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*Research Article*

# Assessing impact of saline intrusion on rice cultivating area in Ke Sach district, Soc Trang province, Vietnam

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## Abstract

This study was carried out to evaluate the effects of saline intrusion on agricultural activities, thereby proposing adaptation and mitigation measures for local people. Salinity was measured at 15 locations on the main and tributary rivers in Ke Sach district, Soc Trang province, Vietnam from January to September 2020. The method of direct interview with farmers was used to evaluate the knowledge and effects of saline intrusion on agricultural production. Salinity measurement results showed that salinity intrusion occurred and lasted from February to the end of May during the dry season (the Winter-Spring rice crop). During the rainy season (June-September), due to the large amount of water, salinity was only between 0.01 and 0.1‰. However, the research has found significant effects in the Summer-Autumn rice crop due to the accumulation of salinity in the soil from the Winter-Spring rice crop, which reduces the rice yield by 10-30%. The interview results revealed that more than 80% of the farmers were aware of the effects of saline water intrusion. Local authorities also regularly organize seminars to disseminate basic knowledge to the community to minimize the risks and impacts of saltwater intrusion. The proposed temporary solutions include rain-water storage, maintenance of saline prevention sluices, construction of more water regulation canals, financial support, and strengthening of salinity monitoring stations. In order to adapt to the long-term salinity conditions, local authorities need to focus on researching changing cropping patterns, crop structure, using new rice varieties that are able to adapt to drought and salty conditions. Besides, there will be technical assistance, capital for people to adapt well to the saline intrusion situation.

## Introduction

Climate change has been and is taking place more and more seriously. According to the IPCC forecast, by 2100, the global temperature will increase from 1.4°C to 5.8°C. The phenomenon of global warming leading to faster thawing rates of the Arctic and Antarctic forces all humanity to respond. The rise of sea level will directly affect the lives of hundreds of millions of people, especially coastal countries and

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territories, and, more importantly, will submerge some small islands and coastal areas in low terrains (MoNRE, 2012). Vietnam is considered one of the countries most severely affected by climate change due to its long coastline (Cullen and Anderson, 2017). If the earth's temperature increases by 2$^o$C, about 22 million Vietnamese people will lose their homes, and 45% of agricultural land in the Mekong Delta, Vietnam's largest granary, will be submerged in seawater and resulted in other serious consequences (Tuan et al., 2009).

The Mekong River Delta (Mekong Delta) is one of the largest agricultural centers in Vietnam (Tin et al, 2018). Every year, the Mekong Delta contributes over 56.7% of rice production, 70.3% of fish production, and about 42.7% of fruit production and aquatic for the whole country (Hoa, 2018), especially providing more than 95% of rice for the national export (General Statistics Office, 2020). The Mekong Delta is also known as Vietnam's largest country of wetlands with high biodiversity and is one of the areas sensitive to changes in extreme weather and climate change factors (Apel et al., 2012; Manh et al., 2015; Binh et al., 2020; Connor et al., 2020), of which, sea-level rise is a direct and strongly influencing factor (Boretti, 2020). Sea level rise will make many current freshwater deltas become brackish water areas, changing the hydrological regime of flow. Farming, aquaculture, and forestry in coastal areas will be greatly affected by sea-level rise and saline intrusion (Boretti, 2020).

Soc Trang is a coastal province located in the South of the Hau River in the Mekong Delta. In addition, Soc Trang is one of the key rice-producing provinces in the Mekong Delta. In recent times, the biggest disadvantages to the development of rice production in the province include the unusual changes in weather conditions, especially local inundation caused by the impact of high tides as well as the decline in surface water resources due to the construction of saline prevention dams. In addition, according to the sea-level rise scenario, Soc Trang will be one of the 10 provinces in the country seriously affected by the sea-level rise phenomenon (National Department of Science and Technology Information, 2016). If the sea-level rises by 1 meter in 2100, Soc Trang will inundate about 45% of the total natural land area during low tide and over 72% of the total natural land area during high tide (Schmitt et al., 2013). Specifically, the Ke Sach district always faces a shortage of freshwater due to salinity intrusion into the inner fields from the sea through the estuary is Tran De and Dinh An (Tuan et al. 2020). Saltwater intrusion is a potential risk damaging crop diversity and productivity due to degraded soil physicochemical properties (Phong, 2017; Sinh et al., 2021). In addition, the unusual change in rainfall and salinity intrusion time in the future will also significantly affect the water supply for rice production of coastal people (Hoang et al., 2014). Therefore, it can be said that saline intrusion is an alarming situation in this area. This study was conducted to evaluate the changes and effects of saline water intrusion on agricultural production activities, from which it is proposing some adaptive solutions for people.

## Materials and methods

In this study, the field survey method was applied to collect information regarding natural conditions, socio-economic conditions, and saline intrusion. During the survey, it directly interviewed farmers of 3 communes (30 households and 6 managers), including Dai Hai, Ke An, and Ke Thanh by the questionnaire, to assess the understanding, development, and effects of saline intrusion on agricultural production and livelihoods of people. The questions in the farmer interview table focused on (1) the main types of agricultural cultivation in the study area, (2) the timing and causes of saline intrusion, (3) the impacts of saline intrusion for farmers, (4) the ability of the farmer to adapt. Meanwhile, the questionnaire mainly collected information related to responding to saline intrusion in the district for the managers. In addition, salinity at 15 locations on rivers in Dai Hai, Ke An, and Ke Thanh communes of Ke Sach district. Soc Trang province was also measured to assess the current state of salinity in terms of space and time for the assessment of the effects of saline intrusion on the livelihoods of the community in the study area. In this study, salinity was determined in-situ by salinity meter EC170 (Extech, USA) according to standard methods (SMEWW 2520-salinity-D:2012) (APHA, 2012). The sites and site description for salinity measurement were shown in Figure 1 and Table 1.


*Figure 1. Salinity measurement locations in the study area*

*Table 1. Description of salinity measurement locations in the study area*

| No | Code | Coordinates | Characteristics | Reason for salinity measures |
|---|---|---|---|---|
| 1 | M1 | 9°47'22.52" 105°51'57.55" | Near the sewer line connecting to Canal 25; | Determine the salinity of water when entering Canal 25. |
| 2 | M2 | 9°47'31.99" 105°51'49.76" | Phap Hue bridge | Determine the salinity concentration when entering the interior area, which is adjacent to the inland tributaries. |
| 3 | M3 | 9°47'58.68" 105°51'23.05" | Mang Ca I bridge | Determination of salinity, where the inland tributaries intersect with water from the sea. |
| 4 | M4 | 9°47'51.06" 105°52'2.91" | 500m from Dai Hai Commune People's Committee toward Ke Sach town. | Determine the difference between the water distances from the sea. |
| 5 | M5 | 9°47'41.99" 105°52'37.09" | Kenh 5 Bridge | Determine the salinity of water at the beginning of Kenh 5; |
| 6 | M6 | 9°47'28.38" 105°53'28.35" | So 2 Bridge | Determine the salinity of water when pouring into So 2 canal |
| 7 | M7 | 9°47'24.68" 105°53'46.33" | 50m from Dai Hai 5 Secondary School toward the town of Ke Sach. | Determine the difference between the water distances from the sea; |
| 8 | M8 | 9°47'11.30" 105°54'35.53" | Near market No. 1 | Determining salinity at the beginning of canal when flowing into rice cultivation area in East canal; |

*... continued Table 1.*

| No | Code | Coordinates | Characteristics | Reason for salinity measures |
|---|---|---|---|---|
| 9 | M9 | 9°47'5.63" 105°55'0.62" | Chinh Tien Bridge | Determination of salinity at the beginning of the canal; |
| 10 | M10 | 9°47'0.79" 105°55'21.52" | Kenh 10 bridge | Determination of salinity of canal headwater when flowing into canal 10; |
| 11 | M11 | 9°46'50.25" 105°55'53.46" | Near Ke An Secondary School 1 | Determine the difference between the water distances from the sea; |
| 12 | M12 | 9°46'57.85" 105°55'36.31" | Chua bridge | Determination of salinity when water flows into the interior of the Chua canal; |
| 13 | M13 | 9°46'38.66" 105°56'31.43" | Nam Loc bridge | Determination of salinity when water flows into Nam Loc canal; |
| 14 | M14 | 9°46'35.05" 105°57'2.93" | Tu So Bridge | Determination of salinity when water flows into Tu So canal; |
| 15 | M15 | 9°46'20.93" 105°57'58.26" | Bung Tiet Bridge | Determine the salinity concentration when water flows into the Bung Tiet canal. |

## Results and discussion

### *Salinity in the study area*

In the Ke Sach district, inland rivers are dominated by the Ke Sach river, which flows into the Hau river. Ke Sach river is influenced by the tide of the Hau river. Water flows from the sea into the Hau river through Tran De estuary and into canals in the inner field. Going deep into the inner field, the canals are still dominated by the Quan Lo Phung Hiep canal, so the salinity concentration changes in spatial and temporal. The study from January to September shows two typical seasons, rainy and dry seasons. The measurement of salinity at the Ke Sach river section follows through 3 communes of Dai Hai, Ke An, and Ke Thanh in the first months of the year: January, February, March, April, and May 2020. Salinity concentration at the study sites over the first months of the year was shown in detail in Figure 2. Figure 2 revealed that the salinity area appeared with high concentration and fluctuated evenly when moving deep inside the field. The average high salinity concentration that appeared in February and March was 3.86 ‰ and 3.87 ‰ from the M15 to M1 location, about 100 meters apart. This has been reported in many previous studies in Ben Tre, Hau Giang and Vinh Long; where salinity was recorded quite high in February and March (Viet et al., 2015; Phong, 2017; Dao and Binh, 2019). Because this period was the dry season, the water flow on the river is relatively small, so the ability to supply fresh water to the people is very low, affecting farming and agricultural production in the study area. The deeper it goes into the inner field from the river mouth (100m-200m), the salinity decreased to 0.5 ‰-2 ‰; similar to the study of Be et al. (2017) at Long Phu district, Soc Trang province. Particularly at position M3, the salinity fluctuated unevenly compared to the other locations because this was where the water flow intersects with other canals in the interior field, so the salinity was diluted.

In the study area, the rainy season was during June, July, August, and September. The salinity measured in the study locations does not change much because this rainy season was with much freshwater that reduced the salinity. Salinity measurement results showed that salinity did not change much and was at a low-level ≤ 0.1‰. However, because this is an area close to the sea, in the rainy season, the salinity decreases but remains at 0.01‰ to 0.1‰.


*Figure 2. Salinity fluctuation over months by location (dry season)*

***Evaluating the impact of saline intrusion on the economy - society - environment of the rice cultivation area***

*Impacts of saline water intrusion on economic efficiency in rice production*

*Rice productivity*

The economic value is closely related to the yield of each season. Usually, the yield of the winter-spring rice crop is the highest. Summer-autumn rice crop is usually lower than the rest due to weather risks (Son et al., 2014). The three-crop rice cultivation area is often at risk of salinity, drought, and freshwater. In general, the productivity of normal crops is at an average level of 700 - 900 kg 1000m$^{-2}$, while for the Winter-Spring rice crop, productivity can reach 1000 kg 1000m$^{-2}$.

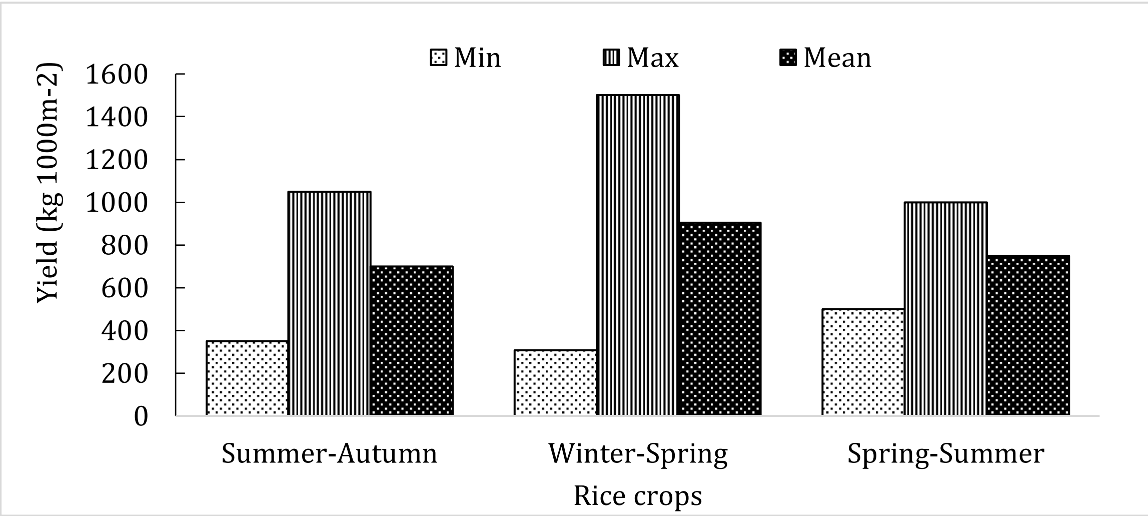


*Figure 3. Usual productivity in crops without external impact*

The saline intrusion have greatly affected the growth and development of rice plants and cause fluctuations in yield (Lam, 2018). In general, rice yield is recorded to be reduced, and the extent of the decline depends on factors of the saline intrusion wave, such as the continuous duration of the saline intrusion, the period when the rice is growing. Freshwater is maintained in the in-field canal system and farmers' farming solutions during the saline intrusion. Figure 3 showed the variation in yield during saline intrusion compared to normal farming crops (years without adverse impacts and changes from nature). The affected rice yield due to saline intrusion usually occurs in Winter-Spring and Spring-Summer rice crop (for 3-crop of rice). As for the Summer-Autumn rice crop, productivity fluctuated, but the main reasons were weather factors, pests, and diseases. The average yield loss was between 1000-2000 kg $ha^{-1}$ (i.e., a decrease of 100 - 200 kg $1000m^{-2}$) during the years affected by salinity. The time of salinity that has the greatest impact on rice yield, which was recorded during flowering and produce rice seeds period, specifically, the yield decreased from 14.8% (Lam, 2018). During this period, a steady source of freshwater is the most important thing for the rice to flower and produce seeds. Inadequate freshwater conditions will impair the flowering and seeding abilities of the rice plant, leading to effects such as grain loss or non-flowering. Accordingly, the salinity intrusion over the years has caused the instability of the freshwater supply for farming, causing problems of lack of freshwater for cultivation and a decrease in rice productivity. Moreover, due to the rice farming practices being associated with the farmer's water in the study area, during the prolonged saline intrusion, people still pump saltwater into the cultivated area to save the rice. The impacts of saline intrusion continue to persist in the following years.

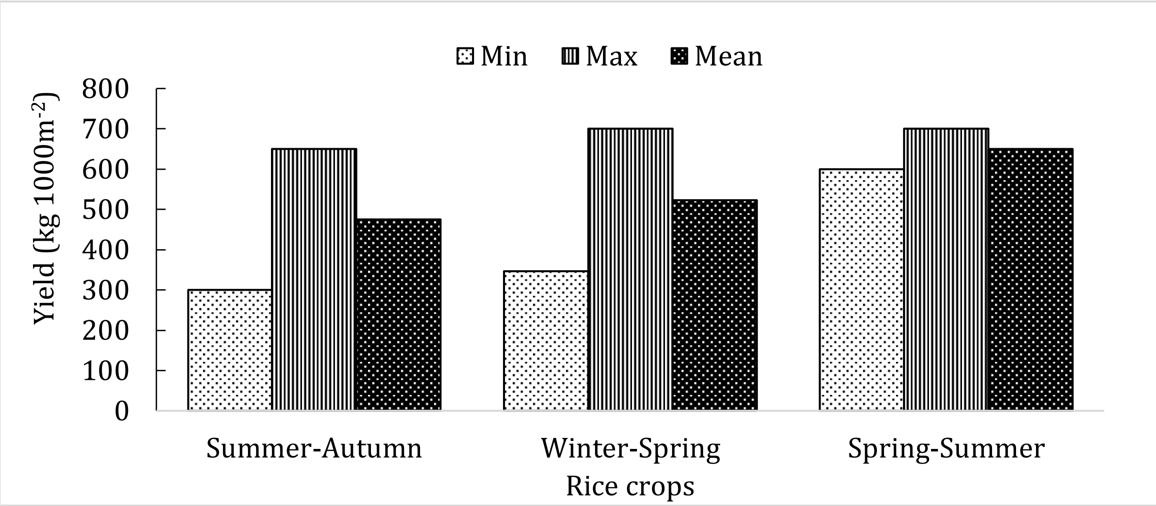


*Figure 4. Rice productivity affected by saline intrusion in the study area*

Rice yields in the following crops since saline intrusion were reported to continue to decline, but at a lower average rate of 500 - 1000 kg $ha^{-1}$ in both Summer-autumn and Winter-Spring rice crop (Figure 4). According to the study by Kham (2019) in Ben Tre and Bac Lieu province, the winter-spring crop's yield was 470 kg $ha^{-1}$ and 750 kg $ha^{-1}$, respectively; which is suitable for the study area. If saline intrusion occurs, agricultural production in the province is reduced. The main reasons for the decline in productivity are mainly due to the accumulation of salinity in the soil, changing seasons, and deteriorating irrigation infrastructure after the saline intrusion. Salt comes from the water source that the farmer pumps into the field to maintain water levels and avoid drought during saline intrusion that accumulates and remains in the arable layer. In the following crops, the water source pumped at the beginning of the crop did not change compared to the normal crops, creating conditions for salinity to persist and causing adverse problems such as damaging rice plants. In addition, due to the prolonged salinity intrusion, the cultivating time is interrupted, and the whole crop is extended. Accordingly, the start time of the new crop will be delayed. At the same time, because the farming system has deteriorated, after going through a saline intrusion period, the works need to be upgraded or will have difficulty in operating and regulating freshwater sources for the crop, leading to decline in rice yield (Figure 4).

*Impact on production costs*

For rice cultivation, investment costs are relatively stable over the years. Investment costs can be divided into main groups, including fertilizers and pesticides (agrochemicals), varieties, land preparation, farming equipment, irrigation, and hiring labor costs. According to farmers, the investment cost for Winter-Spring and Spring-Summer (or Autumn-Winter) rice crops is usually higher than the Summer-Autumn crop cultivated in the rainy season (May - September) due to the use of rainwater. In contrast, other crops in the dry season months were more costly because frequent pumping of water is needed to maintaining yield (Table 2). The cost-benefit aspects of rice cultivation also faced problems due to saline intrusion. Farmers' interview results showed that investment costs increased during and after years of saline water intrusion. The reason for the increase in investment costs during saline intrusion is due to the fee to pay for agricultural materials such as fertilizers, chemicals, water equipment, etc. (Vu et al, 2016). For the following crops, due to both experience of saline intrusion and the consequences of the previous unsuccessful farming season, the farmers' requirements for soil, water, and agricultural infrastructure improvement are required as the costs of agricultural materials increase to maintain or restore the proper character of the field for the new crop. In addition, some areas, due to inadequate improvement (saline washing, acid sulfate washing, plowing, etc.), caused the salinity from the previous season to maintain and partially or completely damage the rice being sowed, leading to re-sowing and increased investment costs for seeds.

*Table 2. Investment cost for the rice cultivation at different seasons*

| Season | Variation | Agrochemicals (USD) | Variety (USD) | Land preparation (USD) | Irrigation (USD) | Total (USD) |
|---|---|---|---|---|---|---|
| Winter-Spring | Lowest | 51.79 | 10.79 | 6.47 | 6.47 | 75.52 |
| | Highest | 64.74 | 17.26 | 8.63 | 8.63 | 99.26 |
| | Average | 58.26 | 14.03 | 7.55 | 7.55 | 87.39 |
| Spring-Summer | Lowest | 64.74 | 12.95 | 10.79 | 12.95 | 101.42 |
| | Highest | 86.31 | 21.58 | 6.47 | 21.58 | 135.94 |
| | Average | 75.52 | 17.26 | 8.63 | 17.26 | 118.68 |
| Summer-Autumn | Lowest | 45.31 | 10.79 | 10.79 | 4.32 | 71.21 |
| | Highest | 51.79 | 21.58 | 12.95 | 12.95 | 99.26 |
| | Average | 48.55 | 16.18 | 11.87 | 8.63 | 85.23 |

(1 USD = 23,170 VND)

*Impact on profit*

Profits in conventional crops are reported to fluctuate between 64.74 and 172.63 USD. Profits in the summer-autumn rice crop usually range from 51.79 to 86.31 USD (Figure 5) but depend heavily on weather conditions such as rainfall and temperature. The price of rice in the Summer-Autumn rice crop is often lower than that of other crops due to the relatively low yield, ranging from 550-600 kg $1000m^{-2}$. For the Winter-Spring rice crop, profits usually fall to 129.47-172.63 USD because the yield is usually high, and the weather, transport, and consumption are favorable for the rice cultivators.

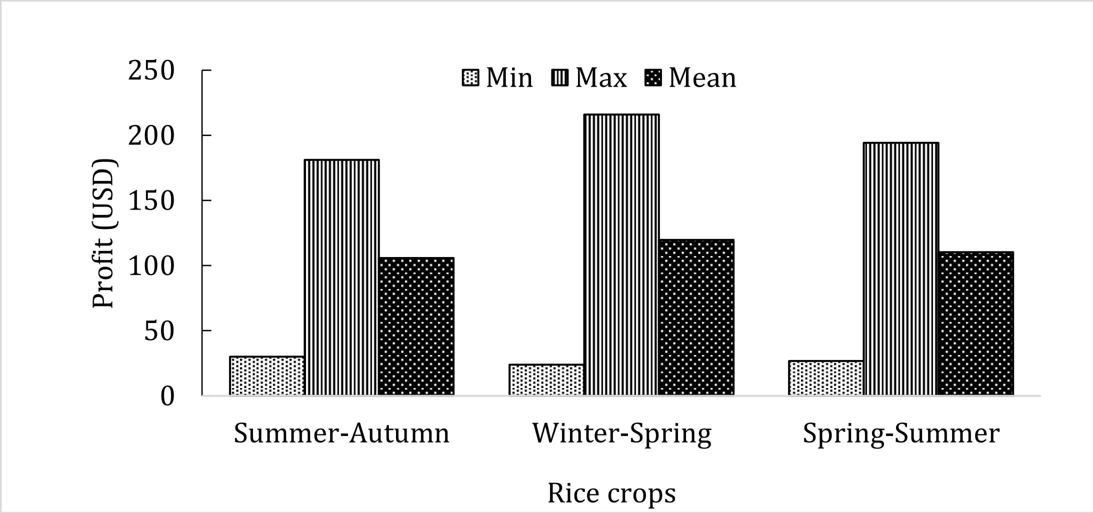


*Figure 5. Profit of rice cultivation without affected by saline intrusion*

Due to the increase in investment costs and the decline in productivity, in general, the income and profits from rice cultivation for farmers affected by saline intrusion are significantly reduced. Profits during the times affected by saline intrusion are reduced by 30 - 100%, depending on the area and level of saline intrusion. Due to the decline in productivity, the harvested rice does not reach the quality required by the collectors, so the cultivator has a lot of difficulties in consuming rice (Figure 6).

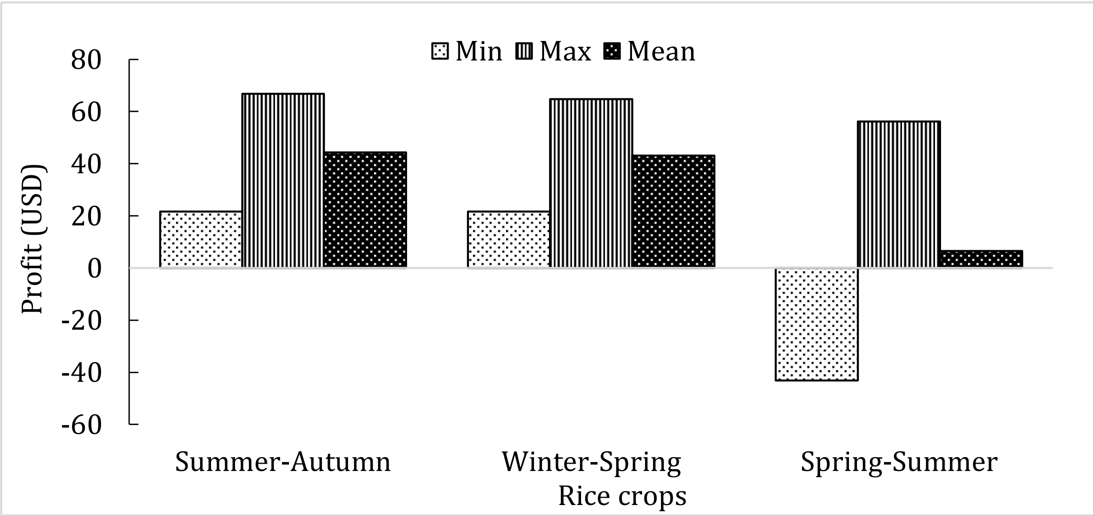


*Figure 6. Profit of rice cultivation with the effect of saline intrusion*

In general, the productivity of the Summer-Autumn and Winter-Spring rice crops has a large variation, but compared to the years that have not been affected by the saline intrusion, there is a big difference in profit, but the Spring-Summer rice crop is not affected. The direct impact of saline intrusion due to soil preparation and water intake from the river into the field and accumulation in the soil affects the productivity of the next crop, resulting in a decrease in profits.

*Impact of saline water intrusion on society aspect*

Social efficiency has changed during the time affected by the saline intrusion, and the local workforce (which can be hired to serve in agricultural cultivation) is still low. Mainly family members participate in agricultural production and work. Renting outside the family is only sufficiently temporary. In terms of security norms, all farmers participate in a cultural lifestyle. Conflicts are very rare. Only a few cases of loss of livestock and agricultural materials occurred during salinity periods, but the loss of property was negligible.

On the other hand, from the influences of economic and farming aspects, the saline intrusion has significantly affected people's life and social context, typically migration. Due to ineffective farming due to saline intrusion, villagers face financial difficulties to continue their lease contracts or invest in the next crop. In addition, if the crop does not generate income or suffers a loss of capital, they have only the way to work as hired labor, especially in big cities. Typical forms of migration are short-term migration, long-term migration, and migration elsewhere. Short-term migration patterns are often accompanied by the seasonal movement of certain young people in the household. Migration times often fall at the end of the crop or the last crop of the farming year, respectively, about 3 - 4 months $year^{-1}$. Long-term forms are usually for households with little or ineffective arable land, and groups of long-term labor migrants will usually be some members of the main working age of the farm household to make sure that the local land is still cultivated by the rest of the family. The group of migrants for settlement usually moves by moving the whole family, and the cultivated land in the locality will be transferred.

Regarding the labor force indicator, during the salty period, there are cases where farmers move to large urban areas such as Can Tho City, Ho Chi Minh City, Dong Nai, and Binh Duong to improve income. Migrants are farm households with small arable land (2,000 $m^2$ on average) with difficult economic conditions (Figure 7). Accordingly, smallholder farmers leave cultivated land to other farmers to rent under a term contract. Middle-aged farmers move to urban areas according to the local rice cultivation season. Specifically, middle-aged people often move to urban areas after the rice harvest is completed and return when the next crop is close to harvest. Accordingly, due to the requirements of health, age, and education, the elderly cannot have stable jobs in urban areas. In contrast, young people moving to urban areas find stable jobs, so they settle permanently due to the high demand for human resources in urban areas.

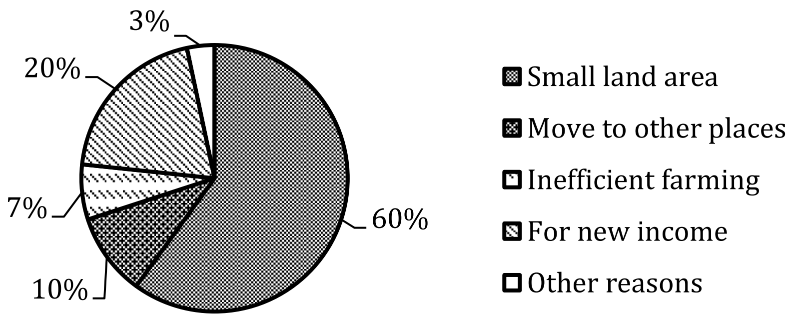


*Figure 7. Reasons for migration*

Farmers' migration to urban areas brings about high economic benefits for them and reduces the risk of social evils in the locality. However, the local workforce is in short supply for non-mechanized jobs such as weeding and covering rice fields. In addition, the small number of cases in which households lead children to move to urban areas results in a delay in children's learning and a higher probability of no continuation of education. Therefore, local authorities play a very important role in supporting local jobs for farmers vulnerable to saline intrusion. In addition, it is necessary to support jobs for farmers after salinity, after saline soils, farming inefficiently, limiting the cases of farmers moving to urban areas, causing an imbalance between urban populations and the countryside.

*Impact of saline water intrusion on environment aspect*

Soil and water quality is the main environmental dimension that is directly affected by the saline intrusion. Saline intrusion events characterize water resources that are inherently fresh, with salinity concentrations usually <1‰, by becoming brackish and salty. The prolonged salinity time makes the salinity increase dramatically. The increase in salinity in the canal system has associated effects on the farming system (cultivation of rice and vegetables) of the people. In particular, people often guess the salinity of the water by simply tasting or measuring, which suggested that the salinity data collected from the river/canal may be inaccurate. At the same time, the notifications from the local authorities are limited in terms of access to the majority of farmers, so in some cases, besides the lack of freshwater pumped into the paddy fields, people pump the whole water, brackish or salty, to deal with severe freshwater shortages in rice fields.

The pumping of saline water into the cultivated area has caused the rice to become salty and completely damaged the growth process (Pradheeban et al., 2017). Moreover, the salt in the water quickly salts the farmland. According to the previous study of Chang et al. (2019) that rice is assessed to be very salt sensitive, especially at the seedling stage, which can be damage to the next seeding crop. According to the survey results, the majority of farmers in the area showed that the arable land was affected by salinity in at least the next 2 crops and greatly affected production efficiency from increasing investment costs and productivity. Productivity is difficult to recover and reaches optimum. The soil and water environment in the rice cultivated areas are affected to a certain degree. Both water and soil environments become polluted, as indicated in Figure 8.

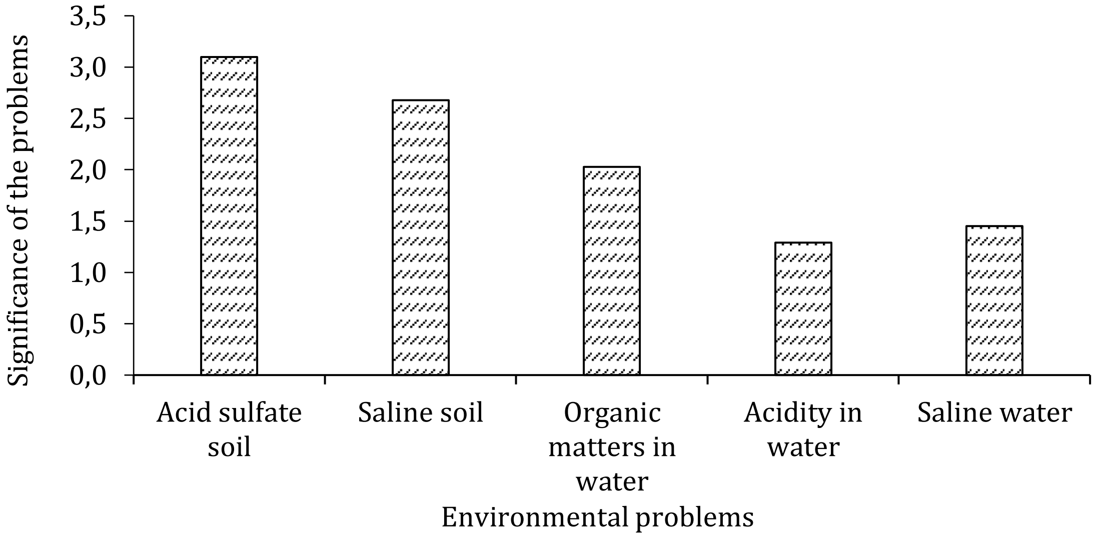


*Figure 8. Impact of saline intrusion on environmental aspects*

During the time of salinity (dry season - in the first months of the year), the soil parameters contaminated with acid sulfate soil (impact point 3.1) and salty soil (impact point is 2.68) will be affected higher than the rest in environmental aspects. The impact on the water with organic pollution, alum water, and salty water is affected at a relatively low level (impact points are 2.03, 1.29, and 1.45, respectively). Accordingly, during the period of continuous salinity, the soil and water environment in the rice cultivation area of Ke Sach district is affected because the saline prevention sluices leak into the inner field canal, in which the soil and water environment of the rice cultivation area get affected near the saline prevention sluice area. During the time near the end of the Winter-Spring crop, due to the lack of timely updating of the information on the water source on the in-field canal, the farmers pumped water into the field.

The pumping of saline water into the field has not only a direct impact on the rice crop leading to a decrease in the current yield but also an indirect impact on the future yield of rice due to the salinity of the soil. In addition, soil salinity combined with long-term sun and drought has affected the latent acidity layer in the soil, leading to alum contamination of arable land for a long time. On the other hand, in the rainy season, a part of rainwater washes away salinity and alum in the soil into the canal, leading to alum contaminated water environment, the rest accumulates in the soil environment, affecting the productivity of the next crops. The rice cultivation areas with low paddy surface are the areas with the most salt accumulation because more concentrated water flows to this area.

In addition, the water environment is more susceptible to the impact of salinity than the soil environment, but the salinity accumulation time in the soil environment is longer. Therefore, it is very important to check the salinity on the in-field canal before being pumped into the field. In the coming time, it is necessary to maintain the saline prevention sluice gates and concretize the ring dikes adjacent to the field banks and the main water channels to avoid the case of salt leakage inside. In addition, local authorities need to provide timely information to farmers, and farmers must regularly monitor the information before pumping water into the field during prolonged salinity. In addition, it is necessary to build more mobile salinity measurement stations in the field canals and support the farmer groups with a hand-held salinity meter to check the salinity before pumping it into the field.

## Conclusion

The results showed salinity had affected rice cultivation in Ke Sach district, Soc Trang province, Vietnam. Salinity intrusion occurs and lasts from February to the end of May during the dry season, while the rainy season (June-September) has low salinity (0.01 - 0.1 ‰). The finding revealed that saline intrusion takes place in Winter-Spring crop, but the effect on rice yield (by 10-30%) only occurs in the Summer-Autumn crop. More than 80% of the people are aware of the effects of saline water intrusion, including the shortage of freshwater for rice irrigation, salty water in canals, salty arable land, and a shortage of labor resources. The proposed temporary solutions include water storage, maintenance of saline prevention sluices, construction of more water regulation canals, financial support, and strengthening of salinity monitoring stations. In order to adapt to saline conditions in the long term, the rice cultivation area of Ke Sach district needs to change the seasonal calendar, crop structure and select tolerable rice varieties. In addition, regularly observing and reporting the situation of saline water intrusion are urgently needed.

## Author declaration

Author declare that there is no conflict of interest

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