Assessing changes in saltwater intrusion in some main rivers of Vinh Long province

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ASBTRACT

Saltwater intrusion (SI) associated with El Nino phenomenon is a particularly concerned issue in a period of 2015–2016. Salinity evolutions in the Mekong Delta and Vinh Long province are becoming serious. Therefore, this work aimed at assessing changes in saltwater intrusion in Vinh Long province during recent ten years (2007–2016), including changes in the highest, the lowest, and average salinities. Besides, 19 surface water samples were collected and analyzed to evaluate the current status of salinization in 2016. Results showed that the salinity tends to propagate into the infield, especially in Co Chien River (0.4 to 1.2 ‰), followed by Hau River (0.2 to 0.7 ‰) and other inland waterways (0.3–0.6 ‰), leading to certain impacts on agriculture, aquaculture, and water supply in the local in general. In Vinh Long province, Vung Liem and Tra On districts were relative significantly influenced by SI, requiring suitable control measures, particularly in the context of climate change.

Key words: *saltwater intrusion, climate change, salinity*

INTRODUCTION

In the context of climate change (CC), many areas around the world are facing to disasters such as heavy storms, flood, drought, saltwater intrusion (SI), etc. leading to serious damages. According to The Australian Foundation for the Peoples of Asia and the Pacific (AFAP) Vietnam [1], to the end of the 21st century, if CC is not effectively reduced, VietNam will lose at least 12.2 % of land, where 23 % of the population are living, leading to serious affects to low delta areas – one of the most important granaries of the world by flood and SI. CC and sea level rise make SI evolution more and more complex. Salinity tends to propagate into the inland, affecting the socio-economic activities such as agriculture [2], aquaculture, using water [3, 4] and natural ecosystems, etc. This is one of the major challenges in Vietnam. Drought and SI were very harsh in the MeKong delta in the dry season of 2015–2016, SI came soon, significantly entered the inland and extended until mid of 2016. Studies showed SI tends to propagate into the estuaries, mainly due to (i) lack of additional water from the upstream and (ii) rising tendency of water level from the downstream [5]. Besides, the important factors (natural and artificial) affecting the SI process could include tide [6-9], temperature, precipitation [6, 9], northeast wind [6], terrain [8, 10], construsting and operating reservoirs [8], socio-economic activities [8, 10-12].

Vinh Long one of the agricultural provinces in the MeKong delta, specializing in growing rice, fruit trees, and freshwater aquaculture – is located along the Tien river and Hau river. Terrain is relatively flat, lower from north to south, and relatively low as compared to the sea level. The infrastructure, farming conditions, economic growth, living traditions, etc.

intimately connect to nature, so Vinh Long province is very sensitive to effects of weather and SI, especially in the context of CC. Therefore, changes in SI in Vinh Long province need more concerning due to its direct and indirect impacts on daily life and agricultural production etc. Therefore, this research mainly aimed at assessing changes in SI on main rivers in Vinh Long province (Co Chien river, Hau river, Mang Thit river, and Tra Ngoa canal) during recently ten years (2007–2016), including changes in the highest, the lowest, and average salinities; assessing preliminarily impacts of SI on socio-economic sectors in the province, creating the basis for proposing suitable management solutions, reducing SI impacts, and contributing to sustainable development strategy of the area.

METHODS

On the basis of monitoring data, changes in salinity in main rivers in Vinh Long province were assessed via:

Characterized salinity: the daily highest salinity (2007–2013), the daily lowest salinity (2007–2011), the yearly highest salinity (2007–2016).

Assessed aspects: changes in salinity by the time, the saltiest month of the year, the saltiest day of the month and the variation by the time.

Data collection and processing

Related data and documents were collected at the agencies and departments in Vinh Long province to assess changes in SI and impacts to socio-econimic activities (planting, fisheries, water supply, etc.). Salinity data (hourly and daily) monitoring in March to May at Vung Liem, Nang Am, Tich Thien, and Nga Tu stations in the period of 2007–2011 and 2012–2016 were collected from the VinhLong Hydrometeorology station and the Vinh Long Department of Natural Resources and Environment, respectively while the daily highest salinity data in 2016 at 4 mentioned stations and Quoi An station was collected from the Vinh Long Department of Agriculture and Rural Development, etc. to assess changes in SI.

Monitoring method

Salinity monitoring method was used to assess the current status of SI in some main rivers of Vinh Long province in 2016. 19 sampling locations (Fig. 1) were distributed in Co Chien river, Hau river, Vung Liem river, and Mang Thit river. Sampling time was on 22 – 23/3/2016 (dry season). *QCVN 08-MT:2015/BTNMT* – National technical regulations on surface water quality was then used to compare and assess the salinity.

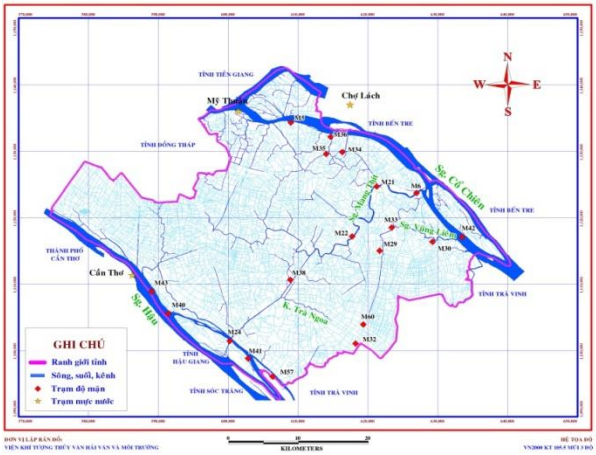


Fig. 1. Water level and salinity monitoring stations

GIS method

Mapinfo and Surfer 10.0 software were used to draw maps, show monitoring locations, draw salinity boundary, and overlay landuse maps and salinity boundary to assess SI impacts.

RESULTS

Change in SI in Vinh Long province in the period of 2007–2016

Previously, SI was not the concern in Vinh Long province. However, in context of the complicated changes in weather and climate combining with the longest period of El Nino in

history (from the end of 2014 to 2016), etc. SI manifestations are increasingly clear, monitoring salinity data were much higher than that in previous years. Some salinity characteristics in the period of 2007–2013 were show in Table 1.

Table 1. Some salinity characteristics in the period of 2007–2013

SALINITY (‰)		Co Chien River		Hau River	Tra Ngoa Canal
		Vung Liem St.	Nang Am St.	Tich Thien St.	Nga Tu St.
Average S_{max}^{day}	*Dry season 2007*	0.4	0.7	0.2	0.4
	The saltiest month	April (0.8)	April (1.1)	April (0.5)	April (0.41)
	Salty peak	21/04 (1.6)	07/05 (3)	22/04 (1.9)	11/04 (0.6)
	Dry season 2008	0.4	0.6	0.2	0.3
	The saltiest month	March (0.5)	March (0.6)	March (0.3)	March (0.3)
	Salty peak	06/03 (2.3)	06/03 (2.5)	03/03 (1.4)	04/03 (0.9)
	Dry season 2009	0.5	0.7	0.2	0.3
	The saltiest month	April (1.1)	April (1.5)	April (0.2)	March (0.25)
	Salty peak	23/04 (3.8)	24/04 (4.5)	28/04 (0.5)	28/03 (1.0)
	Dry season 2010	0.9	1.2	0.6	0.5
	The saltiest month	April (1.1)	April (1.6)	April (1.0)	April (0.63)
	Salty peak	30/03 (5.2)	30/3 (5.4)	29/03 (3.6)	09/04 (1.3)
	Dry season 2011	0.8	1.1	0.7	0.6
	The saltiest month	March (1.2)	March (1.4)	March (1.13)	April (0.75)
	Salty peak	02/4 (4.9)	31/03 (4.5)	01/04 (4.9)	05/04 (1.6)
	Dry season 2012	0.5	0.7	0.2	0.3
	The saltiest month	April (1.0)	April (1.3)	March (0.3)	April (0.28)
	Salty peak	03/4 (3.8)	03/04 (3.8)	10/04 (0.9)	16/04 (0.8)
	Dry season 2013	0.7	0.9	0.2	0.4
	The saltiest month	April (1.05)	April (1.3)	April (0.32)	April (0.4)
	Salty peak	22/4 (3.9)	22/04 (4.1)	28/04 (0.9)	01/03 (0.7)
Average S_{TB}^{day}	*Dry season 2007*	0.2	0.3	0.1	0.3
	Dry season 2008	0.2	0.3	0.1	0.3
	Dry season 2009	0.3	0.4	0.1	0.2
	Dry season 2010	0.5	0.7	0.4	0.4
	Dry season2011	0.4	0.6	0.4	0.5
Average S_{min}^{day}	*Dry season 2007*	0.1	0.1	0.1	0.2
	Dry season 2008	0.1	0.2	0.1	0.2
	Dry season 2009	0.1	0.3	0.1	0.2
	Dry season 2010	0.2	0.3	0.2	0.3
	Dry season 2011	0.1	0.3	0.2	0.4

Evolution of the daily highest salinity (Smax) in the period of 2007 – 2013

Salinities in *Co Chien river* (monitored at Vung Liem and Nang Am stations) in the period of 2007–2013 relative significantly changed. Overall, average S_{max} tended to inscrease from 0.4 to 0.9 ‰. Salty peaks often appeared at the end of March or the last 10 days of April, ranging

from 1.1 to 1.6 ‰. In 2010 and 2011, because of heavy drought, salty peak reached 5.2 ‰ (Vung Liem station) and 5.4 ‰ (Nang Am station). S_{max} in *Hau river* (monitored at Tich Thien station) was relatively stable, ranging from 0.1–0.5 ‰ except 2010 and 2011 with many changes: in 2010, salinity was the highest in April; in 2011, March was in turn with 2 times of heavy salinization, average S_{max} reached 1.13 ‰. In *Tra Ngoa canal*, representing infield areas (monitored at Nga Tu station), S_{max} in the period of 2007–2013 insignificantly changed, ranging from 0.3 to 0.4 ‰. In 2011, a dry year, the salinity of infield areas reached 1.6 ‰.

Evolution of the daily average salinity (STB) in the period of 2007–2011

In the period of 2007–2011, S_{TB} in Co Chien river tended to increase (from 0.2 to 0.5 ‰). In *Hau river*, salinity in the period of 2010 – 2011 ranged between 0.5 and 0.7 ‰. S_{TB} in Tra Ngoa canal were not much different by the years, ranging from 0.2 to 0.4 ‰

Evolution of the daily lowest salinity (Smin) in the period of 2007–2011

Evolution of S_{min} in main rivers of Vinh Long province in dry season ranged from 0.1 to 0.4 ‰ over the years. In *Hau River*, S_{min} increased from 0.1 to 0.3 ‰ in the period of 2007–2011. In *Co Chien river*, average S_{min} was about 0.16 ‰ in the whole dry season. In *Tra Ngoa canal*, the evolution was more complicated. Due to being located in infield area, average S_{min} were lower than those in other stations, ranging from 0.1 to 0.4 ‰.

Evolution of the yearly highest salinity (Smax-year) in the period of 2007–2016

The yearly highest salinity in main rivers of Vinh Long province in the period of 2007 – 2016 was shown in Fig. 2. Evolution of maximum salinity over the years 2007, 2010, 2013, 2016 were shown in Fig. 3.

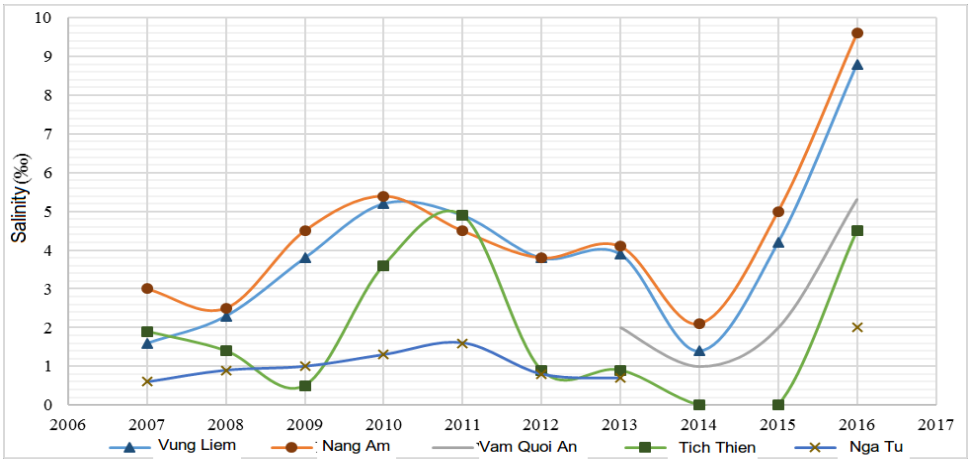
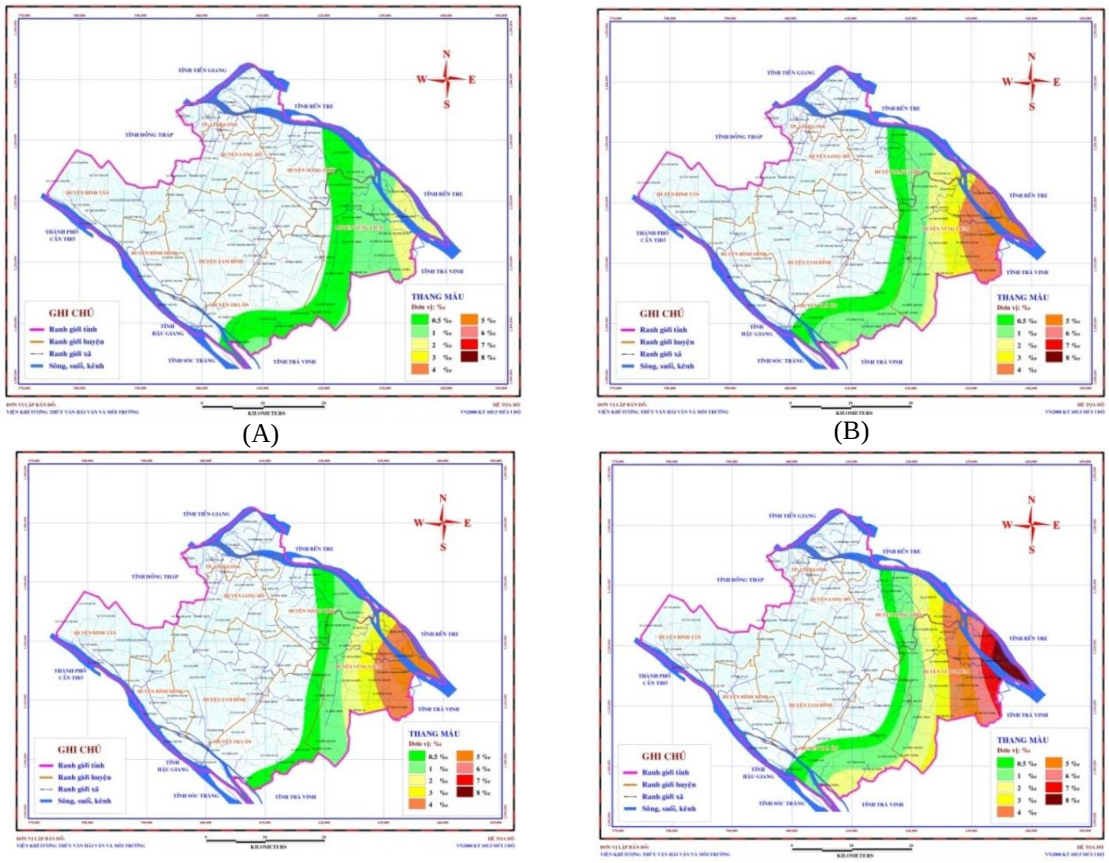


Fig. 2. Evolution of the yearly highest salinity in the period of 2007–2016



(A) (B)

(C) (D)

Fig.3. Distribution of maximum yearly salinity in main rivers of Vinh Long province: (A) 2007, (B) 2010, (C) 2013, (D) 2016

Overall, SI in main rivers tended to increase and spread into the infield. Especially in 2016, higher salinities appeared: 2 ‰ salty boundary started to affect Hau river, Vung Liem district, Mang Thit district, and Tra On district; 8 ‰ salty boundary was also recorded in Vung Liem district. It could partly correspond to the increasing trend of water level in Vinh Long, especially in Can Tho station (about 0.93 cm/year for the period of 1978 – 2015).

Monitoring data in March of 2016 showed salinity ranged from 0.3 to 0.8 ‰, being able to affect water supply plants. In *Co Chien river*, salinity increased from M5, M36 to M42 (increasing toward the sea): 0,3–0,8 ‰. Salinities at M34, M35 (in infield channels) and M36 (in Co Chien river) had relatively similar, indicating the possibility of SI in infield areas following the increase in salinity in Co Chien river. In *Hau river*, differences in salinitiy among monitoring positions were negligible, ranging from 0.5 to 0.6 ‰ and tended to increase toward the sea. Salinities in Mang Thit river (connecting Co Chien and Hau river) were similar among stations, ranging from 0.35 to 0.47 ‰. Vung Liem river is located infield and rather short, consequently, salinities were relatively similar among M29, M30 and M33 stations, ranging around 0.5 ‰. Noted that salinities in small channels (near Tra Vinh province) were relatively high such as: Tra Ngoa cannal (1.2 ‰) and Nga Chanh cannal (0.8 ‰).

Preliminary assessment of impacts of SI to some socio-economic activities in Vinh Long province

Impacts of SI to the agricultural sector

Salty water spreading into inland can affect crops (make flowers and fruits fall during flowering-fruiting period or kill shrubs, etc.). Besides, SI can cause the decline of agricultural areas, leading to crop yield decrease. Based on the current status of land use and SI at Vinh Long province, calculated results of perennial and rice planting areas potentially affected by SI showed Vung Liem to be the most affected area by SI (Table 2). SI significantly affected agricultural sector of Vinh Long province, especially the cultivation one. The breeding sector was not directly affected by SI but facing the consequences related to water and food resources, diseases, etc. In the context of climate change, SI will increase, leading to the lack of water for crop, difficulties of farming conditions, high risks of epidemic diseases, etc. and then affecting the economy and food security.

Table 2. Calculated results of the current status of perennial and rice planting areas potentially affected by SI at Vung Liem District

Object	Salinity and salinization area		Value
Rice	≥ 2 ‰	Salinization area (ha)	7,002.86
		Rate (%)	47.24
	≥ 4 ‰	Salinization area (ha)	767.28
		Rate (%)	5.18
	Total rice area (ha)		14,824.06
Perennial plants	≥ 2 ‰	Salinization area (ha)	2,062.51
		Rate (%)	64.42
	≥ 4 ‰	Salinization area (ha)	257.42
		Rate (%)	8.04
	≥ 7 ‰	Salinization area (ha)	-
		Rate (%)	-
	Total perennial plant area (ha)		3,201.85

Impacts of SI to aquaculture

The increase in SI leads to the increase in impacts to fresh water aquacultural areas. Significant changes in salinity make organisms cannot adapt to the new environment, inhibit development, reduce fertility or even make mortality. On the other hand, when the sea level rises, aquaculture area of brackish can be expanded. However, at the present no greater benefits are achieved because water quality in these areas are often degraded. The popular aquacultural species in Vinh Long province such as *Pangasius* catfish, *Basa* fish, *Red tilapia,* and shrimp have large salt tolerance threshold, <12 ‰, <28 ‰ and <25-33 ‰, respectively. Therefore, SI has not been an alarming issue for aquacultural sector in the local (Fig. 4). However, SI can change the water quality and increase risks of developing some pathogens for aquacultural species.

Impacts of SI to water supply sector

There are 4 types of water supply at Vinh Long province: (i) centralized water supply; (ii) rainwater; (iii) wells; (iv) rivers and lakes. People living in the infield areas usually use water from

rivers and rainwater for bathing, washing, and other domestic activities. Overall, the rate of people using centralized water supply services is still low (average of 55 %), especially in Tra On and Vung Liem districts corresponding to 29.8 % and 52 %, respectively [15]. Meanwhile SI in these districts are increasingly serious, 2.5 ‰ in the infield area of Vung Liem district and 1 ‰ in Tra On district, leading to risks for water supply facilities (Table 4, Fig. 4), lack of domestic water, subsequently affecting the health (intestinal diseases, skin diseases, etc.) and living activities of people. It could be inferred the sensitivity to SI (especially in climate change context) of the domestic water supply sector in Vinh Long province is increasing, and thus needs detailed investigating.

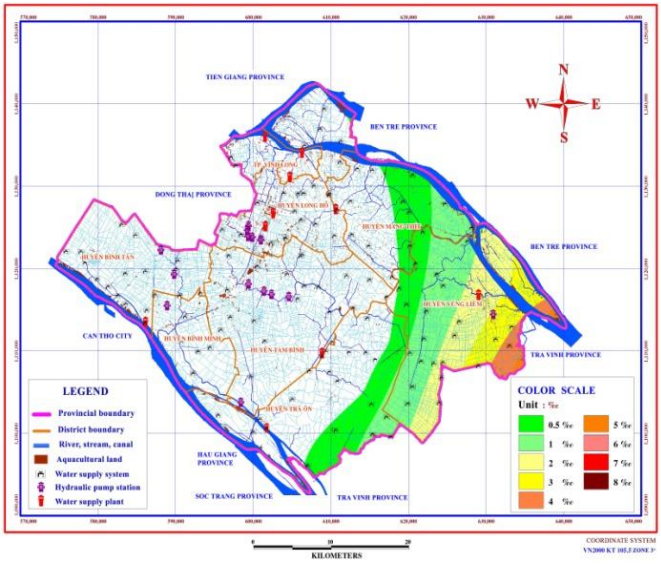


Fig.4. The current status of aquacultural areas and water supply systems in the salty areas in Vinh Long province

Table 4. The current status of water supply facilities potentially affected by SI

District	Current status			
	Water supply plant	Water supply system	Water supply station	Total
Mang Thit	-	6	-	6
Vung Liem	1	23	1	25
Tra On	-	7	-	7

CONCLUSION

SI evolution (the highest, the lowest, and the average salinities) at Vinh Long province during 2007 – 2016 tended to increase; salinity in March is often the highest; salinity peak usually appears from the end of March to the beginning of April. Monitoring results in March of 2016 recorded the increase in salinities as compared to those in the previous years. The salinity in Co Chien River was the highest, impacting Vung Liem, Tra On, and Mang Thit districts. Therefore, assessing vulnerability to SI of specific sectors needs carrying out, serving propose appropriate control measures, ensuring response effectively to SI, especially in the context of climate change.

Đánh giá diễn biến xâm nhập mặn trên các sông chính ở tỉnh Vĩnh Long

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TÓM TẮT

Xâm nhập mặn (XNM) là vấn đề đáng quan tâm trong năm 2015–2016 cùng với hiện tượng El Nino. Diễn biến XNM tại đồng bằng sông Cửu Long nói chung và tỉnh Vĩnh Long nói riêng đang ngày càng trầm trọng. Nghiên cứu nhằm mục tiêu đánh giá diễn biến XNM trên các sông chính ở tỉnh Vĩnh Long trong 10 năm gần đây (2007–2016), bao gồm diễn biến độ mặn cao nhất, thấp nhất và trung bình; kết hợp lấy mẫu nước mặt tại 19 vị trí nhằm đánh giá hiện trạng mặn trong năm 2016. Kết quả cho thấy, mặn có xu hướng lấn sâu vào nội đồng, nhiều nhất phía sông Cổ Chiên (trung bình mùa khô qua các năm dao động từ 0,4–1,2 ‰), tiếp theo là sông Hậu (0,2–0,7 ‰) và các kênh rạch vùng nội đồng (0,3–0,6 ‰) – ảnh hưởng nhất định đến ngành trồng trọt, nuôi trồng thủy sản và hoạt động cấp nước sinh hoạt. Trên địa bàn tỉnh Vĩnh Long, các khu vực đáng quan tâm trong mối quan hệ với XNM là huyện Vũng Liêm và Trà Ôn, theo đó, đòi hỏi những biện pháp kiểm soát và thích ứng phù hợp, đặc biệt trong bối cảnh biến đổi khí hậu.

Từ khóa: *xâm nhập mặn, biến đổi khí hậu, độ mặn*

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