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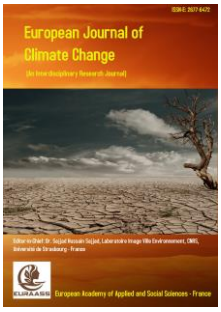

Research Article

Impact of climate change on the environmental security of the Mekong Rever Delta area

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Abstract

Affected strongly by climate change, Mekong Delta faces lots of challenges in the development process. By means of inheritance, synthesis and statistics, and sociological investigation methods, the article has figured out that Mekong Delta is a vulnerable area due to climate change and exogenous factors, such as water security; environmental pollution; degradation of forest resources and biodiversity. It is necessary to establish a long-term framework for climate change adaptation and national security towards sustainable development.

Keywords: Mekong Delta, climate change, adaptation, water security, degradation, biodiversity.

1. Introduction

The Mekong Delta (MD) locates in southwestern of Vietnam where the Mekong River approaches and empties into the sea. It has 3 sides of East, West, and South that connect to the East Sea and the South West Sea with 700km coastline and a dense river (Ministry of Natural Resources and Environment, 2017). It includes 13 provinces and cities under central, with the total area of 4.08 million hectares and the population is about 17.8 million. This area plays a significant important role in both geographic and economic of Vietnam (General Statistics Office of Vietnam, 2018).

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Being a region with many advantages and potentials for development, the Mekong Delta currently faces many challenges in the development process. It is one of the three deltas in the world most affected due to climate change (World Bank, 2007). It has been observed that climate change makes serious impacts in this area. According to updated meteorological and meteorological data in the Mekong Delta 2014 of the Ministry of Natural Resources and Environment, the climate parameters such as temperature and the precipitation in MD have visual impacts on the area. From 1958 to 2014, the average temperature has risen about 0.5°C, the amounts of rain are different in different areas of the MD every year. The rainfall in most areas has increased from 5 to 20%. However, this parameter in some areas has decreased by 0-10% in Ca Mau and 10-20% in Phu Quoc islands (Ministry of Natural Resources and Environment, 2017). Moreover, because of its geographical location, MD is affected of both climate change and activities for water usage of upstream nations. The data from 1996 to 2016 shows the flows of the Mekong River have decreased in both flood season and dry season. The total volume of water flow into the MD decreases every year (about 1.87 billion m^3 in the flood season and 0.18 billion m^3 in the dry season). The average volume flow per year is only about 75-90% comparing to the data from the past 2015-2016 (Department of Water Resources Management, 2017) due to abnormal weather, climate change and salinization, the decrease in water flow from the upstream, 13 provinces of MD had faced severe drought and saline intrusion, which is one of the most serious droughts within 100 years of Vietnam. Estimating about 160 thousand hectares of paddy was seriously damaged and about 800 thousand tons of paddies of MD were lost in the drought season. The damage is estimated about thousand billion VND in 2016 (General Statistics Office of Vietnam, 2016).

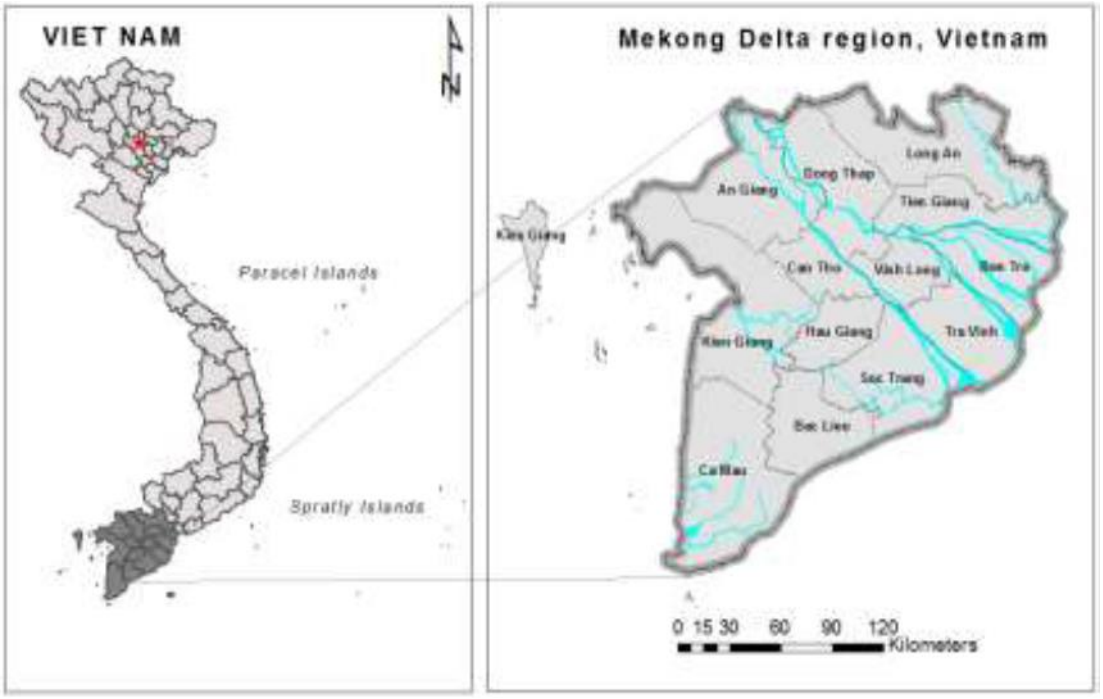


Figure 1: The Area of Mekong Delta.

Climate Change and other impacts from economic development activities both endogenous and exogenous in the region are creating challenges to the MD. Due to being one of the largest granaries of Vietnam, it has a critical position in economic development. It also plays an important role in ensuring national food security.

National security (NS) is a political-legal concept, expressing the nature of the social regime of a country. In Vietnam, the 2004 National Security Law defined “national security is the stability, sustainable development of the socialist regime and the Socialist Republic of Vietnam, the inviolability of independence, sovereignty, unity, territorial integrity of the Land (National Assembly of the Socialist Republic of Vietnam, 2004). The basic content of NS is to protect national interests and eliminate threats to those interests. National security covers traditional security and non-traditional security. Depending on the context and time, challenges of security or

security arise to threaten national security. In the current context, due to the sharp development and the globalization trend, the national security problem is not only limited to preventing and responding to war risks but also involving many Security issues such as climate change, pollution, environmental degradation, depletion of water resources, terrorism, epidemics, transnational crimes, high-tech crimes, etc. Currently, many domestic and world scholars have agreed on the viewpoint on the relationship between national security and environmental security, because intrinsically, security is a component of the security program, a structural component into NS, besides political security, economic security, cultural security. Depending on the context of each country and each stage of development of history, the position and role of security in the NS have changed. But overall, in the world and Vietnam, the position and role of environmental protection are increasingly playing an important role. Studies have been consistent in identifying the major environmental security issues facing the world, including the impact of global climate change, which emphasizes the greenhouse effect causing warming. Global; risk of water and destruction of marine resources; destruction and damage of the ozone layer; land desertification phenomenon; destructive forest flora; biodiversity declines and acid rain problem. In the same trend, at present, Vietnam is also facing many urgent threats to address, such as climate change; security of water sources and security of the marine environment are threatened; pollution in key areas and cross-border pollution cannot be controlled; degradation of forest resources and biodiversity, never has environmental issues been posed to all humanity as urgent today.

Environmental security is an inseparable element of national security. Therefore, the systematic and comprehensive research and evaluation to fully identify weaknesses, opportunities, and challenges develops models and appropriate solutions to be proactive and flexible. Facing with abnormal fluctuations to ensure the security of the region is extremely necessary and urgent today. This study aimed to analysis the impacts of climate change on environmental security in the Mekong Delta.

2. Methodology

In order to make the overal link between climate change and it threats to MD area, this study used synhesis of several method as following:

2.1 Inheritance method

Selectively acquiring and inheriting research documents of domestic and foreign organizations that have published issues on environmental protection, climate change and Mekong Delta of World Bank, IMHEN, IPONRE, IPCC , MONRE serves the purpose of the article;

2.2 Methods of synthesis and statistics

Use to synthesize, statistic and analyze information database from sociological questionnaires; Socio-economic data, hydrometeorology, environment, and climate change, Reports of localities serving the process of assessing the status of the issue of environmental protection in the Mekong Delta;

2.3 Methods of sociological investigation

Gathering information and opinions of state management agencies and local environmental management officials to get practical views on issues: Current situation of environmental issues The school is happening in the locality, causes and limitations, the difficulties in policies and coping solutions that localities in the Mekong Delta are facing in order to analyze and propose appropriate solutions.

3. Results and Discussion:

3.1. Climate change evidences in the Mekong Delta

As mentioned above, the Mekong Delta is rated as one of the world's three most vulnerable deltas due to climate change and sea-level rise. Under the scenario of climate change and sea-level rise of Vietnam (Ministry of Natural Resources and Environment, 2016). Climate change will cause changes in temperature, rainfall and sea-level for the Mekong Delta as follows:

3.1.1 Average temperature and extreme temperature increase

According to the average RCP4.5 scenario, the average annual temperature in the Mekong Delta region tends to increase compared to the average in the baseline period (1986-2005), the increase in the middle of the century is about 1.4^{o}C (0.9 ÷ 2), first); by the end of the period, it will increase about 1.8^{o}C (1.2 ÷ 2.7). According to the high RCP8.5 scenario, in the middle of the century, it will increase about

1.9°C (1.3 ÷ 2.7); By the end of the century, it will increase about 3.4°C (2.6 ÷ 4.6). Regarding the extreme temperature, according to RCP4.5 scenario, by the end of the 21st century, the average annual maximum and minimum temperature tends to increase from 1.9 to 2.1°C. Under the high RCP8.5 scenario, the increase could reach 3.8°C. In the middle of the 21st century, the number of hot days (the highest temperature day Tx ≥ 35°C) tends to increase from 20 to 40 days compared to the baseline. By the end of the 21st century, the number of hot days increased to 40 to 60 days.

3.1.2 Annual rainfall and extreme rainfall change

According to the average RCP4.5 scenario, annual rainfall tends to increase. Mid-century increased by 8.8-20.6%, by the end of the century increased by 9.6-21.2%. According to the high RCP8.5 scenario, in the middle of the century, it increased by 10.8-18.3%, by the end of the century, it increased by 12.6-22.7%. The largest daily rainfall and the largest 5 days are both expected to increase in the 21st century under the medium and high scenarios. By the end of the 21st century, under the RCP4.5 average scenario, the increase of the largest 1-day rainfall and the largest 5-day rainfall could increase by 40-80%. The rainfall in winter and spring tends to decrease and the increase in temperature causes evaporation to rise, leading to more serious drought risk in the winter and spring months in the Mekong Delta.

3.1.3 Sea levels change

Sea level rise scenarios show that, in general, climate change will make the sea-level rise in the western coastal area of the Mekong Delta a little higher than the eastern region.

Table 1: Sea level rise in the eastern coastal area of the Mekong Delta (Unit: cm). Source: Ministry of Natural Resources and Environment, 2016).

Scenarios RCP	**Timeline of the 21st Century**							
	2030	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
RCP 2.6	12 (7 ÷ 19)	17 (10 ÷ 25)	21 (12 ÷ 32)	26 (15 ÷ 39)	30 (18 ÷ 46)	35 (20 ÷ 52)	39 (23 ÷ 59)	44 (26 ÷ 66)
RCP 4.5	12 (7 ÷ 18)	17 (10 ÷ 25)	22 (13 ÷ 32)	28 (17 ÷ 40)	33 (20 ÷ 49)	40 (24 ÷ 58)	46 (28 ÷ 67)	53 (32 ÷ 77)
RCP 6.0	11 (7 ÷ 16)	16 (10 ÷ 23)	21 (14 ÷ 31)	27 (18 ÷ 39)	34 (22 ÷ 48)	41 (27 ÷ 58)	48 (32 ÷ 69)	56 (37 ÷ 81)
RCP 8.5	12 (8 ÷ 17)	18 (12 ÷ 26)	25 (16 ÷ 35)	32 (21 ÷ 46)	41 (27 ÷ 59)	51 (33 ÷ 73)	61 (41 ÷ 88)	73 (48 ÷ 105)

Table 2: Sea level rise in the western coastal area of the Mekong Delta (unit: cm). Source: Ministry of Natural Resources and Environment, 2016).

Scenarios RCP	**Timeline of the 21st Century**							
	2030	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
RCP 2.6	13 (8 ÷ 19)	17 (10 ÷ 26)	22 (13 ÷ 33)	27 (16 ÷ 40)	31 (19 ÷ 47)	36 (22 ÷ 54)	41 (25 ÷ 61)	45 (27 ÷ 68)
RCP 4.5	12 (7 ÷ 18)	17 (10 ÷ 25)	23 (14 ÷ 32)	28 (17 ÷ 40)	34 (21 ÷ 49)	41 (25 ÷ 58)	48 (29 ÷ 68)	55 (33 ÷ 78)
RCP 6.0	11 (8 ÷ 16)	16 (11 ÷ 23)	22 (15 ÷ 31)	28 (19 ÷ 40)	35 (23 ÷ 49)	42 (28 ÷ 59)	50 (33 ÷ 70)	58 (39 ÷ 82)
RCP 8.5	12 (9 ÷ 17)	18 (13 ÷ 26)	25 (17 ÷ 35)	33 (23 ÷ 47)	42 (29 ÷ 59)	52 (36 ÷ 73)	63 (44 ÷ 89)	75 (52 ÷ 106)

Sea level rise can make coastal areas often flooded. Depending on the sea level rise scenario, the percentage of flooded area in the Mekong Delta at the end of the century is: If sea level rise 50cm, 60cm, 70cm, 80cm, 90cm and 100cm, the corresponding flooded area is 4.48%, 8, 58%, 14.7%, 21.0%, 28.2%, and 38.9%. Agricultural production will be affected due to inundated areas due to floods, tides and prolonged flooding. If the sea level rise of 100 cm will affect 38.9% of the Mekong Delta's land area, the most affected provinces are Hau Giang (80.62%) and Kien Giang that of 76.9% (Ministry of Natural Resources and Environment, 2016).

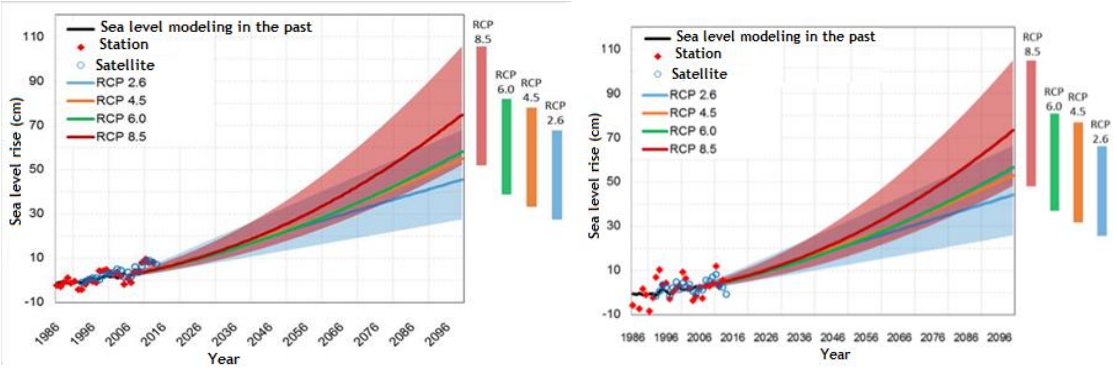


Figure 2: Sea-level rise scenario in the Mekong Delta: (a) Eastern coastal region; (b) Western coast region. Source: Advisory Council of National Committee on Climate Change (2017).

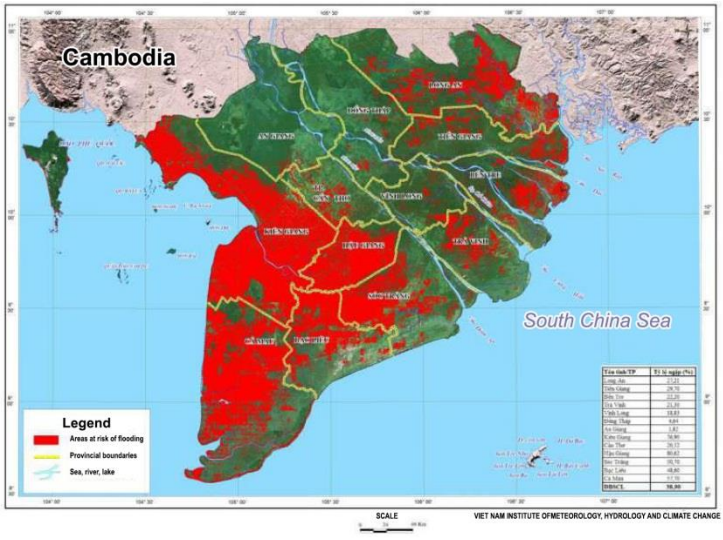
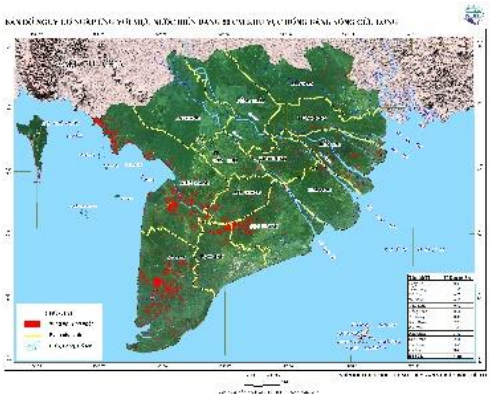
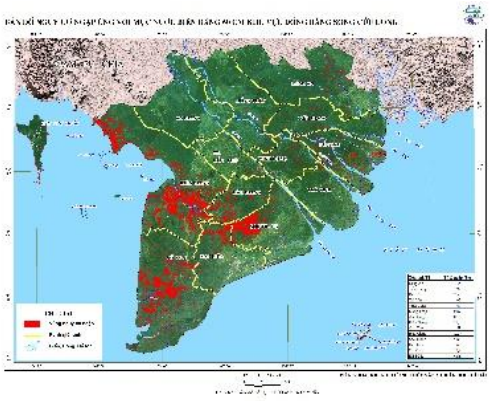


Figure 3: The risk of flooding in the Mekong Delta corresponds to a sea level rise of 100cm.

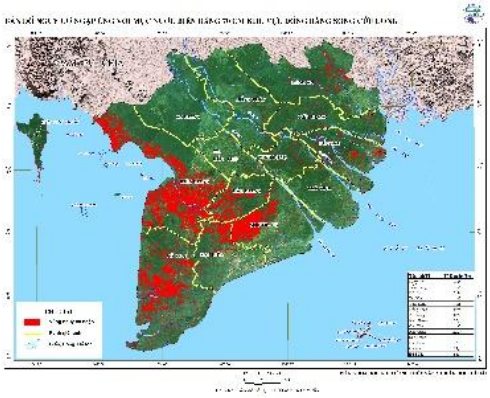
- Storms and extreme weather events: According to the climate change scenario, in the East Sea, the number of weak and medium storms tends to decrease while the number of strong to very strong storms tends to increase significantly. Storms and tropical depressions tend to move to the south and may have significant impacts on the MD. The risk of heavy rain, strong winds during strong storms, super typhoons landing in the MD is as follows: The largest rainfall a day during storms: 300 - 350 mm; The largest three-day rainfall during the storm: 400 - 450 mm; The strongest wind speed in the storm: 45 - 50 m/s (levels 12 - 15). Particularly the southernmost region of the South (Ca Mau, Bac Lieu, Kien Giang, ...) may be at risk of stronger winds than other areas in the region. The area from TP. Ho Chi Minh City to Ca Mau, the highest storm surge has occurred to 2.0 meters, in the future, when the storm is likely to get stronger, the storm surge may reach over 2.7 m. Tide amplitude in this area ranges from 1.8 to 2.0 m (Institute of Hydrology and Meteorology Science and Climate Change, 2016).



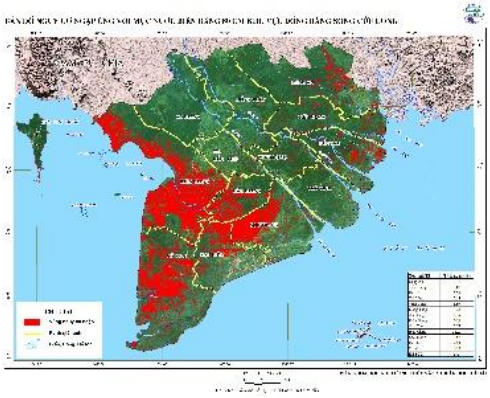
(a) 50 cm



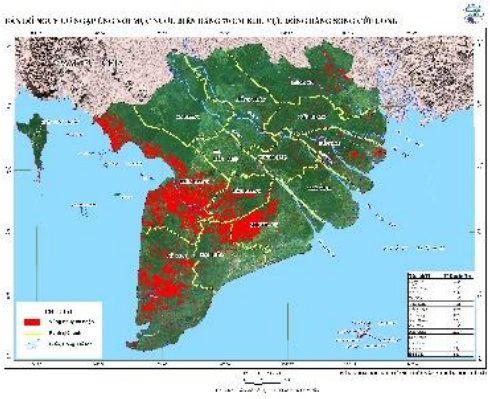
(b) 60 cm



(c) 70 cm



(d) 80 cm



(e) 90 cm

Figure 4: Risk of flooding in the Mekong River Delta with sea level rise of 50 cm (a), 60 cm (b), 70 (c), 80 cm (d) and 90 cm (e).

3.2 Challenges for environmental protection in the Mekong Delta under climate change and sea-level raises situation

3.2.1 The impairement of water, biodiversity impacts on socio-economic due to upstream economic development

Mainstream projects in the Lower Mekong Basin (144 hydroelectric lakes) will cause rapid and significant fluctuations in water levels downstream; causing huge depletion of sediments and disrupting ecological - hydrological seasons. Mainstream projects could result in permanent loss of aquatic and terrestrial biodiversity. About 17% of the wetland area of the Mekong River will be lost and some important species may become extinct. Communities living within 15 km of the Mekong River will be affected by declining fishing and agricultural losses. Climate change will strengthen the impacts on food security caused by mainstream dams, reducing agricultural and fishery products in the context of increased food demand. In addition, in recent years, due to the decrease of alluvium and sand mining has increased the erosion of river banks on the Mekong mainstream and the coast of the peninsula of Ca Mau. In the future, the impact of sediment reduction will be more serious, when all hydropower projects on the mainstream and tributaries of the Mekong are put into operation. The estimated total decrease in sediment is about 75% (Department of Water Resources Management, 2017; Advisory council of National committee on Climate Change, 2017).

3.2.2 Environmental pollution due to population growth

Population growth accompanied by urbanization and industrialization put pressure on agricultural land and infrastructure of the region. According to statistics, in 2018 the Mekong Delta has a population of about 17.8 million people with a density of 440ng / km2, with an estimate of 30 million people by 2050 with a density of 750ng / km^2 (General Statistics Office of Vietnam, 2020. This development about space is not synchronized with the technical infrastructure system (transport, water supply, drainage, solid waste treatment, etc.), leading to increased environmental pollution.ăng.

3.2.3 Increasing riverbank erosion due to the development of industrial and urban areas along the river banks

To attract industrial investment, thousands of hectares of land along Tien and Hau rivers are prioritized for agricultural production, which is planned to be converted into industrial zones (industrial parks). Industrial parks and residential areas along the riverside have soft ground (young sediments) and flood flows with high-velocity increase the erosion of river banks (Ministry of Planning and Investment and World Bank, 2017).

3.2.4 Plain flooding and urban flooding

The statistics show that in 2002, there was a particularly huge flood in the Mekong Delta which is considered to be a record over the past 80 years. Floods in the Mekong River in 2002 were one of the 5 biggest floods in the period of 1961-2004 in terms of total floods and peaks (equivalent to floods in 1966, 1961, 1978, 2000 and 2001).

The flood of 2015 in the Mekong Delta has the highest peaks and volumes for the past 90 years. The total amount of water during the flood season in 2015 was about 220 billion m^3, equaling 50% of the five major floods (400-440 billion m^3) and 60% of the average flood year (350-370 billion m^3). The total volume of temporary floods in all flooded areas in the Mekong Delta in 2015 was less than 2 billion m^3, less than half of the average flood year (4 billion m^3) and 40% of the five major floods (5 billion m^3). Due to low rainfall in 2015, the dry season 2015-2016 dry flow into the Mekong Delta is very low (from 7,000 to 200 m3 / s, equal to 20-30% of the annual supplement). With such a flow decline, salinity intrusion in the 2016 dry season has been the most severe ever (Nguyen Ngoc Anh, 2016.

Along with the increase of floods and storms due to climate change, urban flooding in the Mekong Delta is increasing. This is partly due to more extreme rainfall and urban concrete loss of water storage areas and suburban areas.

3.2.5 Saline intrusion increases

Saline intrusion in the Mekong Delta tends to increase both in frequency and frequency. Sea level rise will increase saline intrusion into the river branches in the Mekong Delta. If the sea level rises by 1 meter, the area affected by the salinity of 4 g / l could increase by 334,000 ha compared to the 2004 level, which is an increase of 25% (MD-ICRSL, 2016).

Under the impact of climate change, saline intrusion process will tend to increase compared to the baseline period. The largest increase in major rivers can be up to about 10 km. The largest 1 mặn saline boundary on the Co Chien River is far from the city. Vinh Long 5 km (saline intrusion is 9.5 km deeper than the baseline period) and on the Hau River through the city. Can Tho 3 km (saline intrusion deeper than the base period 8.8 km). The largest 4 mặn saline boundary on the Co Chien River is far from the city (Ministry of Natural Resources and Environment, 2015).

Figure 5: Mainsteam dams on the Mekong.

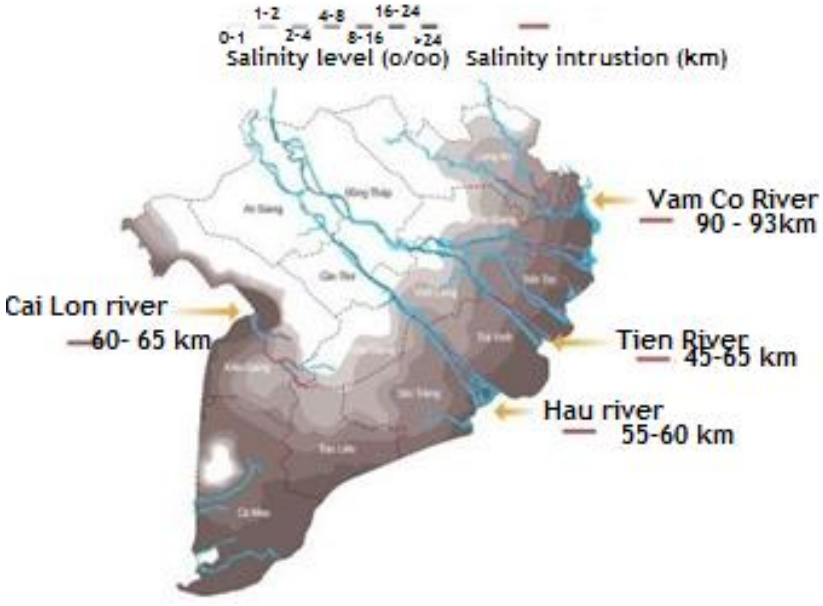


Figure 6: Saline intrusion in the Mekong Delta in 2016.

3.2.6 Increasing coastal erosion due to climate change

The Mekong River Delta has geological features, coastal soil with alternating layers of clay, sand, sand grains due to no cohesive force, in the rainy seasons when the water level is high, landslides occur a little; or very little. Once inundated and in the dry season, the soil structure is weak, in addition to land use activities that increase the load on the shore, it will create a frog-like shape, due to the effects of currents. In the river leading to sudden landslides due to the shear strength of the landmass, landslides occurred in the complex An Giang area in 2016. Currently, the Mekong Delta has about 550 landslides with a total length of approximately 800 km, mainly taking place along Tien, Hau, Vam Co Dong and Vam Co Tay rivers. The severity tends to increase.

Since 2005, the coast of the Mekong Delta has eroded at a rate of about 300 ha/year, occurring mainly along the coast of Kien Giang and Ca Mau. The total area of erosion is 280 km^2 with an average speed of 26-30m /year in which the highest eroded section is 50-67m/year in Bo De estuary area. The impacts of climate change and SLR will increase the risk of coastal erosion, especially in the Cape Ca Mau area, which will become more serious (Institute of Hydrology and Meteorology Science and Climate Change, 2013).

3.2.7 Ecosystem degradation due to climate change and conversion of land use purpose

Climate change with manifestations such as increasing temperature, changing rainfall, changing Mekong river flow, drought, saline intrusion, sea level rise; with significant impacts on the ecosystem and biodiversity of wetlands in the Mekong Delta. In addition, due to the impact of mainstream hydropower on the Mekong River will reduce sediment load, leading to a decrease in the food chain for coastal seafood, the risk of coastal seafood has many unfavorable changes. coastal erosion instead of accretion as before has led to many lost coastal resources such as mangrove ecosystems.

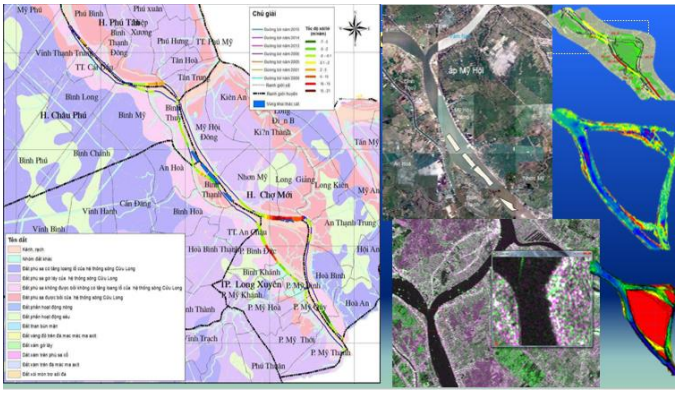


Figure 7: Bank erosion of Hau river and propose a master plan to overcome.

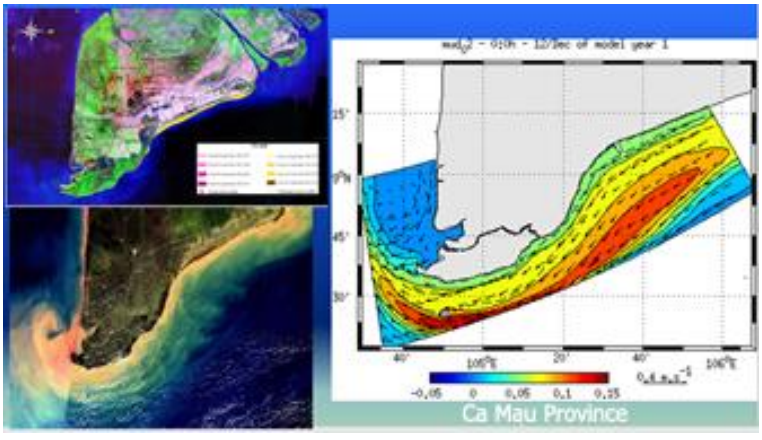


Figure 8 Sediment, erosion in Ca Mau area due to the impact of climate change during 1989-2012. Source: Institute of Hydrology and Meteorology Science and Climate Change (2013).

3.2.8 Subsidence due to groundwater extraction

Currently, the use of groundwater for domestic and production activities in the Mekong Delta is depleting the aquifers especially in Ca Mau peninsula and Ho Chi Minh City area. According to the initial results of a cooperative study between Vietnam and the Norwegian Geotechnical Institute for Ca Mau province, the rate of geological subsidence due to groundwater extraction in Ca Mau is 1.9 ÷ 2.8 cm/year, maximum settlement rate can reach 3.3 cm/year. Hau Giang area has the rate of subsidence due to groundwater extraction of about 3.01-3.3 cm/year and can occur in most areas of the province. For Ca Mau, the area with the highest rate of subsidence is 3.01-3.3 cm/year due to groundwater exploitation with the area at risk of subsidence at this rate of about 38,450 ha (Norwegian Geotechnical Institute, 2013). According to the 2015 test results of the Vietnam Survey and Mapping Department, most subsidence areas of 5cm to 10 cm can be seen, especially in coastal areas of Ca Mau and Bac Lieu with subsidence values above 10 cm in the 2005-2015, in a period of 10 years (Vietnam Department of Surveying and Map, 2016).

The causes of settlement related to the geological elevation (Figure 12) may come from: (i) gradual tectonic movement in the outcrop area before Holocene; (ii) consolidation of young sediment (sediment auto compaction); (iii) groundwater extraction; (iv) human activities (loading of buildings, urbanization, ...), and (v) from the variable of rock. Depending on the geodynamic structure characteristics, these causes may affect different specific areas. According to the results of the General Department of Geology and Minerals of Vietnam, the vertical movement at 5 geodynamic landmarks is the most stable and reliable (A001, A007, A011, A013, A016) in the Mekong Delta region. , the average annual lowering speed is 2.7mm / year, the largest rate of lowering is 19.9mm / year (milestone A014 in Can Gio), the largest ± speed reaches 20.6mm / year (landmark A005 in Hon Dat) (Department of Geology and Minerals of Vietnam, 2015).

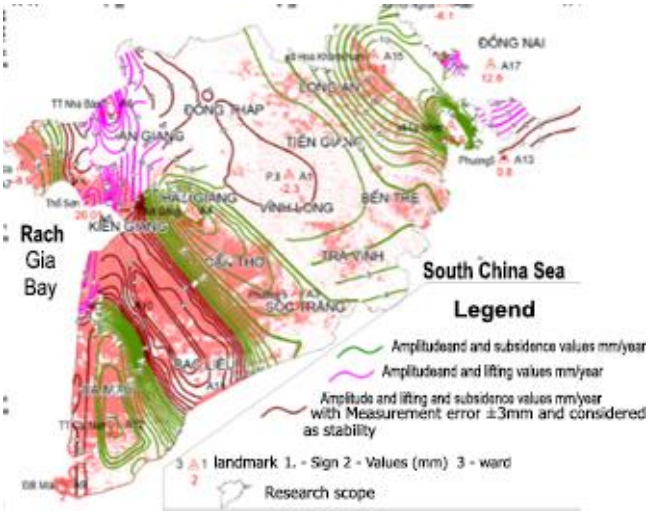


Figure 9: Geological elevation and lowering speed in the Mekong Delta. Source: Department of Geology and Minerals of Vietnam, 2015.

The lack of freshwater in the dry season due to climate change, the operation of the upper water exploitation works will lead to increased use of underground water taken from deep aquifers (> 110m) to supplement fresh water, especially is to control salinity in shrimp farming and to produce fruits and vegetables (both in shrimp and rice farming areas) that will make subsidence and lower the water table becomes more and more serious.

4. Conclusion

Within the scope of this paper, the authors focus on researching the impact of climate change and urgent environmental security in the Mekong Delta. It is demonstrated that MD is vulnerable area due to climate change and exogenous factors. As such, ensuring environmental security in the Mekong Delta means ensuring that there is no major environmental impact on the political, social and economic stability of the region. Means challenges: Climate change; water security; environmental pollution; degradation of forest

resources and biodiversity in the Mekong Delta is addressed. It is necessary to establish a long-term framework for climate change adaptation and national security towards sustainable development

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