

Ecolo-urbanistic conditions of territorial zoning of the settlement system in the Mekong Delta, Vietnam

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Abstract. The Mekong Delta is one of the four deltas of Vietnam that are deeply impacted by climate change and thus influencing heavily on the population distribution. This conference paper studies the scenarios of climate change, assesses the impacts of climate change, and on this basis, divides the Mekong Delta into three regions according to the ecolo-urbanistic conditions, while also introducing conceptions and solutions to restructuring the sustainable residential development system in response to climate change.

1 Introduction

The Mekong Delta is the southernmost region of Vietnam, in which Can Tho is the municipality and 12 provinces: Long An, Tien Giang, Ben Tre, Vinh Long, Tra Vinh, Hau Giang, Soc Trang, Dong Thap, An Giang, Kien Giang, Bac Lieu and Ca Mau.

On 17 November 2017, the Government of Vietnam issued Decision No. 120/NQ-CP on Sustainable and Climate Change Resilient Development of the Mekong Delta Region which identifies that the Mekong Delta has special significance to national socio-economic development but also a vulnerable region to natural disasters and the impact of climate change [1]. This paper contributes to specify the orientation by the Government of Vietnam.

2 General overview of the the Mekong Delta

2.1 Geographical position

A part of the Mekong River basin, Mekong Delta Region (MDR) has area of 40.8 thousands km², located next to the South-eastern region, borders Cambodia to the north, Gulf of Thailand to the south-west, East Sea to the south-east.

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2.2 History and development in the Mekong Delta

The Mekong Delta was developed through three historical periods: (i) Primitive period; (ii) The period under French Colonial and the War against the American; (iii) The unification period to present day. On 26 November 2003, the National Assembly of Vietnam issued Resolution No. 22/2003/QH11 that divided the Mekong Delta into 12 provinces: An Giang, Ca Mau, Bac Lieu, Soc Trang, My Tho, Rach Gia, Ben Tre, Long An, Dong Thap, Can Tho, Tra Vinh and Vinh Long; then divided Can Tho province into Can Tho city directly under the central government (municipality) and the newly established Hau Giang province [2].

2.3 The natural environment

The terrain of the Mekong Delta is relatively low and flat, with an average slope of 2.0m, consisting of four main areas: (i) Dong Thap Muoi, elevation: 0.7 - 2.00m; (ii) the Long Xuyen quadrangle, elevation: 1.0 - 1.50m; (iii) the Coastal area, elevation: 1.0- 2.0m, 2-3m high; (iv) the Central area is flat, high, shallow area under 1.0m.

Formed from alluvial deposits and sedimentation to create coastal and riverside sand dunes, 2 - 3m high and saline sediment such as: Dong Thap Muoi, Long Xuyen Quadrangle, Ha Tien, south-western Hau river and Ca Mau Peninsula.

Tien river and Hau river join the Mekong Delta basin to enter the sea via 09 estuaries. Besides Mekong river, the coastal system in the Mekong Delta is 28.550km long, in which 13,000km can be used for water transport. The whole region has 37 rivers (1700km); channel axis (6700km); level II channel (3000km).

The Mekong Delta has a monsoon climate, including the dry season and the rainy season, average temperature annually is 24 - 27 Celcius degree. Each year, the whole region receives a rainfall of about 1,600 - 2,200 mm. From the middle to the end of the rainy season, the Mekong River's western and northern regions are flooded by the Mekong river. An estimated 1.2 to 1.9 million hectares are flooded, mainly in the Long Xuyen Quadrangle, Dong Thap Muoi and the middle of Tien River - Hau river.

The main resources of the Mekong Delta include: (i) Peat, limestone, soils, brick, gravel, oil and gas; (ii) arable land and land for agriculture (30% nationwide); (iii) mangrove forests; (iv) Tourism resources, of which more than 2.4 million hectares of agricultural land and 700,000 hectares of aquaculture provide more than 50% of rice production and 65% of freshwater brackish water aquaculture production and about 70% of the fruit production nationwide; annually, contributing an average of 27% of gross domestic product (GDP) of Vietnam.

In recent years, increased saltwater intrusion from the sea has affected more than 50% of cultivated area, especially in dry season. In addition, the problem of alum soil - alum water, has affected about 1.6 million hectares.

2.4 Socio-Economic characteristics

2.4.1 Economic

The main economic sectors of the region include: (i) Agriculture, including rice production which occupies 47% of the area; (ii) Services mainly of import, export, transportation, tourism and administrative management; (iii) Limited industrial development, of which Can Tho is an industrial center: Thermoelectricity, metallurgy, food processing, textiles, construction materials ... of the region [3].

Economic structure: shifting towards service - industry and agriculture: (i) in 2005, services 29.8%, industry 20.3% and agriculture 49.9%; (ii) in 2013: services 39.7%, industry 25.5% and agriculture 33.2%; (iii) in 2015: services 43.6%, industry - construction 33.3%; agriculture, forestry and fishery 23.1%; according to forecasts, economic structure in 2020: agriculture, forestry and fishery 17.3%; industry - construction 37.4%; Service 45.3%; high economic growth, average GDP growth rate of 11% annually in 2011-2015 and 10.5% annually in 2016-2020; Low income: GDP per capita in 2013 is 1650 USD; average income per capita is 40.2 million VND (nation average is 47.9 million VND/person/year).

2.4.2 Social population and urbanisation

The population of the region in 2016 is 17660700 people, with a density of 433 people/km²; the average natural growth rate (2016) is 0.73%, and is on the downward trend. Emigration has increased, on average about 0.67% per year. From 2005 to 2013, the number of immigrants was about 240000; while the number of out-migrants is 1200000. Quality of life of the population is low: lack of employment; low income; poverty rate is 20%; limited access to housing, social services. The ethnic groups living here are mostly Kinh. In addition, there are Khmer, mainly in Tra Vinh, Soc Trang; Muslim Cham people in Tan Chau, An Giang and Hoa people in Kien Giang and Tra Vinh. The urbanisation rate (2013) is 25% lower than the national average (33.1%). The population is mainly concentrated in the area between south of Hau river and north of Hau river, of which 70% of the population is concentrated in the South of Hau river. Rate of urbanization (2017) is 27%; lower than national average which is 37%.

2.4.3 Use of land

Total natural land is 4081.6 km² including: agricultural land: 2607.1 km² (63.8%); dedicated land: 262.7 km² (6.4%); residential land: 124.3 km² (3.0%); unused land and other land: 1087.5 km² (26.6%).

2.4.4 Technical infrastructure

About traffic: (i) Ho Chi Minh – Trung Luong expressway; routes QL1A, QL50; QL 60; QL 61, QL 61B; QL80; QL N1, QLN2 (Vertical axis); routes QL62; QL30, QL 53; QL54, QL63, QL57, QL91, QL91B (Horizontal axis); (ii) 04 airports, including 2 international (Can Tho, Phu Quoc); (iii) Waterway: 28550 Km of river waterway, 13 seaports, capacity of over 10 million tons/year.

About irrigation, technical preparation land: the irrigation system faces difficulties, unconnected to other infrastructure system. There are 04 lowland areas: Dong Thap Muoi (deep flood); Long Xuyen Quadrangle (medium flood); coastal and central Mekong Delta (shallow flood); highlands: mainly riverside and coastal (2-3m).

About water supply: 40 water supply systems: 1424000 m³/day, using: 67% surface water, 33% ground water.

About power infrastructure: 04 major power plants; Tra Noc (193.5 MW), O Mon (600 MW), Ca Mau (1500 MW), wind electricity Bac Lieu (99 MW); 500 KV (My Tho, O Mon, Duyen Hai) besides there are 220 KV powerplants is shown in Fig. 1. These infrastructure facilities create a main technical corridor: Expressway QL1A from Ho Chi Minh City to Can Tho City.

2.5 Population distribution

The Mekong Delta has 149 urban centres, of which 02 are class I cities; 05 class II cities; 17 class III cities; 10 class IV towns; 125 class V cities; 1294 rural residential areas. The residential areas are mainly located along two systems: south of Hau river and north of Hau river, of which Can Tho city is the center. The region has 24 cities, including one regional city, 12 provincial cities and 11 regional metropolitan centers. Distance between provincial centers: 40 - 60km/1 node. Group distribution systems: 13 urban clusters and 01 independent urban area and 125 rural population clusters.

Population distribution is mainly through the "point route" model along the river, canal and traffic axis is shown in Fig.2 [4, 5, 6].



Fig. 1. Traffic status of the Mekong Delta [2].



Fig. 2. Population Distribution status of the Mekong Delta [2].

2.6 Some comments

Comment 1: The Mekong Delta is a key economic region for food production in Vietnam where natural conditions are favourable; is densely populated; closely linked with the Mekong River and Southeast region basins; has an important strategic location for national defence and international trade.

Comment 2: Challenges faced: (i) Slow development region compared to national average; (ii) low natural population growth rate; (iii) increased emigration, aging population; (iv) Deeply impacted by climate change, sea level rise: flood, saline intrusion, coastal and riverbank erosion, etc.; (v) Poor livelihoods.

Comment 3: An unsustainable system of settlements with 50% of population located in areas affected by climate change, inadequate settlement conditions; is dependent on the Ho Chi Minh City area and is impacted in the upper Mekong.

3 The impact of climate change on the sustainable development of the system of settlements in the Mekong Delta

3.1 Scenarios on climate change

According to the National Strategy on Climate Change - Sea Level Rise published by Ministry of Natural Resources and Environment on 07 March 2012 [7, 8]. Scenarios on climate change and sea level rise for the Mekong Delta at medium level (B2) are as follows:

Temperature: The annual average temperature increase is 0.3-0.5 celcius degree by 2020, from 0.8-1.4 celcius degree by 2050 and from 1.6-2.6 celcius degree by 2100.

Rainfall: Increasing the annual rainfall in the dry season and the beginning of the rainy season will decrease by 3% by 2020 and 8% by 2050.

Sea level rise: Continue to increase: 17cm by 2030; increase 30cm in 2050 and 75cm in 2100. For the Mekong Delta, climate change causes flow, saline intrusion and flooding have a direct impact on settlement conditions. (Table 1) [7].

Table 1. Scenarios on climate change.

No	Fluctuations	2020	2050	2100
1	Temperature (Celcius degree)	+ 0.3 – 0.5	+0.8 – 1.4	+1.6 – 2.6
2	Rainfall (%)	+ 0.3 – 1.6	+ 0.7 – 4.1	+ 1.4 – 7.9
3	Sea level rise (cm)	12.0	30.0	70.0

3.2 Evaluate the impacts of climate change on the conditions of settlement in the Mekong Delta

3.2.1 Impact of saline intrusion

Upstream flow in Kratie by 85% by 2020, considering upstream climate change (down 5%); tidal sea level rise 12cm; by 2030 upstream flow at Kratie by 85% (down 10%) will change the tide of sea level rise by 17cm; by 2050, the upstream tide in Kratie will be 85% (down by 15%), and the tide will rise by 30cm (Table 2) [9].

Table 2. Saline intrusion due to reduced upstream and sea level rise.

No	Impact of saline intrusion	2020	2050	2100
1	Upstream flow decreases	- 5%	- 10%	- 15%
2	Sea level rise	12 cm	17 cm	30 cm
3	Saline intrusion	- Coastal and Ca Mau Peninsula -The rivers	- Coastal and Ca Mau Peninsula - The rivers	- The rivers - Coastal and Ca Mau peninsula - 45% of area, 1.7 million ha
4	Population affected by saline intruded water	40%	47%	50 %

The areas most severely damaged by salinity intrusion are coastal areas of the Mekong Delta, especially Ca Mau. Approximately 1.7 million hectares (about 45% of the area is saline). The mangrove areas, despite the conditions for mangrove development, expand the marine and brackish water aquaculture areas, but it causes great damage to the lake areas, industrial shrimp ponds and the supply of domestic water, Irrigation for the population are showns in Figs. 3 - 4.

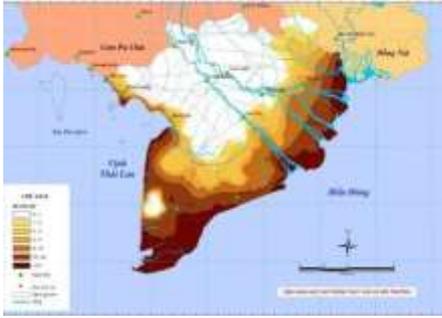


Fig. 3.] Saline intrusion areas of the Mekong Delta [7].

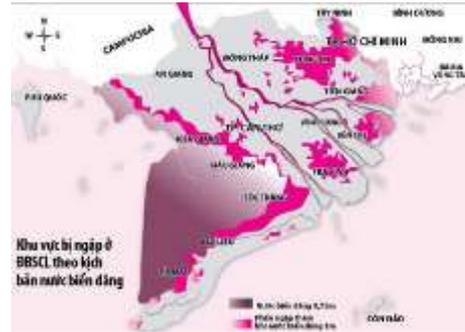


Fig. 4. Flooded area in the Mekong Delta according to climate change scenarios [7].

3.2.2 Impact of flooding by sea level rise

According to climate change and sea level rises scenarios for Vietnam (updated 2016), if the sea level rises by 100cm, the Mekong Delta has the highest risk of flooding: 38.9% of area. Hau Giang has the risk of flood at 80.62%, Kien Giang 76.86%, Ca Mau 57.69%. [7, 9]. Sea level rise will expand, the flood area, many places will be flooded more than 4m deep as Dong Thap Muoi.

3.2.3 Evaluate the impacts of climate change on settlement conditions

Boundary of saline intrusion on the main rivers will overcome the current intake resulting in deeper saline intrusion into the inner field. By 2050, when upstream flow will fall by 15%, sea level will rise by 30cm in Tien River, saltwater through Vinh Long City will be 11km and on Hau river will pass Can Tho City by 5km, thus affecting water resources in Ben Tre, Soc Trang and Bac Lieu.

Some low areas are difficult to drain, causing stored water in the field leading to the risk of alum. The construction of dams, dykes to prevent floods has increased the environmental pollution affecting the quality of domestic water.

The proportion of the population affected by salinity intrusion increases from 39.5% in 2012 to 47.6% in 2030 and 2050; and proportion of population affected by flood increases from 66.70% (2012) to 79.2% by 2050. Salt water is penetrating into the mainland of the coastal area of the Mekong Delta from 40 to 50 km, the average salinity is also increased by 2 - 3% o over many years. Hundreds of thousands of hectares of rice are affected by salinity and drought. One third of the rural population lives in areas lacking fresh water.

Due to the impacts of climate change, the migration flows of farmers in coastal areas and urban centers in the north and west (such as Chau Doc, Long Xuyen, Can Tho, Vinh Long, My Tho and Tan An, etc.) is increasing.

3.3 Solutions to climate change adaptation applied in the Mekong Delta

3.3.1 Mekong Delta development plan

Master Plan for socio-economic development of the Mekong Delta until 2020: the Prime Minister's Decision No. 939/QĐ-TTg dated 19 July 2012 [10].

Major Development Plans for the Mekong Delta: Transport, Irrigation, Water Supply, and some economic sectors.

Mekong Delta Regional Construction Planning: Prime Minister's Decision No. 1581/QĐ-TTg (2009; Prime Minister's Decision No. 938/QĐ-TTg (2012); Prime Minister's Decision No. 68/QĐ-TTg dated 15 January 2018 approving the amendment of construction planning of Mekong Delta until 2020 with a vision to 2050 is shown in Fig. 5 [11].

3.3.2 General comment

Plans have been prepared and approved sectorally, with the same goal of responding to climate change, but the planning solutions are sectoral, field-specific achievements are very limited. To address the issues of climate change in relation to the distribution of population in the territory of the region, there needs to be a comprehensive, multi-sectoral plan using an integrated approach.



Fig. 5. Below the figure Regional Construction Planning in Mekong Delta [11, 12].

4 Ecolo-urbanistic conditions of territorial zoning for the sustainable development of the settlement system in the Mekong Delta, Vietnam

4.1 Conceptions and objectives

4.1.1 Conceptions

Fully analyze and assess the challenges posed by climate change to settlement in the Mekong Delta.

Territorial zoning according to ecological and urban planning conditions as the basis to determine the tolerance and population capacity per each sub-region.

Predict the trends of impact and evolution of climate change and socio-economic development, its impact on sustainable development of population distribution systems.

Renovate growth models and construction of sustainable and adaptive settlements to climate change suitable to each stage of development.

4.1.2 Objectives

Building a sustainable settlement model that is capable of responding to climate change in the Mekong Delta aims to: Improve the adaptively and resilience of urban and rural areas based on solutions to build the flexible settlement system structure, adapting to socio-

economic structural change, mode of production, population growth, demand for land use, conversion of forms of settlement and environmental protection.

4.2 Model of evaluation of the eco-urbanistic conditions for territorial zoning by the sustainable development of system of settlements adapting to climate change in the Mekong Delta

The ecological conditions of settlement include: (i) natural environment; (ii) social environment; (iii) conditions for the organization of the human habitat as a basis for choosing the direction and development of the population structure system in a scientific way, to determine the optimal population distribution in relation to the natural environment, in order to ensure sustainable development and ecological balance, there needs to rely on the combined assessment of settlement conditions from the ecological perspective - model of V.V. Vladimirov is shown in Fig. 6.

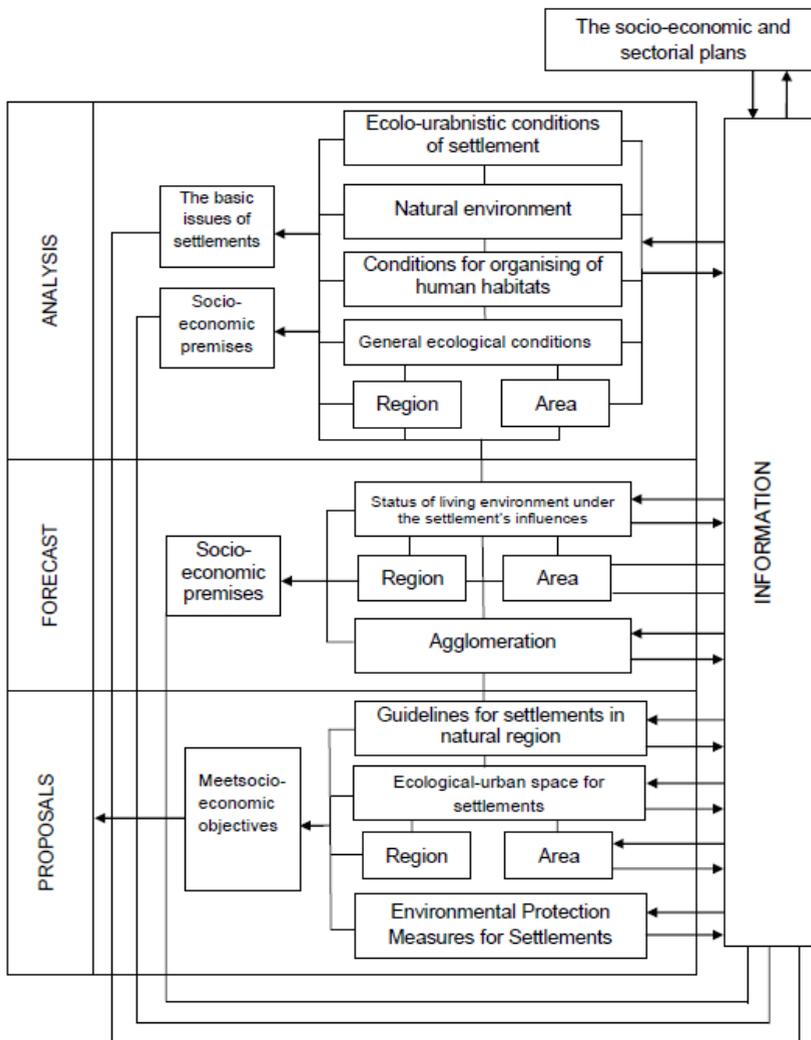


Fig. 6. Comprehensive Assessment model of Urban Ecological Conditions of V. V. Vladimirov [13].

4.3 Zoning the territory according to ecological urban planning conditions and principles of sustainable development of the system of settlements in the Mekong Delta

4.3.1 Zoning of territories according to ecological conditions - urban planning

Based on the assessment of the ecological conditions - urban planning based on the model of V.V.Vladimirov by overlapping maps according to each group of criteria for general evaluation, it is possible to divide the Mekong Delta into 03 regions according to the level of favourability and adaptability of climate change is as follows: (i) Region I: The area of the Song Hau river basin from Can Tho to My Tho covers an area of 0.96 million hectares, which is favorable for settlement. (ii) Region II: Long Xuyen Quadrangle and West Hau river, of which the Long Xuyen Quadrangle is 0.45 million ha and the western Hau river is 0.65 ha which is less favorable for settlement. (iii) Region III: The remaining area is 2.10 million hectares, of which deep submerged area is about 0.5 million hectares, Ca Mau peninsula is 10 million hectares and coastal area is 0.6 million hectares. These areas are heavily affected by climate change, especially saline intrusion and andalkalinisation in Ca Mau peninsula, coastal flooding and natural disasters; while the Dong Thap Muoi is 0.5m lower than the water level; it is submerged, has been acidic, is not favorable for settlement is shown in Fig. 7.

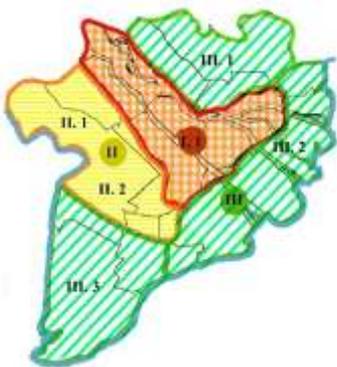


Fig. 7. Zoning of territory according to ecological conditions - urban planning adaptation to climate change of the Mekong Delta [12]



Fig. 8. Sustainable settlement model adaptive to climate change based on public transport [11, 14]

4.3.2 Principles of sustainable development of the system of settlements, adaptation to climate change in the Mekong Delta

Principles :

Building a system based on a backbone of the region is "Corridor Ho Chi Minh City - Can Tho City and Ca Mau City" and 15 axes ribs, connected to the countryside.

Development of public transport direction in the model of urban ecology "compact structure" and TOD.

Connecting the Mekong Delta with the South East and countries in the Mekong river basins, facing the sea; "Replace dependency on Ho Chi Minh City by sharing, supporting the mutual development".

Unified regulation of urban growth through: (i) Integrated system of infrastructure on 16 population distribution axes; (ii) enhancing pendulum traffic; (iii) jointly exploitation of the resources in the Region; (iv) Effective sharing, risk of population boundaries.

Establishment of a green belt, "Adaptation belt, corridor" from Ca Mau Peninsula, Coastal Zone, Dong Thap Muoi, where rural population is located, associated with 03 ecological agriculture zones [15].

Measures to adapt to climate change of settlements (Table 3).

Table 3. Measure to adapt to climate change of settlements.

No	Regions	Land		Popula tion %	Favor a- bility	Solutions to adapt to climate change
		Million hectares	%			
I	Center of Tien River, Hau River and route 1A	0,96	23.6	44	I	-Protect fresh water resources; - Economical use of land; -Development of the ecological agriculture; -Apply the Eco2 City model; -Modernise infrastructure.
II	Long Xuyen Quadrangle and West Hau River	1.10	27.1	20	II	-Treatment of alum; floods and natural disasters; -Adaptive agricultural production; - Resettlement; - Afforestation; - Eco city model.
III	The Ca Mau Peninsula, the coastal area and Dong Thap Muoi	2.1	49.3	36	III	-Treatment of salinity intrusion, erosion, natural disasters; -Transformation of production into ecology and adaptation; -Reduce population concentration; - Development of mangroves.
	Total	4.06	100	100		

5 Conclusion

The Mekong Delta is one of the four deltas of Vietnam that are deeply impacted by climate change: rising sea levels causing temperature, natural disasters and salinity intrusion, etc. which have a great impact on socio-economic development, environmental protection, especially the issue of future population distribution. This conference paper has studied the scenarios of climate change; assessed the impacts of climate change on the conditions of settlement in the Mekong Delta; at the same time reviewed some planning solutions applied

to respond to climate change; On that basis, the Mekong Delta has been divided into 3 regions according to the eco-urbanistic conditions, while also introducing conceptions and solutions to restructuring the sustainable residential development system in response to climate change.

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