A STUDY ON SALTWATER INTRUSION RISK ASSESSMENT FOR AGRICULTURAL PRODUCTION IN TIEN GIANG PROVINCE

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Abstract: *The study has developed a set of criteria for assessing saltwater intrusion risk at commune level for Tien Giang province, a region with a relatively well-developed irrigation system, in three periods including present, 2030s and 2050s. The criteria for occurrence time of saltwater intrusion event have been added to show the impact of saltwater intrusion on agricultural production. The results show that the level of risk tends to increase from East to West, and the area at a very high level of risk gradually expands to the East over time. By 2050s, all communes in Tien Giang province show moderate to very high levels of risk due to saltwater intrusion. The study shows the influence of the irrigation system in reflecting the severity of saltwater intrusion in the area, through the opening/closing time of sluice gates, regulation systems of fresh water and the water storing capacity for production during saltwater intrusion event.*

Keywords: *Saltwater intrusion, risk assessment, criteria set, agriculture, Mekong Delta.*

1. Introduction

The Mekong Delta (MKD) is the most productive agricultural region in the country but frequently affected by saltwater intrusion (SWI), especially in the dry season. Therein, Tien Giang province is known as the “rice granary” and “fruit granary” but suffers losses due to SWI every year. So, various studies and assessments on SWI have been carried out in MKD region in general, and Tien Giang province in particular. These studies have mostly focused on assessing the variation of SWI over time due to climate change impacts, intra-regional development and dam construction in the upper Mekong River [1-2]. A commonly used research method is numerical modelling and spatial analysis based on the SWI lengths of 1g/l, 2g/l, 4g/l using hypothetical scenarios, in which, the area affected by SWI is normally estimated based on interpolation or isohaline which connects points of equal salinity in river branches, leading to not reflecting the real situation or the ability of irrigation systems to respond to SWI. Several studies have focused on assessing the impact of SWI on different objects such as famers [3], rice production [4], farming models [5], crop yields [6], etc. These studies have been conducted based on different data, such as natural, economic and social, providing guidance for local management and policy making. In addition, some authors have studied and assessed SWI risk components in MKD, such as assessing hazards (H), exposure (E), vulnerability (V) and risks (R) due to SWI in the entire region [7]; assessing the vulnerability of SWI to agriculture [8]. These studies have applied the framework of risk assessment of the Intergovermental Panel on Climate Change (IPCC) to determine and calculate the risk components (H, E, V, R). The authors have proposed different groups of indicators and indices, covering many fields to assess the risks caused by SWI.

In terms of management, with fully aware of SWI impacts on production and daily life, the Prime Minister has issued a number of relevant documents, most recently Decision 18/2021/QĐ-TTg to set regulations on forecasting,

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warning, reporting on natural disaster and risk level [9]. Accordingly, the SWI risk level in MKD is based on the SWI length of 1 g/l and 4 g/l salinity concentration. However, the application of the Decision to production management and operation in the Mekong Delta region is facing some difficulties, such as the duration of SWI event has not been specified in the risk categorization. In fact, if the SWI occurs for a short period (a few hours to a few days), even if the salinity is very high, it will have less impact on production; on the contrary, a long duration of a SWI event (a few days to a few weeks) can cause serious consequences because the fresh water in the water storage system has depleted below the usable level. In addition, the variation of SWI length in each risk level is too large (25 km ~ 40 km), leading to the difficulty in reflecting the spatial fluctuation of salinity/freshness under the provincial irrigation infrastructure; therefore, the applicability of this decision is limited.

Hence, to assess the risk of SWI, it is necessary to develop a set of assessment criteria suitable for regional conditions. The results will help relevant agencies clearly understand their roles and tasks to proactively coordinate and deploy timely and apply effective solutions to prevent SWI, ensuring systematic synchronization between agencies in Tien Giang province.

2. Data and Method

2.1. Study area

Tien Giang is one of 13 provinces in MKD, located at the end of the freshwater source and adjacent to the East Sea. The main direction for SWI in the province is from the sea into the Cua Tieu River - Tien River and partly by the Vam Co River (Figure 1); Besides, for extreme droughts such as 2015-2016, 2019-2020, 2023-2024, the level of SWI will increase due to additional direction from the Ham Luong River [10].

According to statistics in 2023 [11], Tien Giang province has a total land area of 255,636 hectares, of which agricultural land is 189,873 hectares, accounting for 74.29%. The province's strengths are rice and fruit cultivation, with a rice growing area of 56,461 hectares, mainly distributed in Cai Be, Go Cong Tay, Cai Lay, Go Cong Dong districts, and a fruit growing area of 82,352 hectares, mainly distributed in Cai Be, Cai Lay, Tan Phuoc, and Cho Gao districts.

In order to meet the water demand of agricultural irrigation and production, Tien Giang province has invested in developing a relatively well-developed irrigation system for SWI prevention with 141 sluices, including 06 main sluices (04 sluices under Go Cong project, 02 sluices under Bao Dinh project), 10 main freshwater source sluices, 09 large sluices B>8 m, 126 medium and small sluices and over 1,000 semi-permanent dam sluices.

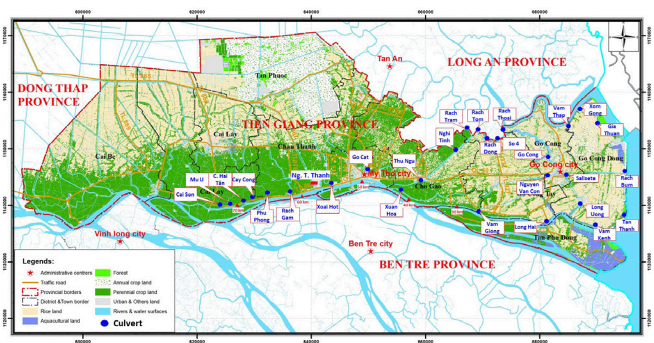


Figure 1. Saltwater intrusion direction and main sluice gates in Tien Giang province

2.2. SWI simulation

To assess the variation of SWI in Tien Giang province, it must be placed in the overall context of water exchange and water resource fluctuations of the entire region. Therefore, in this study, the MIKE model developed, calibrated and validated by the Southern Institute of Water Resources for the entire

Mekong Delta region (NSE = 0.79-0.91 for water level, and NSE = 0.63-0.78 for salinity) was used to simulate SWI in Tien Giang province in a low water hydrological year (P=85%). Details of the model's configuration and calibration process have been described in previously published study [12]. Three simulation scenarios were developed to assess the variation of SWI under the impact of sea level rise, upstream discharge changes, and topographic changes for the present (PRE), 2030 and 2050 periods based on the published Climate Change Scenario 2020 (RCP 4.5) [13], information on upstream hydropower dam construction [14] and regional annual land subsidence rate (20cm/year) due to changes in the amount of sediment to the downstream [15] (Table 1). The salinity of 1g/l was chosen as the threshold for impact assessment because the freshwater sluices will be closed if exceeding this threshold according to the operating procedures of the provincial irrigation system.

Table 1. Simulation scenario of SWI

Scenario	**Driven factors**		
	Upstream discharge changes due to dam construction [14]	*Terrain (lowering channel due to land subsidence) [15]*	*Sea level rise due to climate change [13]*
1st scenario	Current state (2023)	Current state (2021)	Current state (2016)
2nd scenario	Expected 2030s	Lower 1 m	Tides + 12 cm (2030)
3rd scenario	Vision 2050s	Lower 2.4 m	Tides + 17 cm (2050)

2.3. SWI risk assessment

2.3.1. Assessment method

The risk of SWI (R) is determined based on the calculation, analysis, and combination of hazard (H), exposure (E) and vulnerability (V) according to the IPCC method (see [7]). In which, vulnerability (V) is combined from sensitivity (S) and adaptive capacity (AC) to the impacts of SWI. The risk assessment framework is shown in Figure 2.

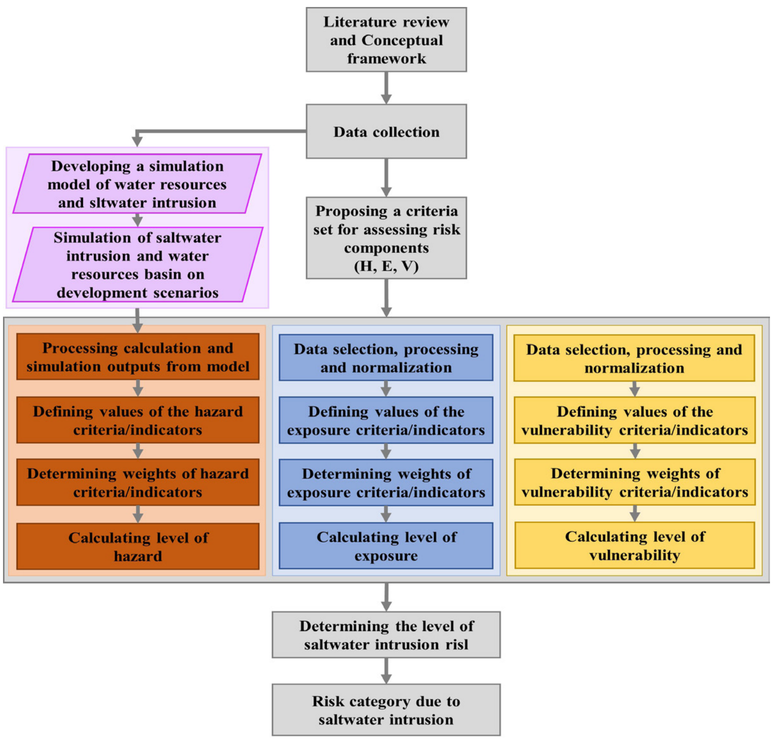


Figure 2. Framework for assessing the risk of SWI

Table 2. Criteria for defining the hazards (H) due to SWI

Component	Criteria (i)	Index (ij)	Data source
Hazard (H)	Intensity	Maximum salinity	SMR
		Length of SWI	SMR
	Occurrence time	Number of days when salinity at the sluice gate ≥1g/l	SMR
		Longest duration when salinity at the sluice gate ≥1g/l	SMR

Table 3. Criteria for defining the exposure (E) of the area

Component	Criteria (i)	Index (ij)	Data source
Exposure (E)	Nature	Distance from main sluice gate to the shore	GIS
		Total area affected by SWI	SYB
	People	Number of people affected by SWI	SYB + GIS
	Agricultural production	Area of fruit cultivation affected by SWI	SYB + GIS
		Area of rice cultivation affected by SWI	SYB + GIS
		Area of crop cultivation affected by SWI	SYB + GIS
		Area of aquaculture land affected by SWI	SYB + GIS

Table 4. Criteria for defining the vulnerability (V) of the area

Component	Criteria (i)	Index (ij)	Data source
Sensitivity (S)	People	Average rural population ratio	SYB
		Population density	SYB
	Agricultural production	Ratio of fruit cultivation area/total area	SYB
		Ratio of rice cultivation area/total area	SYB
		Ratio of crop cultivation area/total area	SYB
		Ratio of aquaculture land area/total area	SYB
	Socio -Economic	Percentage of households with unsystematic water supply	PID
		Rate of poor and near-poor households (%)	SYB
		Agricultural water demand	SMR
	Nature	Farthest distance to main water intake gate	GIS
Adaptive capacity (AC)	Education	Ratio of high school students/total population	SYB
	Economic	Average income per capita/year	SYB
	Water supply and irrigation system	Total canal system capacity/total area	PID
		Canal density	PID
		Percentage of households with systematic water supply	PID
	Production	Total value of agricultural products / agricultural land area	SYB

Table 5. Indicators showing the SWI hazard (corresponding to the threshold of 1 g/L)

Maximum salinity (g/l)	Length of SWI (m)	Number of days when the salinity at sluice gate ≥ 1g/l	The longest duration when the salinity at sluice gate ≥1g/l	Normalized value
<1	25 - 50	<10	<5	1
1 - 4	50 - 90	10 - 20	5 - 10	2
>4	>90	20 - 30	10 - 30	3
		>30	>30	4

The risk components due to SWI (H, E, V) are determined based on the actual conditions of the area, each component can include a number of specific criteria (H_i, E_i, S_i, AC_i) which is calculated from a number of specific indicators (H_{ij}, E_{ij}, S_{ij}, AC_{ij}). The data sources for calculation include simulation results (SMR), statistical yearbooks (SYB) and data from the Provincial Irrigation Department (PID).

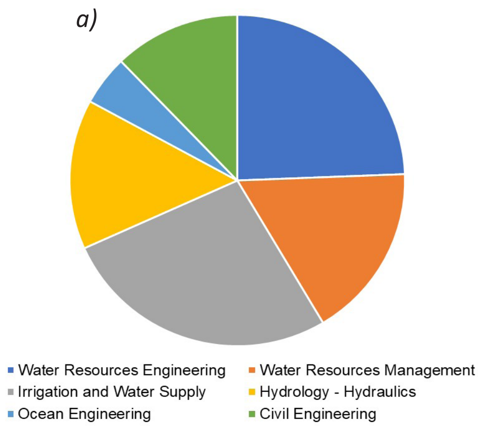
In this study, criteria and indicators for assessing SWI risk are proposed as shown in Table 2 to 4.

After being determined, the values of the criteria and indicators used to calculate the SWI risk components need to be normalized to dimensionless values . The normalization applied to E and V components is mentioned in previous studies [7-8]. For H component, the normalization applied for the indicators (Hij) is shown in Table 5.

2.3.2. Weighting method

Normally, the method for determining the weight of each indicator representing hazard, exposure, sensitivity and adaptive capacity is selected based on data availability and regional characteristics. Due to the specific characteristics of SWI disaster, in this study, the selected weighting method is the expert method.

Total 41 independent experts with relevant expertise (Figure 3) are consulted to assess the importance and contribution of each criterion and indicator in assessing the SWI risk components on a scale of 1 to 10. The results were then processed using statistical methods, removing outliers, then finally grouped to calculate the weight for each indicator and criteria.



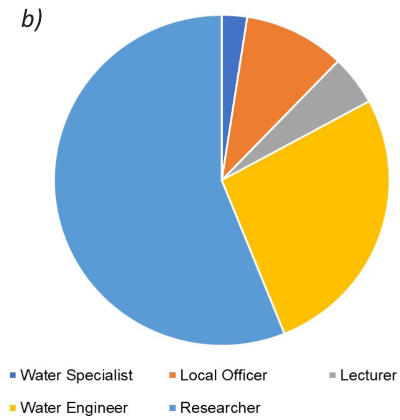


Figure 3. Expertise (a) and job position (b) of the consulted experts

Unlike other natural disasters, SWI is characterized by a large and difficult-to-determine impact area, a long-term impact period, and direct and indirect influences. Meanwhile, solutions to prevent and respond to SWI have only shown effectiveness on a local scale. Therefore, the risk components of SWI (H, E, V) should not be considered to contribute equally to the overall risk level. The weight of each component will also be determined using expert method, similar to the weights of assessment criteria and indicators. The weights are classified into 3 classes (components, criteria, indicators), with the sum of corresponding weights in each group in each class is 1, specifically as follows:

- The weights of the risk components (H, E, V) are WH, W_E, W_V respectively;

- The weights of criteria in component calculation (H, E, AC, S) is w_i^H, w_i^E, w_i^S, w_i^{AC};

- The weights of the indicators (H_{ij}, E_{ij}, AC_{ij}, S_{ij}) in calculating criteria (H_i, E_i, AC_i, S_i) is w_{ij}^H, w_{ij}^E, w_{ij}^S, w_{ij}^{AC}.

2.3.3. Risk calculating

After determining the normalized values of the hazard indicators, the level of SWI hazard is calculated from the criteria and indicators with corresponding weights according to equations (1), (2).

$$H_i = \sum_{j=1}^{m} H_{ij} \times w_{ij}^H \quad (1)$$

$$H = \sum_{i=1}^{N} H_i \times w_i^H \quad (2)$$

The exposure to SWI of the area is calculated from the normalized values of the criteria and indicators defined in Table 3 and the corresponding weights according to equations (3), (4).

$$E_i = \sum_{j=1}^{n} E_{ij} \times w_{ij}^E \quad (3)$$

$$E = \sum_{i=1}^{N} E_i \times w_i^E \quad (4)$$

Similarly, sensitivity and adaptive capacity are also calculated from the normalized values of the criteria and indicators in Table 4 and the corresponding weights according to equations (5)-(8). Then, vulnerability is calculated from the S and AC according to equation (9).

$$S_i = \sum_{j=1}^{k} S_{ij} \times w_{ij}^S \quad (5)$$

$$S = \sum_{i=1}^{N} S_i \times w_i^S \quad (6)$$

$$AC_i = \sum_{j=1}^{m} AC_{ij} \times w_{ij}^{AC} \quad (7)$$

$$AC = \sum_{i=1}^{N} AC_i \times w_i^{AC} \quad (8)$$

$$V = \frac{(S + AC)}{2} \quad (9)$$

In which, *m*, *N* are the number of indicators and criteria of the risk components, respectively. H_i, E_i, S_i, AC_i are the criteria of the risk components, respectively; w_i^H, w_i^E, w_i^S, w_i^{AC} are the weights of the corresponding criteria; H_{ij}, E_{ij}, S_{ij}, AC_{ij} are the normalize values of the j-th indicator in criterion *i* of the risk components; w_{ij}^H, w_{ij}^E, w_{ij}^S, w_{ij}^{AC} are the weights of the corresponding risk indicators.

The risk level due to SWI is calculated from the H, E, V components with corresponding weights using equation (10).

$$R = H \times w_H + E \times w_E + V \times w_V \quad (10)$$

The SWI risk components are classified into 4 levels from 1 to 4 based on calculated values as shown in Table 6.

Table 6. Classification of risk components

Value of H	Value of E	Value of V	Value of R	Level	Category
[0-1.5)	[0-0.25)	[0-0.25)	[0-1.5)	1	Low
[1.5-2.5)	[0.25-0.50)	[0.25-0.50)	[1.5-2.5)	2	Medium
[2.5-3.5)	[0.50-0.75)	[0.50-0.75)	[2.5-3.5)	3	High
[3.5-4]	[0.75-1]	[0.75-1]	[3.5-4]	4	Very high

3. Results and Discussion

3.1. SWI affected by climate change and upstream development

Simulation results from the MIKE model for salinity observed stations along the Tien River during the dry season (from January to April) are shown in Table 7, showing that at hydrological stations along the Tien River, SWI is more severe over time, with a clear increase in all indicators showing the level (maximum salinity), scale (length of SWI) and period of impact (total number of days and duration). Compared to PRE, during 2050s, the maximum SWI length increases by ~13 km, the highest salinity value increases from 1.5 to 3 times, the number of days to close the sluice gates due to salinity exceeding the threshold of 1 g/l increase from 14 to 60 days, the duration when salinity at the sluice gate exceeding the threshold of 1 g/l increase from 2 to 8 times.

Table 7. Variation of SWI in the dry season at present, 2030s and 2050s

Scenario / Station	Maximum salinity (g/l)			Maximum length of SWI (km)			Number of days when salinity ≥1‰ (day)			Longest duration when salinity ≥1‰ (day)		
	PRE	*2030s*	*2050s*	*PRE*	*2030s*	*2050s*	*PRE*	*2030s*	*2050s*	*PRE*	*2030s*	*2050s*
Cai Be	0.1	0.1	0.8	74	83	87	0	0	0	0	0	0
Ba Rai	0.1	0.7	2.3				0	0	11	0	0	5
Ngu Hiep	0.7	2.2	3.2				0	17	23	0	6	7
Phu Phong	1.3	3.5	3.7				5	27	35	2	9	16
N.T. Thành	2.6	3.8	5.2				17	46	77	6	19	32
Xoai Hot	3.2	4.2	6.2				20	53	79	8	22	33
Bao Dinh	4.8	5.9	7.3				52	96	100	22	40	41
Xuan Hoa	7.6	7.9	10.8				103	115	117	42	47	95
Hoa Dinh	12.1	12.4	13.7				117	120	120	95	120	120
Vam Giong	13.5	15.5	18.4				117	120	120	95	120	120

3.2. Weights of SWI risk assessment criteria

The results of expert consultation on the importance, effectiveness and contribution of risk assessment criteria were collected, synthesized and processed. The weights of the criteria are shown in Table 8.

According to most experts, for areas with relatively well-developed irrigation systems, such as MKD in general and Tien Giang province in particular, the ability to prevent SWI using sluices developed along river branches is quite effective. SWI, even at very high salinity, is unlikely to encroach into irrigation canals or directly affecting production activities. If SWI occurs in a short period, the canal system can still play its role in storing water and regulating production, so agricultural production is not significantly affected. However, if the SWI lasts for a long time, the amount of water stored in the canals gradually depletes, and the drought due to saltwater intrusion can seriously affect all production activities and people's lives in the entire region.

Table 8. Weights of criteria and indicators for assessing risks due to SWI

Index	Value	Criteria	Value	Component	Value
Maximum salinity	0.50	Intensity	0.30	Hazard	0.50
Length of SWI	0.50				
Number of days when salinity at the sluice gate ≥1‰	0.40	Occurrence time	0.70		
Longest duration when salinity at the sluice gate ≥1‰	0.60				
Distance from main sluice gate to the shore	0.80	Nature	0.70	Exposure	0.20
Total area affected by SWI	0.20				
Number of people affected by SWI	1.00	People	0.10		
Area of fruit cultivation affected by SWI	0.20	Agricultural production	0.20		
Area of rice cultivation affected by SWI	0.50				
Area of crop cultivation affected by SWI	0.10				
Area of aquaculture land affected by SWI	0.20				
Average rural population ratio	0.60	People	0.20	Vulnerability	0.30
Population density	0.40				
Ratio of fruit cultivation area/total area	0.30	Agricultural production	0.20		
Ratio of rice cultivation area/total area	0.40				
Ratio of crop cultivation area/total area	0.20				
Ratio of aquaculture land area/total area	0.10				
Percentage of households with unsystematic water supply	0.30	Socio-economic	0.30		
Rate of poor and near-poor households (%)	0.30				
Agricultural water demand	0.40				
Farthest distance to main water intake gate	1.00	Nature	0.30		
Ratio of high school students/total population	1.00	Education	0.10		
Average income per capita/year	1.00	Economic	0.20		
Total canal system capacity/total area	0.50	Water supply and irrigation system	0.60		
Canal density	0.35				
Percentage of households with systematic water supply	0.15				
Total value of agricultural products /agricultural land area	1.00	Production	0.10		

Based on various experts' opinions, agricultural production is the most heavily affected by SWI, while natural system reflects most clearly the scale of aSWI, and investment in developing infrastructure system to prevent and monitor saltwater intrusion is the most effective response to SWI in the region.

3.3. SWI risk assessment for Tien Giang province

The calculation results of the exposure and vulnerability to SWI in Tien Giang province are shown in Figure 4.

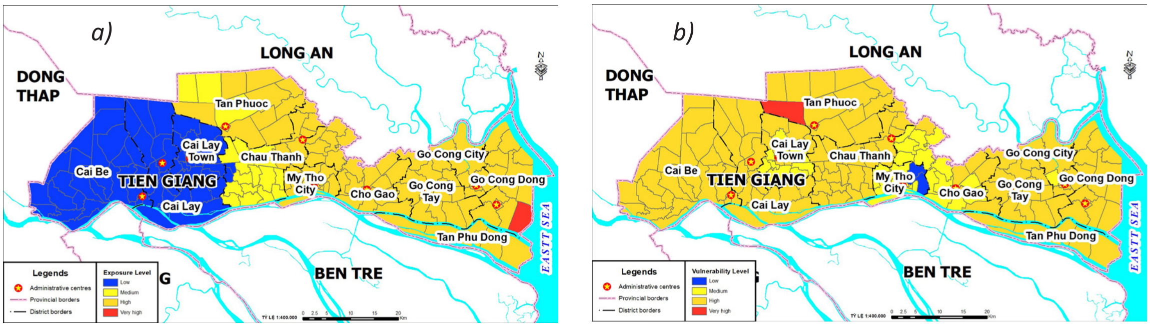


Figure 4. Spatial distribution of the exposure (a) and vulnerability (b) to SWI in Tien Giang province

The results of the exposure calculation (Figure 4a) show that the eastern area of Tien Giang province is at a higher exposure level than other areas, in which the exposure level of Tan Thanh commune, Go Cong Dong district is the highest. This coastal commune is located in the Go Cong desalination project area, with a relatively large area of rice and fruit cultivations, while the irrigation system of the whole commune only takes fresh water through Xuan Hoa sluice which is relatively close to the estuary. Communes in Cai Be and Cai Lay districts have a low exposure level, although the rice and fruit cultivations cover large area, because many regional water intake sluices are located far from the estuary, less affected by SW.

The spatial distribution of vulnerability levels (Figure 4b) also highlights two areas with lower vulnerability than other areas, namely My Tho city area, in which My Phong and Tan My Chanh communes having low level and the others having medium level, and Cai Lay town area, with 10/16 communes and wards having medium vulnerability. These regions are relatively developed urban areas, with high education levels, high incomes, low poverty rates, and a small proportion of agricultural land. Other areas mostly show high, even very high, vulnerability, such as Tan Hoa Tay commune, Tan Phuoc district. This is a commune where people mainly live on agriculture, and is far from freshwater intake sluices, so production still faces many difficulties.

The calculation results of the hazard and risk due to SWI in Tien Giang province in the three periods including PRE, 2030s and 2050s (Figure 5) show a clear increasing trend of hazard level and risk over time. Regarding the hazard, under current conditions (Figure 5a), it can be seen that Tien Giang province is divided into four distinct regions with hazard levels decreasing from very high to high, medium and low from East to West. By 2030s (Figure 5c), the area at very high hazard level expands to the West, narrowing the area with low hazard level. By 2050s (Figure 5e), the area with low hazard level has totally disappeared, all areas in Tien Giang province have hazard levels from medium to very high which decrease from East to West.

Regarding the risk, the calculation results show that, under current conditions (Figure 5b), most communes in the Eastern region have a high level of risk, except for Long Chanh ward, Go Cong city, which shows a medium level of risk. This is a commune having a relatively dense irrigation system, with a large capacity of water storage, diverse agricultural production, in which the strength is livestock, bringing high economic efficiency. Many communes and wards in Cai Lay town have a low level of risk, due to their average level of vulnerability and being less affected by SWI. By 2030 (Figure 5d), the area at a very high level of risk expands to the West, covering a number of communes in Chau Thanh, Cho Gao and Tan Phuoc districts, the area with medium and low levels of risk will be gradually narrowed. By 2050s (Figure 5g), the high-risk area continues to expand, and there are no communes in Tien Giang province at low-risk levels due to SWI.

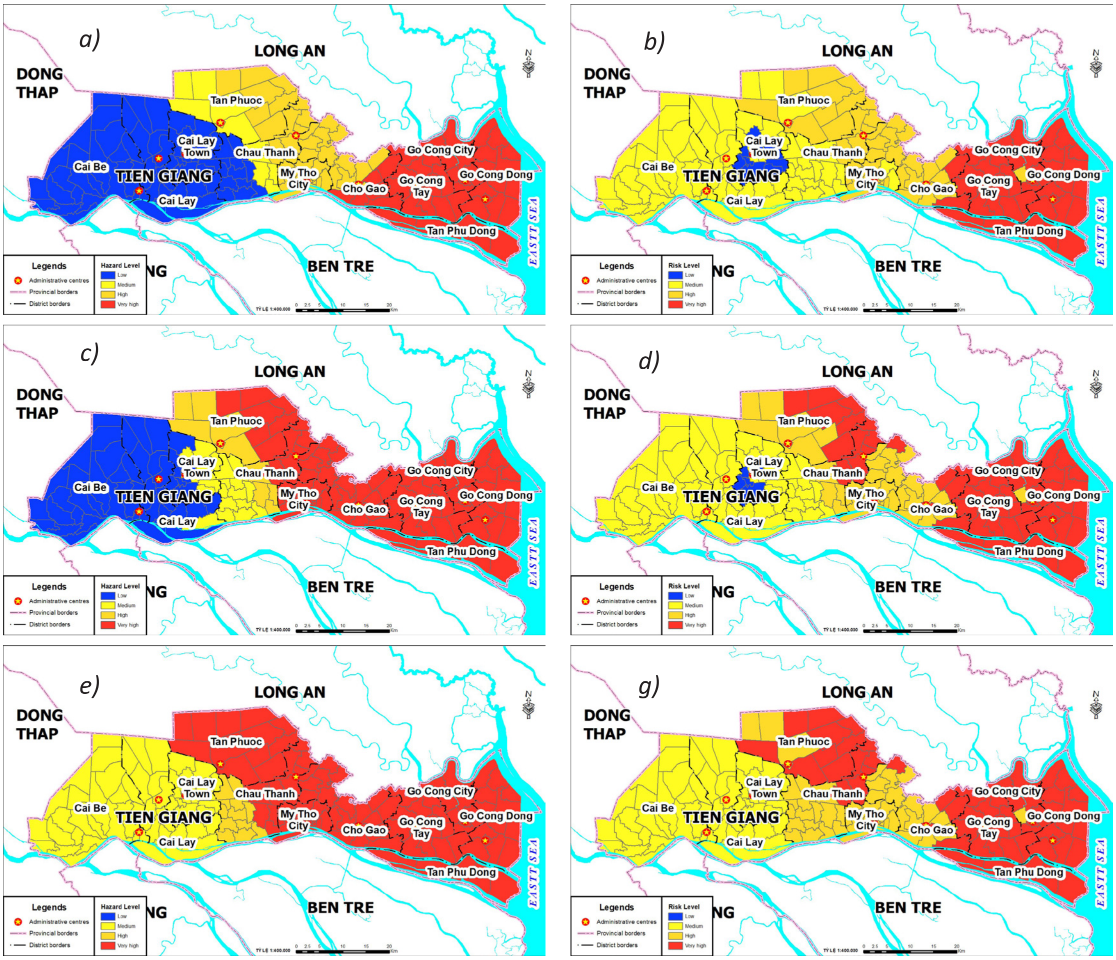


Figure 5. Spatial distribution of the hazard (left) and risk (right) caused by SWI for the PRE (a, b), 2030s (c, d), 2050s (e, g) in Tien Giang province

4. Conclusion

SWI is a complex process, occurring relatively slowly and for a long time, with a wide range of influence, difficult to determine directly and related to many processes, as well as being influenced by many different factors. To assess the risk of SWI for agricultural production areas with relatively well-developed irrigation systems, it is necessary to demonstrate the driven factors as well as the affected objects associated with the irrigation infrastructure system.

This study assessed the risk of SWI on agricultural production in Tien Giang province under the combined impacts of climate change and upstream development of the Mekong River based on a risk assessment method that has been widely used in previous studies, in which risk is contributed from three components: hazard, exposure and vulnerability. However, when considering the application of the above-mentioned assessment method to the Mekong Delta region, the assessment criteria and indicators were selected and proposed to best reflect the typical conditions of the region, especially the development of irrigation systems serving agricultural production.

The research results show the impact of the irrigation system in reflecting the severity of SWI in the region, through the number of days of opening/closing the sluice gates, the way of regulating freshwater sources in the region and the ability to store water for production during drought event due to SWI. This is the new findings of the present study that is different from previous assessments, in which the affected area of SWI is often determined using interpolations based on salinity and length of SWI on river branches. The research results also show the importance of indigenous knowledge and experts' understanding of local conditions in assessing the impact and risk of SWI, especially in areas with relatively well-developed irrigation systems such as Tien Giang province.

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Disclaimer: *The authors declare that this article is the work of the authors, has not been published, and has not been copied from previous studies; there is no conflict of interest in the author group.*

References

1. Duong Hong Son et al. (2024), *"Quantitative assessing impacts of climate change and upstream developments on saltwater intrusion in the Viet Nam Mekong Delta", Viet Nam Journal of Hydro-meteorology,* no. 763, 13-23. (in Vietnamese).
2. Nguyen Huu Tuan et al. (2023), *"Modeling and Assessing the Salinity Intrusion Level in the River System of Tiền Giang Province in the Context of Climate Change and Rising Sea Levels", Viet Nam Journal of Hydro-meteorology,* no. 755(1), 1-10. (in Vietnamese).
3. Nguyen, X.H. et al. (2019), *"Assessing the adaptive capacity of farmers under the impact of SWI in the Vietnamese Mekong Delta", Journal of Environmental Planning and Management*, vol 62(9), 1619-1635.
4. Nguyen Thi Hong Diep et al (2017), *"Impact of saline intrusion as a result of climate change on rice cultivation in Soc Trang province", Can Tho University Journal of Science*, no. 2, special issue on Environment and Climate Change, 137-143 (in Vietnamese).
5. Nguyen Huu Trung et al. (2021), *"Assessing the effect of saline intrusion on agricultural farming models in Binh Dai district, Ben Tre province", Can Tho University Journal of Science*, no. 2, special issue on Environment and Climate Change, 137-143 (in Vietnamese).
6. Vo Thi Anh Nguyet and Son Thi Que Tran (2022), *"Impacts of saltwater intrusion on crop yield in the Mekong River Delta", Journal of Viet Nam Agricultural Science and Technology,* no. 136, 24-33, (in Vietnamese).
7. Le Van Tuan et al (2021), *"Assessments of hazard, vulnerability, and risk of saline intrusion in the Mekong River Delta", Journal of Climate Change Science*, no. 17, 12-18 (in Vietnamese).
8. Tran Thi Kim et al (2023), *"Determining the Vulnerability of Agriculture to Salinity Intrusion in the Mekong Delta Provinces", Viet Nam Journal of Hydro-meteorology,* no. 755(1), 67-82 (in Vietnamese)
9. Prime Minister (2021), *Decision 18/2021/QĐ-TTg Regulations on forecasting, warning, communication of natural disasters and disaster risk levels* (in Vietnamese).
10. Southern Institute of Water Resources Research (2020), *Annual report of the project titled "Investigating, forecasting and monitoring saltwater intrusion in the Mekong Delta for agricultural production management"* (in Vietnamese).
11. Tien Giang Statistics Office (2024), *Tien Giang Statistical Year Book 2023* (in Vietnamese).
12. Tran Minh Tuan et al (2024), *"Analyze the variations, forecasts of saltwater intrusion and proposed*

solutions to upgrade and modernize the irrigation system to service agricultural production and population in Tien Giang province", Proceeding of Science and Technology Research Results, The Southern Institute of Water Resources Research. (in Vietnamese)

13. Ministry of Natural Resources and Environment (2021), *Climate Change Scenarios,* Viet Nam Publishing House of Natural Resources, Environment and Cartography, Ha Noi (in Vietnamese).
14. Tran Ba Hoang et al. (2023), *Final report of the project titled "Assessment of water development and exploitation activities in the upper Mekong River for irrigation planning and production management"* (in Vietnamese).
15. Nguyen Nghia Hung et al. (2021), *Final report of the project titled "Research on scientific and technological solutions to adjust and stabilize river sections with aits that are experiencing major changes in morphology on the Tien and Hau rivers"* (in Vietnamese).