period from 2010 to 2021. On the contrary, forest land area decreased slightly during the same period (Figure 7). The change in forest land area is due to the conversion of production forest land to fruit trees to improve the economic efficiency of farmers.

Overall, during 2010–2021, the changes in agricultural land use by local farmers in Nga Nam district was determined to be caused by changes in environmental and socioeconomic conditions and the policy of support by the government (Figure 8). Therein, factors relating to saltwater intrusion were greatly damaged because the salinity was not controlled properly during 2010–2015. In the period from 2015 to 2021, the changes in farming models by farmers relied on the economic efficiency of a farming model while the infrastructure controlled the effects of saltwater intrusion. The shortage of freshwater for crops as well as other soil obstacles were also determined as factors influencing the changes in land use by farmers in Nga Nam district.

3.2. Factors Influencing Agricultural Land Use Change in Nga Nam District

(a) Determination of factors influencing changes of agricultural land use in Nga Nam district

Based on the consultants from managing officers and local farmers who directly participated in farming in Nga Nam district, factors influencing changes in agricultural land use during 2010–2021 were determined (Table 3).

Table 3. Factors affecting agricultural land use change in Nga Nam.

Factors	Sub-Factors	Sources
Physical	Acid sulfate	[45,46,51–60]
	Salt intrusion	
	Flooding	
	Drought	
Economic	Costs	
	Profits	
	Capital efficiency	
	Consumer market	
Social	Investment capital	
	Support policy	
	Cultivation habits	
	Cultivation techniques	
	Labor settlement	
Environmental	Reducing biodiversity	
	Increasing disease	
	Acumination	
	Salinization	
	Soil pollution	
	Water pollution	

Experts claimed that the changes in agricultural land use in Nga Nam district were affected by four principal factors: the physical factor, economy, society, and the environment. For the physical factor, there were problems of saltwater intrusion, acid sulfate contamination, and local floods during the wet season in regions with low terrain. Prolonged drought also led to more complicated saltwater intrusion progress. Crop yields were damaged, leading to changes from other farming models to ones that were suitable for the current natural situation. Farmers usually chose crops of high economic value to farm, and the stable current market brought economic efficiency. However, the changes can lead to a situation when products cannot be sold, leading to decreased selling price. Thus, the profit and the efficiency of the investment capital for the land use types were not effective, and the investment capital was not guaranteed for reproduction. The social factors interested in by experts were principally investment capital sources, supporting policies, farming practices, farming techniques, and agricultural labor sources. The reason was that the shift from agricultural labor to other types of labor was common, so the farmers chose a farming model that required less labor. From there, the farming and techniques and farming habits of farmers here changed. Environmental factors were claimed by experts to influence the changes in land use and included water pollution, reduced biodiversity, increased diseases, soil pollution because of intensive farming and multi-cropping, and the overuse of chemical fertilizer and pesticides by farmers. Moreover, salinization and sulfurization also needed attention, because during the saltwater intrusion, farmers brought saline water into farming fields, which salinized soils. During the dry season, farming models failed to maintain water, leading to the oxidation of acid sulfate materials, which caused the adverse impacts for crops.

(b) Level of influence of factors on changes in agricultural land use in Nga Nam district

The results show that the physical factors tremendously affected the changes in land use by farmers in Nga Nam district, while the economic, social, and environmental factors showed less influence (Figure 10).

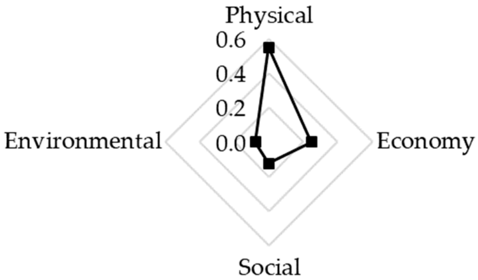

Figure 10. Weighting of primary factors affecting changes in farming models in Nga Nam district.

The managing officers and farmers that directly took part in agricultural farming claimed that climate change and the growing number of hydroelectric dams upstream have caused an increasingly complicated situation of saltwater intrusion [61]. The lack of freshwater could lead to greater saltwater intrusion into the inland fields, and during the dry season, it can damage crop yield [62]. In addition, the occurrence of unseasonal rains also caused acid sulfate leakage, affecting the yield of numerous crops [46]. Therefore, the farmers changed to other crops that can adapt to the saltwater intrusion, limiting the damages caused by this physical condition. The economy was also considered by experts. The reason was that farming models were inefficient because of low selling price and unsecured output [63]. Hence, the farmers used other farming models that had better economic efficiency and secured their people's lives. The current labor source for agriculture was still limited because of the shift in labor to other careers. The experts assumed that the social aspect should be considered as well. The environmental factor was considered to be less influential because the changes in agricultural land use by farmers did not remarkably affect the environment, which can change the farmers' farming models.

Among the natural factors, the saltwater intrusion status was considered to be important by the experts, while acid-sulfate-contaminated soils, flooding, and drought were less considered (Figure 11a). The experts believe that the progress of saltwater intrusion has become more and more complicated because of global climate change [38,40]. Therefore, the damage caused by saltwater intrusion to crop yield was more severe, though farmers and local governments had approaches to adapt and mitigate saltwater intrusion. However, negative effects also occurred in agricultural production and the water source for people. The acid sulfate soils also affected crop yield, especially at the beginning of the wet season, when acid sulfate leakage reduced crop yield [53]. Hence, farmers changed to another farming model with suitable crops. Flooding and drought in the current state showed fewer effects in terms of changes in agricultural land use because the occurrence of floods was rare and the infrastructure can assure production by farmers [4,56]. The farmers could also make a farming schedule that was suitable for the periods of flooding and drought.

Farmers can change farming models according to the trends of the consumer market [45,46]. This caused a huge variation in land use, because the changes were fragmented and at a small scale and did not follow the local land use planning orientation. Thus, this led to a situation where the supply outweighed the consumption, so the price decreased and farmers changed to another farming model. Therefore, the experts assumed that the consumer market was one of the important factors affecting the changes in agricultural land use by farmers in the economic aspect (Figure 11b). Other factors relating to investment cost, profit, and capital efficiency were considered by experts because of their connection; if the market was stable and selling prices increased, the reproduction by farmers was ensured, the economic efficiency of the farming model was high, and the investment capital was assured [45,46,58]. Therefore, the dependance on the market of agricultural products was considered, and it can directly affect the change in agricultural land use.

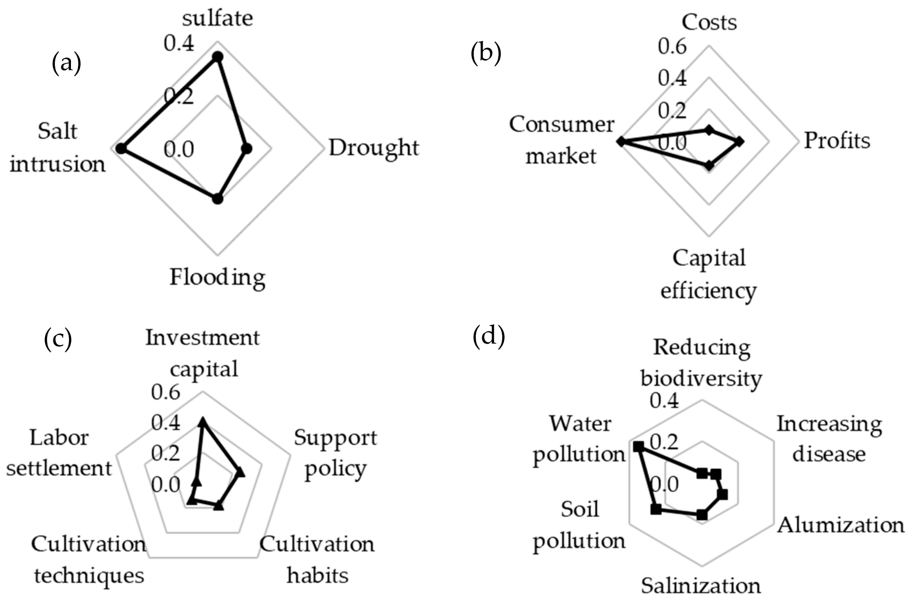

Figure 11. Weights of influences of secondary factors of the physical factor (**a**), economy (**b**), society (**c**), and environment (**d**) on the change in agricultural land use in Nga Nam district.

Among the social factors, the experts claimed that the factors that greatly affected the change in land use by farmers were principally the investment capital source, followed by less influencing factors related to supportive policies, farming practices, farming techniques, and labor source (Figure 11c). This assessment by the experts was due to the fact that farming models were vulnerable under saltwater intrusion conditions, leading to the death of plants and serious drops in productivity. Thereby, the production activities of farmers were interrupted due to no economic profit, production loss, and no investment capital for reproduction [60,63]. Therefore, the farmers used other crops that can both adapt to the saltwater intrusion and bring economic efficiency. Furthermore, the supporting policies from the government also contributed to stimulating the changes in farming by the farmers and comprised cultivar support, conversion cost, farming techniques, and support in the construction and improvement of infrastructure that limits the influence of saltwater intrusion [60]. This allowed farmers to change their crop system to be suitable to the physical conditions following recommendations by the local government to limit risks in agricultural production. The labor source showed less influence on land use change in Nga Nam district, despite the conversion of labor from rural areas to urban areas and from agricultural labor to commercial and service labor. However, because of the application of science and technology, mechanization in farming from soil preparation to harvest also contributed to reducing labor in production by farmers.

The experts assessed that water pollution had a great effect on changes in land use by farmers in Nga Nam district (Figure 11d) because during agricultural production, farmers used too much chemical fertilizer and pesticides. This could affect the water source, households, and surrounding areas. When exposed, crops can be poisoned, causing conflict in agricultural production, so farmers converted to other farming models to suit the production conditions. Soil pollution was also considered by the experts because of pesticide residues, intensive farming, and multi-cropping, leading to soil degradation and contamination. The occurrence of saltwater intrusion along with the cultivation by farmers resulted in the salinization of rice farming combined with brackish aquaculture. This salinization caused a variation in agricultural land area because farming models in the freshwater ecological regions were no longer suitable or adapted to the salinized soils. Instead, there were other farming models that were more suitable under saline conditions and brought better productivity. Other factors, such as reduced biodiversity, increased pests, and sulfurization, insignificantly affected the changes in land use by farmers because the use of chemical pesticides by farmers reduced beneficial species, leading to increased pests. However, these issues did not affect the agricultural farming by farmers, and pests were also well controlled by applying scientific technological approaches to production. Soil-ameliorating approaches such as using lime fertilizer to reduce acid sulfate materials and digging canals to flush away acid sulfate materials were conducted, so the acid sulfate soils insignificantly affected the production by farmers.

Figure 12 shows that among the 19 sub-factors of the physical factors, economy, society, and environment, saltwater intrusion showed the greatest influence, then acid sulfate contamination; the consumer market and local flooding tremendously affected the land use change by farmers in Nga Nam district. Saltwater intrusion damaged the crop yield, so farmers converted to a farming model that had better suitability to saltwater intrusion. In acid-sulfate-contaminated regions, farmers selected crops that can tolerate and adapt the acid sulfate condition in order to enhance crop yield to improve agricultural production efficiency and to improve the people's lives. In addition, the output of the agricultural products was one of the most-considered issues. Because farmers following fragmented and small-scale production usually follow the market trend, when the market dramatically changed, the event of rescuing agricultural products occurred and made the price drop, leading to low economic efficiency. Hence, farmers changed into different farming models with greater selling price and profit.

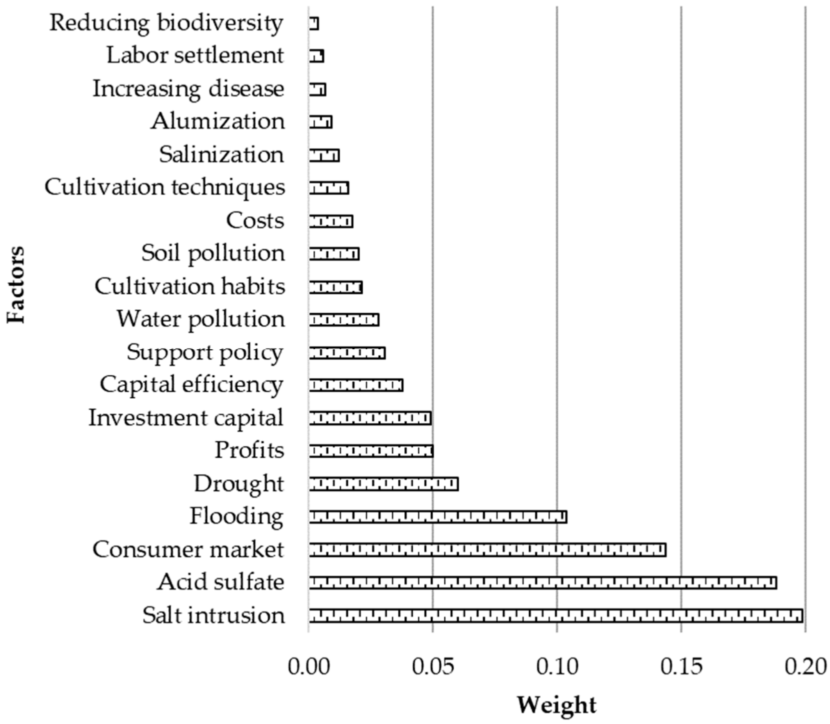

Figure 12. Weights of secondary factors influencing changes in farming models in Nga Nam district.

3.3. Solutions for Limiting Changes in Agricultural Land Use in Nga Nam District

According to the assessment of the influences of factors on agricultural production in Nga Nam district, long-term, short-term, and medium-term approaches have been proposed for the suitable and sustainable goal of the studied regions. It is necessary to prioritize key approaches such as:

Approaches for saltwater intrusion: The infrastructure of sluices should be constructed along the Phung Hiep Road canals. At the same time, stations automatically measuring salinity should be built to make farmers aware of timely adaptation measures in production. The local government should recommend farmers to change their cropping schedules to be suitable to the weather and saltwater intrusion. Cooperation should be performed with the surrounding regions of Ca Mau, Bac Lieu, and Kien Giang to observe and operate the saltwater preventing structures.

Approaches for acid sulfate soil: Acid sulfate toxicity was a direct factor influencing the yield, crops, and livestock. Thus, to limit the effects of acid sulfate soils, some approaches should be followed, such as fertilizing lime with a dose recommended by the local government. In addition, a canal system should be constructed to flow acid sulfate materials from the fields. Furthermore, local farmers should receive training in proper water management to prevent the oxidation of acid sulfate materials into active acid sulfate materials, which could poison crops. Moreover, it is necessary to develop farming and methods of preparing beds that are suitable for each depth of acid sulfate and acid-sulfate-bearing horizon.

Approaches for the consumer market: The consumer market was the central problem for agricultural farming in Vietnam and in the Mekong Delta and Nga Nam district in particular. The local government should establish links between enterprise and farmers in agricultural production to ensure the output of the products. Cooperative societies and groups for manufacturing products that are uniform in quality and design and oriented to establish an intensively producing region that cultivates and develops towards the GlobalGAP to build a brand in international markets should be formed.

Approaches for flooding: The local government should construct a dyke system and sub-regions for producing key crops of the district to limit the effects of flooding during the wet season. Electric and drainage pumping stations also need to be built synchronously. The local government should recommend farmers to change their crop structure, which is suitable for flooding conditions to enhance economic efficiency, such as rice–shrimp or rice–fish farming systems.

4. Conclusions

In the period from 2010 to 2021, the effects of saltwater intrusion in Nga Nam district were assessed and found to significantly damages the agricultural land, especially from 2010 to 2015. Since then, this has resulted in a situation where farmers changed their land use purposes to limit the damage. During the period from 2015 to 2021, because of the effects of the saltwater-preventing structures, the influence of saltwater intrusion was reduced. Based on the consultation with experts, it was determined that the changes in agricultural land use in the Nga Nam district were heavily affected by physical and economic factors. Therein, factors relating to saltwater intrusion, acid-sulfate-contaminated soil, the consumer market, local flooding, drought, and investment capital and profit were the main influencing factors. Thereby, groups of structural and non-structural approaches are proposed to enhance the efficiency of using agriculture land and to reduce the land use change in the coming time in Nga Nam district, such as constructing and upgrading infrastructure to prevent saltwater intrusion and flooding. Furthermore, acid-sulfate-soil-ameliorating approaches also need to be conducted, such as lime fertilization and conversion to appropriate crops. Additionally, to ensure the output of agricultural products, approaches that established linkage in product consumption should be implemented.

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