Assessment of climate change impacts on agricultural sector in Vinh Long province

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Abstract – **Climate change is one of the major challenges for humanity in the 21st century, has negatively affected many sectors. This work aimed at assessing impacts of climate change (CC) on agricultural sector in Vinh Long province till 2020 via data collection and processing method, Geographic Information System (GIS), risk assessment matrix, and SWOT. Flood, saltwater intrusion (SI), drought, landslide, storm, temperature, and precipitation were taken into consideration. Flood, SI, and temperature were found as main factors affecting on agricultural sector in Vinh Long province, especially rice. In Vinh Long province, Vung Liem, Long Ho, and Binh Tan districts were significantly effected. Besides, this work proposed some solutions to improve the adaptive capacity to CC of this sector, contributing to the local sustainable development.**

Index Terms – **Agriculture, climate change, saltwater intrusion, flood**

1 INTRODUCTION

Climate change is one of the major challenges for humanity in the 21st century. Disasters and severe weather events are increasing in quantity, strength, and affecting scale, considered as top concerns of the world, including VietNam, especially in the MeKong Delta where would be in danger of flooding about 39% of the area under sea level rise 1 m [1]. Therefore, both positive and negative impacts of CC need assessing to develop suitable adaption plans.

Agriculture is a sensitive sector to climatic conditions and disasters, such as temperature, precipitation, SI, drought, and flood, etc., thus can be seriously affected by CC [2 –6].

Many different methods have been used to assess impacts of CC on agricultural sector, based on the historical climate data [7], modelling as DSSAT Ver 4.0.2 model (Decision Support System for Agrotechnology Transfer) [8 – 10], AquaCrop [11, 12], Cropwat [13], etc., lab-scale empirical methods for annual and perennial crops, pests, and epidemics [14], GIS and remote sensing [14], expert method, and community survey [15, 16]. In general, according to research objectives and scope, suitable individual or combined methods are used.

Vinh Long province (including Vinh Long city, Vung Liem, Mang Thit, Tra On, Tam Binh, Binh Tan, Binh Minh, and Long Ho districts), located in the Mekong Delta, on one hand has a thriving agriculture sector, especially rice, fruit, and freshwater aquaculture with about 79% of its natural area being agricultural land [17]. On the other hand, it also would be one of the most flooding area in the context of sea level rise [1]. Besides, natuaral disasters such as riverbank landslide, storm, drought, SI, etc. have occured quite frequently [18] and then seriously affected the local agricultural sector, especially in the context of CC.

Therefore, assessing CC impacts on agricultural sector is necessary to provide scientific basis for developing adaptive solutions in each specific condition, reducing risks, and contributing to the local sustainable development.

2 METHODS

Impacts of CC on the agricultural sector of Vinh Long province were assessed by the effects of flood, SI, drought, storm, temperature, and precipitation variations (called as CC factors in this work).

Data collection and processing method

Concerning data of the current status and development plans of the agricultural sector, the changing in disasters and climate, CC scenarios (developed by SIMCLIM software according to AR4 of IPCC), SI and tidal flooding scenarios, as well as response action plans, etc. was collected,

then processed by Excel software. For CC scenarios in VinhLong province in 2020, according to the average greenhouse gas emission scenario (B2), temperature and precipitation would be 27.64ºC and 1,491.80 mm, respectively; water level would rise about 9 cm as compared to that in the reference period (1980–1999) [19].

Geographic Information System (GIS) method

Mapinfo 11.5 and ArGIS softwares were used to mapping impacts of flood, SI, temperature, and precipitation, etc. on agricultural sector in Vinh Long province to 2020.

CC risk assessment matrix

This method was used to determine areas needing to be paid special attention and respective causes based on the risk level due to CC which was evaluated by risk index as presented in Table 1.

Table 1. Risk index scale due to CC

0 < RR ≤ 1	1 < RR ≤ 2	2 < RR ≤ 3	3 < RR ≤ 4	4 < RR ≤ 5
Very low	Low	Average	High	Very high

The risk index to CC was integratedly calculated by risk index to each CC factor (basically determined based on occurrence possibility and related damages) and its weight in relation to the agricultural sector.

The weight of each CC factor was determined as follows:

- Ranking the importance of each factor based on 20 experts' opinions. The more important the factor is, the higher the ranking score will be.
- Determining the ranking score of each factor (m_i): $m_i = M_i/n$ where M_i is total score of factor i and n is number of questionaires.
- Calculating the intermediate weight of each factor (w'_i): (i) for the factor having the lowest m_i, accepting its $w'_i = 1.0$; (ii) calculating w'_i of other factors: $w'_i = m_{i(min)}/m_i$
- Calculating the final weight of each factor (w_i):

$$w_i = \frac{w_i'}{\sum_1^n w_i'}$$

SWOT method (S-Strengths; W-Weaknesses; O-Opportunities; T-Threats)

SWOT was used to determine causes and corresponding adaption measures: (i) determing S and W of the agricultural sector in Vinh Long province; (ii) determining O and T of external factors in relation to CC; (iii) Analysing and combining suitable pairs (S-O, S-T, W-O, W-T), then determing defective chains and proposing adaptive measures.

3 RESULTS AND DISCUSSION

Current status and the development plan of the agricultural sector in Vinh Long province till 2020

Current status: for the period of 2005–2015, reverse with the planting sector, the proportion of the breeding sector and service agricultural activities was increased. However, the planting sector still held the leading role, accounting for 67.78% of the agricultural sector in 2015 (followed by breeding sector and service agricultural activities, according to 26.46% and 5.76%), including major crops such as rice, annual crops, fruit and perennial plants. The largest areas of rice and fruit in the province were mainly located in Vung Liem, Tra On, Tam Binh, and Mang Thit districts [17].

Development plan: The agriculture, forestry, aquaculture sector of Vinh Long province has strived to achieve the growth rate of 4.0-4.5%/year in the period of 2016–2020, reducing the proportion of planting sector but conversely for the breeding sector. By 2020, the proportion of planting sector, breeding sector, and agricultural services are 61.91%, 32.92%, and 5.17%, respectively. Besides, it is oriented to reduce the rice land instead of fruit land, to reduce the third crop of rice, to increase the alternation of crops, to exploit the strengths of fruit and aquaculture [20].

Assessment of CC impacts on agricultural sector in Vinh Long province

Temperature

Maximum temperature fluctuated in 35ºC–36.5ºC (in the period of 1986–2005) and affected about 5,000 ha of agricultural land, corresponding to 65.9% and 34.1% of the annual and perennial-plant land, mainly distributed in Binh Tan (about 2,000 ha), followed by Long Ho, Mang Thit, Vung Liem districts (about 500–600 ha).

By 2020, temperature will be increased but the affected agricultural land could be decreased due to the change in agricultural land-use planning as

mentioned: about 3,163 ha, mainly in Binh Tan district (about 32% of affected area).

Precipitation

Heavy, erratic, and unseasonal rain create favorable conditions for pest development. In the context of CC, the epidemics are increasingly complex, such as brown backed plant hopper, rice blast disease, sheath blight disease, leaf roller disease, twisted leaf disease, yellow leaf disease, yellow dwarf disease, etc. and affect the ability of intensive farming in Mekong Delta as well as VinhLong province [21].

Flooding

Flooding has the most impacts on rice-land and perennial-plant land in the province (Table 2). On one hand, it causes the decrease in agricultural yield and product quality, consequently provincial gross domestic product. On the other hand, it results in alluvium and then fertility for soil, etc.

Current status: rice-land (LUC) and perennial-plant land (CLN) have been significantly affected by flooding: about 24,500 ha (accounted for 27% of agricultural land of the province), mainly located in Vung Liem (about 7,327 ha, accounted for 40.7% of agricultural land of the district), Long Ho (about 3,867 ha, 37.4%) and Tam Binh district (3,175 ha, 16.8%) (Table 2).

In 2020, flooded agricultural land could be decreased due to the change in rice land-use planning: about 23,394 ha, 29.8%. Vung Liem, Long Ho, and Tam Binh districts would be still affected the most, thus need suitable adaption measures (Fig. 1, Table 2).

Saltwater intrusion

Sea water entering inland can impact crops as making flower and fruit loss during blooming and fruiting periods, even killing plants due to high salinity of water. Besides, salinity reduces planting area, leading to the decrease in crops yield. Calculated results showed that VungLiem district is always the most affected in the current status and 2020 – B2 scenario (Fig. 2, Table 3)
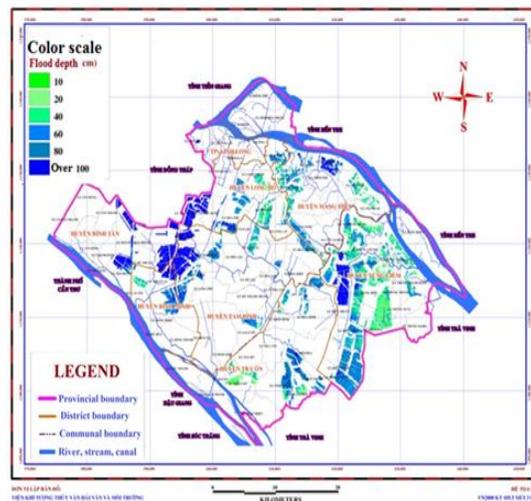

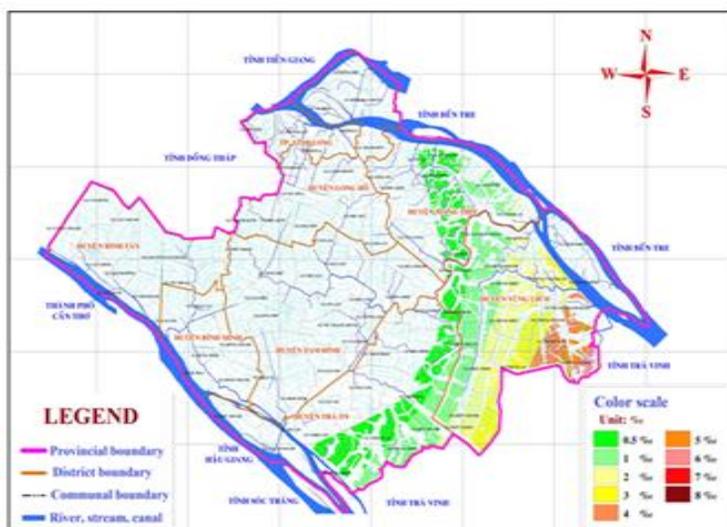Fig. 1. Flooded rice-land in Vinh Long province in 2020

Fig. 2. Salt-intruded rice-land in Vinh Long province till 2020

Table 2. Area (ha) having the risk of flood in current status and 2020 - B2 Scenario

			Binh Minh	Binh Tan	Long Ho	Mang Thit	Tam Binh	Vinh Long city	Tra On	Vung Liem	Total
Rice – land	Current	Total	3,946.8	9,618.5	6,779.0	6,953.2	16,750.6	464.4	12,101	14,790.9	71,404.7
		Flooded	1,465.6	2,050.4	2,909.1	1,713.1	2,886.9	107.8	2,141.2	6,680.2	19,954.3
		%	37.1	21.3	42.9	24.6	17.2	23.2	17.7	45.2	27.9
	2020	Total	2,986.9	8,376.4	5,806.7	6,161.1	15,877.5	292.2	11,453.1	13,527.3	64,481.2
		Flooded	1,084.1	1,733.4	2,607.3	1,839.1	2,650.6	26.6	2,327.1	7,581.9	19,850.1
		%	36.3	20.7	44.9	29.8	16.7	9.1	20.3	56.1	30.8
Perennial plant – land	Current	Total	1,581.4	1,012.8	3,566.1	2,045.8	2,152.1	1,235.6	4,423.8	3,200.7	19,218.3
		Flooded	879.6	115.4	957.6	404.2	288.1	577.5	674.4	646.4	4,542.9
		%	55.6	11.4	26.8	19.8	13.4	46.7	15.2	20.2	23.6
	2020	Total	988.2	697.8	2,931.8	1,610.6	1,773.7	37.8	3,464.2	2,625.2	14,139.4
		Flooded	579.3	76.5	970.0	457.2	245.7	4.8	532.2	678	3,543.7
		%	58.6	10.9	33.1	28.4	13.8	12.8	15.4	25.8	25.1
Total	Current	**Total**	**5,528.2**	**10,631.3**	**10,345.1**	**8,999.1**	**18,902.8**	**1,700.1**	**16,524.8**	**17,991.6**	**90,623**
		Flooded	**2,345.2**	**2,165.9**	**3,866.6**	**2,117.3**	**3,174.9**	**685.3**	**2,815.6**	**7,326.5**	**24,497.3**
		%	**42.4**	**20.4**	**37.4**	**23.5**	**16.8**	**40.3**	**17**	**40.7**	**27**
	2020	**Total**	**3,975.1**	**9,074.3**	**8,738.4**	**7,771.7**	**17,651.2**	**330**	**14,917.3**	**16,152.5**	**78,620.6**
		Flooded	**1,663.4**	**1,809.8**	**3,577.4**	**2,296.2**	**2,896.3**	**31.4**	**2,859.3**	**8,259.9**	**23,393.8**
		%	**41.8**	**19.9**	**40.9**	**29.6**	**16.4**	**9.5**	**19.2**	**51.1**	**29.8**

Table 3. Area (ha) of rice land and perennial plant land affected by SI

Object			Current			2020		
			Mang Thit	Tra On	Vung Liem	Mang Thit	Tra On	Vung Liem
Salt-intruded rice-land	≥ 2 g/L	ha	-	-	7,002.9	123.4	42.6	9,083.6
		%	-	-	47.2	2.0	0.4	66.9
	≥ 4 g/L	ha	-	-	767.3	-	-	2,032.3
		%	-	-	5.2	-	-	15.0
	Total area (ha) of rice-land		6,953.8	12,067.4	14,824.1	6,206.2	11,386.4	13,584.1
Salt-intruded perennial plant-land	≥ 2 g/L	ha	-	-	2,062.5	226.1	6.7	2,038.8
		%	-	-	64.4	14.1	0.2	77.6
	≥ 4 g/L	ha	-	-	257.4	-	-	834.4
		%	-	-	8.0	-	-	31.9
	≥ 7 g/L	ha	-	-	-	-	-	2.6
		%	-	-	-	-	-	0.1
	Total area (ha) of perennial plant - land		2,041.8	2,041.8	4,443.4	3,201.8	1,607.6	3,476.5

Table 4. CC risk index of agricultural sector in Vinh Long province

		Temper-ature	Precipi-tation	Flood	SI	Drought	Land-slide	Storm	Average	Max
Weight		0.15	0.07	0.18	0.23	0.15	0.08	0.13		
BinhMinh town	Current	1	1	2	0	1	0	1	0.86	2
	2020	1	1	3	1	1	0	1	1.27	3
BinhTan	Current	2	1	2	0	1	0	2	1.14	2
	2020	2	1	3	1	1	0	2	1.55	3
Long Ho	Current	1	1	3	2	1	0	4	**1.89**	4
	2020	1	1	3	3	1	0	4	**1.89**	4
Mang Thit	Current	2	1	1	1	1	0	1	1.52	3
	2020	2	1	2	0	1	0	1	1.70	3
Tam Binh	Current	1	1	1	0	3	0	1	1.21	3
	2020	1	1	2	2	3	0	1	1.62	3
Tra On	Current	1	2	1	3	1	1	1	1.52	3
	2020	1	2	2	3	1	1	1	1.70	3
VinhLong city	Current	1	1	1	1	3	0	1	1.21	3
	2020	1	1	2	2	3	0	1	1.62	3
Vung Liem	Current	1	1	3	4	1	0	1	**1.96**	4
	2020	1	1	3	4	1	0	1	**1.96**	4
Total	Current	10	9	**14**	**14**	12	1	12		
	2020	10	9	**20**	**18**	12	1	12		

Drought

Drought often occurs at the end of winter-spring crop and prolongs until the end of summer-autumn crop -low tide period (end of April). In 2015, drought affected about 30% of summer-autumn rice area (about 17,600 ha), most in Vung Liem (5,000 ha) and BinhTan (5,000 ha), followed by Tam Binh (4,600 ha), and Tra On district (3,000 ha). In 2020, the increase in temperature and decrease in precipitation in Vinh Long province would result in drought risk with undesirable impacts on agricultural sector (water shortage, SI, reduction of productivity, etc.).

Other disasters

Storm affected crops in Long Ho (about 102 ha) and Tam Binh (1 ha), resulting in damage of 7 billion VND, as well as fruit area in Tam Binh district (0.4 ha) [18].

To sum up, there has been the impacts of CC on the agricultural sector, especially (rice) planting sector in Vinh Long province till 2020.

Determining CC factors of concern and hotspot areas

Table 4 presented risk index to CC of the agricultural sector in Vinh Long province, especially due to flooding and SI, where Vung Liem and Long Ho district had the highest values corresponding to 1.96 and 1.89 (Fig 3a),

By 2020, flooding and SI tend to increase, leading to the increase in risk level of the agricultural sector. Risk index of other factors would not be significantly changed. Vung Liem and Long Ho district should be taken into pay special attention (Fig 3b, Table 4).
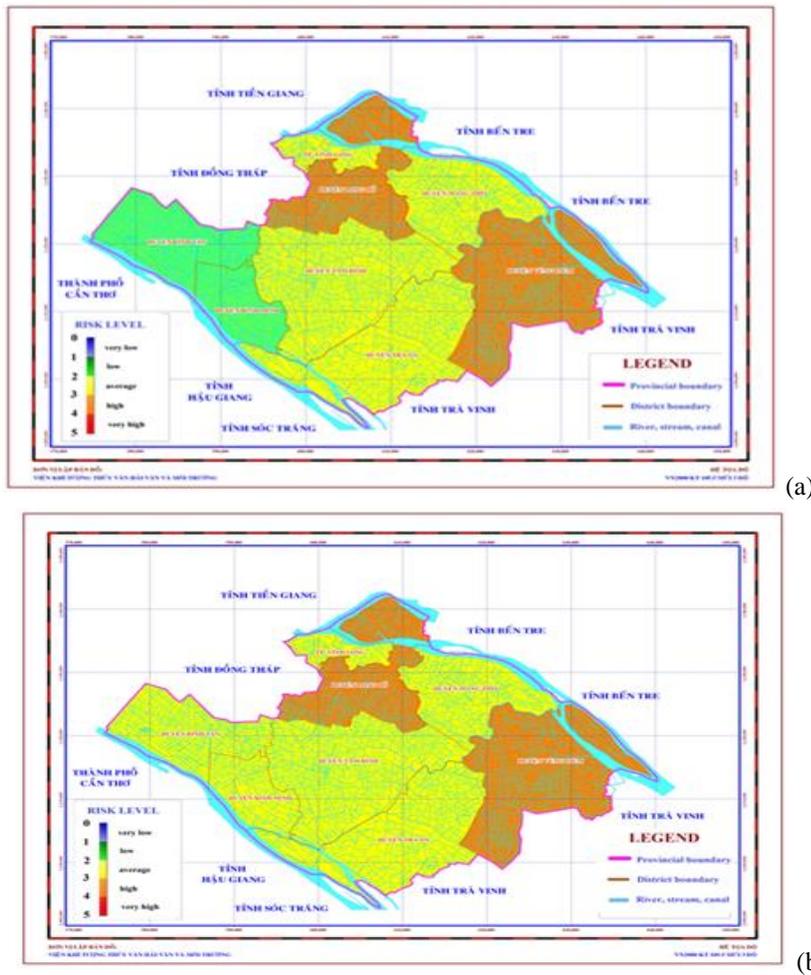
Fig. 3 The max CC risk index of the agricultural sector in Vinh Long province: (a) current status, (b) 2020

Table 5. Strenghts, weaknesses, opportunities, and threats of agricultural sector in Vinh Long province in the context of CC

	S – Strenghts		W – Weaknesses
S1	Taking advantages of alluvium from Tien River and Hau River [22]	W1	Hollow terrain and relative low (high risk of tidal flooding)
S2	Located in the center of Mekong Delta, facilitating trade (including agricultural products)	W2	Complex river system; Being affected by semi-diurnal tide (risk of SI)
S3	Considerable land fund for agricultural development (about 79% of natural area) [17]	W3	Difficulties in mobilizing social resources to invest in the agricultural sector [23]
S4	Investing irrigation system and dikes to prevent flood, riverbank landslide, etc [23]	W4	Less capital to invest in seeds, animals, and infrastructure for agricultural development [23]
S5	Investing water supply infrastructure, increasing the closed and proactive irrigation area (about 90% of the agricultural area) [23]	W5	Limitation in mechanization of production and harvest as well as application of advanced technologies in the pre-processing, preserving, and processing [23]
S6	Focusing on animal and seed farms to provide high-yield and good quality varieties [23]	W6	Difficulties in accessing information of CC [22]
S7	Restructuring the agricultural sector in the period of 2014 – 2020 [21]	W7	Lack of adequate attention of CC response in a number of state authorities [22]
S8	Medium adaptive capacity to CC of the community and local authorities [22]	W8	Low effective implementing the CC response action plan in some local [22]
	O – Opportunities		**T – Threats**

O1	Taking advantages of temperature increase and dry season prolonging to dry agricultural products, etc.	T1	Flooding is a matter of concern for the agricultural sector and tends to be more seriously.
O2	Mobilizing finance to cope with CC from the government, local authorities, and international sources (ODA, AFD, New Zealand Partnerships for International Development Fund, etc) [23, 24]	T2	SI significantly affected the agricultural production in Long Ho, Tra On, Vung Liem district and tend to increase in the future
O3	Taking advantages of studying and transferring technology from other provinces to improve adaptive capacity to CC of the agricultural sector [23]	T3	Limited investment from the Government in the provincial agricultural sector [23]
		T4	Increase in competition of agricultural products with other prvinces [23]

Strenghts, weaknesses, opportunities, and Threats of the agricultural sector in the context of CC

The relationships of S, W, O, and T of the agricultural sector in Vinh Long province in the context of CC (Table 5) are following:

(i) S1, S2, S3 + O1: Maximizing the strengths of natural conditions and geographical position to maintain the growth rate of agricultural sector.

(ii) S6 + O3: Promoting the cooperation with research institutes, universities, companies from other provinces in studying and constructing seed and animal farms able to adapt to CC (increasing tolerance to salinity ...).

(iii) S7 + O2: When restructuring the agricultural sector, CC should be taken into consideration; promoting capital mobilization, creating financial sources in order to effectively respond to CC.

(iv) S8 + O2: Leveraging national and international funds to improve CC adaptive capacity of community via communication programs.

(v) S4, S5 + T1, T2: Maintaining and constructing new irrigation systems to prevent salinization and inundation; investment in developing water supply infrastructure; enhancing closed and proactive irrigation area in the context of salinization increase.

(vi) S8 + T1, T2: Enhancing communication activities to improve the awareness, responsibilty, and participation of communities and authorities in the mission of CC response in the province.

(vii) W4 + O2: Strengthening and taking full adventages from support capitals to increase the investment in plant and animal varieties adapting to CC and infrastructures for agricultural development.

(viii) W5 + O3: Strengthening the mechanization of production, harvest; applying advanced technologies to improve quality of agricultural products and increase market competitive capability, especially in the context of CC.

(ix) W6 + O2: Taking full advantages from support capitals to increase the capability of community in accessing information of CC via communication activities.

(x) W7, W8 + T1, T2: Proposing solutions and timeline to implement CC response action plan, focusing on flood and SI impacts on the agricultural sector and cooperations among related organizations.

Besides, the following solutions are needed considering and applying:

(xi) Improving management capacity of local agencies in response to CC.

(xii) Cooperation of 4 important parties, including farmers, government, scientists, and entrepreneurs in agricultural production and consumption; strengthening trade promotion and agricultural product brand.

(xiii) Developing policies to attract the investment in the agricultural sector, large-scale and high-tech agriculture development, and CC adaptation. Focusing on studying and applying scientific and technological achievements, especially in bio-technology to produce crops and livestock breeds suitable to local climate conditions.

(xiv) Mobilizing social resources to invest in agricultural infrastructure, taking into account CC factors.

(xv) Take advantages of high temperature to diversify the ways of processing agricultural products and to save energy.

(xvi) Applying science and technology, cleaner production technologies, fewer greenhouse gas emissions in preliminary processing, storage and processing stages to enhance the brand of agricultural products as well as to contribute to CC mitigation.

In summary, solutions to increase the response capacity to CC of the agricultural sector in Vinh

Long province should be focused on adaption measures (i – xiv) and then mitigation ones (xv, xvi).

4 CONCLUSION

The research aimed at assessing CC impacts on agricultural sector in Vinh Long province till 2020. Rice was found to be the most affected object, mainly by flooding, SI, followed by extreme temperature, where Vung Liem, Long Ho, Binh Tan district, etc. should be of concern.

Besides, this study analyzed strengths, weaknesses, opportunities, and threats of agricultural sector in relation to CC, measures to improve the adaptive capacity to CC were suggested, contributing to ensure the effective production, food security and sustainable development.

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Đánh giá tác động của biến đổi khí hậu đến lĩnh vực nông nghiệp tỉnh Vĩnh Long

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Tóm tắt – Biến đổi khí hậu là một thách thức lớn đối với nhân loại trong thế kỷ 21, tác động tiêu cực đến nhiều ngành, nhiều lĩnh vực. Nghiên cứu nhằm mục tiêu đánh giá tác động của biến đổi khí hậu (BĐKH) đến lĩnh vực nông nghiệp tỉnh Vĩnh Long đến năm 2020 thông qua các phương pháp thu thập tài liệu và xử lý số liệu, GIS, ma trận đánh giá rủi ro, tham vấn chuyên gia và phương pháp SWOT. Các yếu tố được xem xét, đánh giá bao gồm ngập, xâm nhập mặn (XNM), hạn hán, sạt lở, giông lốc, nhiệt độ và lượng mưa. Kết quả đánh giá cho thấy các tác động đến ngành nông nghiệp tỉnh Vĩnh Long chủ yếu thông qua các yếu tố ngập, XNM và nhiệt độ, trong đó, cây lúa là đối tượng đáng quan tâm. Các địa phương có khả năng chịu nhiều ảnh hưởng là Vũng Liêm, Long Hồ và Bình Tân. Nghiên cứu cũng đề xuất một số giải pháp góp phần nâng cao năng lực ứng phó với BĐKH cho ngành nông nghiệp, cung cấp cơ sở cho quá trình hoạch định các chính sách phát triển có liên quan tại địa phương.

Từ khoá – nông nghiệp, biến đổi khí hậu, xâm nhập mặn, ngập lụt