



VULNERABILITY TO CLIMATE CHANGE OF MANGROVES IN XUAN THUY NATIONAL PARK, VIETNAM

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ABSTRACT

To quantitatively assess the vulnerability to climate change of mangroves in Xuan Thuy National Park, mangrove cover change, climate change, sea level rise, community awareness and participation in the mangrove protection and rehabilitation were measured, investigated and analyzed. The results confirmed that in recent years mangroves in Xuan Thuy National Park are not very vulnerable to climate change. For instance the mangrove area has increased of about 600 ha mangroves in the period 1995-2010 and the sedimentation rate (10.4 mm/year) is much greater than the rate of sea level rise (1.9 mm/year). This is explained that Xuan Thuy National Park has good management mechanism with the participation of many stakeholders, especially the active participation of communities in the buffer zone in mangrove protection and rehabilitation. The results also indicated that mangroves in Xuan Thuy National Park could be more vulnerable to climate change in the future due to decrease of afforestation projects and the failure of landward, seaward transgressions caused by seafood aquaculture and seaward margin erosion.

Keywords: vulnerability, climate change, mangroves, Xuan Thuy national park.

INTRODUCTION

Climate change, specifically global warming, precipitation change and sea level rise, is great threat which mangroves are facing. Climate change is likely to impact on the survival and development of mangroves, largely through its effect on the sedimentation, erosion, salinity, and tidal inundation frequency, interval and depth [1].

Vulnerability to climate change of mangroves depends on the nature, magnitude, extent of climatic changes, other pressures caused by climate change, and sensitivity and adaptive capacity of mangroves. The vulnerability could be increased due to the great effects of climate change on mangroves and weak adaptability of mangroves to climate change.

Vietnam is one of the countries most severely affected by climate change. In recent years, the consequences of climate change are considered to be fierce, serious and impacting on the survival and development of natural ecosystems, including coastal mangrove ecosystem [2].

Xuan Thuy National Park was established on January 02, 2003. It was approved as the first Ramsar site of Vietnam in January 1989. Xuan Thuy National Park is known for its hundreds of hectares of mangroves with high biodiversity and an important role in providing coastal protection and livelihoods for communities in the buffer zones. However, mangroves in Xuan Thuy National Park are now under tremendous pressure from climate change.

In order to enhance the adaptive capacity to climate change of mangroves in Xuan Thuy National Park as well as those in other coastal wetland ecosystems in Vietnam, a number of studies assessing the vulnerability of Xuan Thuy National Park have been conducted [3]. However, this study is the first to assess the vulnerability to climate change of mangroves in Xuan Thuy National

Park basing on the integrated assessment of climatic factors affecting mangroves, mangrove cover change, climate change, sea level rise, community awareness and participation in the mangrove protection and rehabilitation.

MATERIALS AND METHODS

Study site

Xuan Thuy National Park has a core area of about 7,100 ha and the buffer zone area of approximately 8,000 ha in 5 communes: Giao Thien, Giao An, Giao Lac, Giao Xuan and Giao Hai (Figure-1). Xuan Thuy National Park is a silt-rich, wide tidal flat and suitable for mangrove trees which are mostly *Kandelia obovata* (L.) Druce, *Aegiceras corniculatum* (L.) Blanco, *Sonneratia caseolaris* (L.) Engl., *Bruguiera gymnorhiza* (L.) Lam. and *Avicennia marina* (Forsk) Vierh.

Data collection

Mangrove cover change: Satellite images (Landsat and SPOT) for the Xuan Thuy National Park in 1995 and 2010 were acquired through Department of Remote Sensing and GIS (Forest Resources and Environment Center, Forest Inventory and Planning Institute) to map recent and historical mangrove area coverage. An analysis of individual images was then undertaken and mangrove cover change was estimated through an overlay methodology using ArcGIS 9.x software.

Climate change and sea level rise: Temperature, rainfall and sea level data in the study area from 1990 to 2010 provided by Hydrometeorological Data Center (Ministry of Natural Resources and Environment) was analyzed for the temperature, precipitation change and sea level rise.

Sedimentation rate: The bamboo stakes approach was used to measure the sedimentation rate. We



established four transects (Figure-1), then selected three locations (A, B and C) per transect for sedimentation rate measurement. At each location, we put into the mud three sedimentation stakes, spaced 1 m apart by pushing each stake into the mangrove substrate so that 30 cm of the stake is sticking out of the sediment surface. Then we measured the height from sediment surface to the top of each sedimentation stakes. These works were done in October 2013. Remeasurements were done two times, in March 2014 and August 2014. The sedimentation rate was calculated from the values of height changes.

Community awareness and participation in mangrove conservation: We conducted the direct observation and interview of 100 people in 4 communes closed to the study site (Giao Thien, Giao Xuan, Giao Lac and Giao An) with constructed questionnaire. The questionnaire contained both closed- and open-ended

questions and composed of basic information about socio-economics, uses of mangrove, attitude toward mangrove conservation and participation in mangrove conservation.

RESULTS AND DISCUSSIONS

Mangrove cover change

Satellite images analysis indicates that mangrove area of Xuan Thuy National Park increased by approximately 600 ha (985 ha in 1995 and 1586 ha in 2010). The mangrove area in the North of Ngan bar decreased because a large area of mangroves have been converted to shrimp, clams ponds while in the South of Ngan and Lu bars (belonging to Giao An, Giao Xuan and Giao Lac), hundreds of hectares of mangroves was planted by local communities with supports from domestic and foreign agencies and institutions (Figure-1).

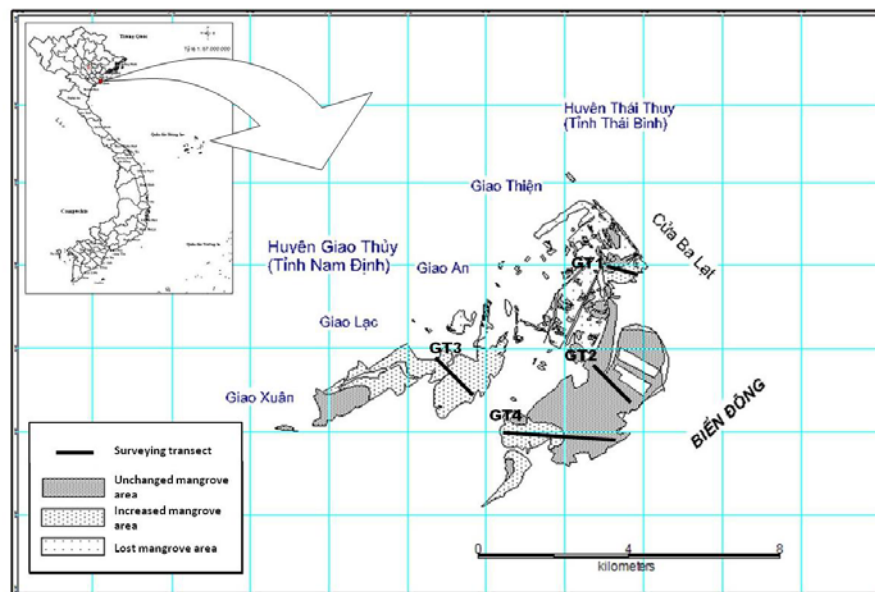


Figure-1. Change of Mangrove spatial distribution from 1995 to 2010.

The increase and expansion of mangrove area contributed to demonstrate that the vulnerability to climate change of mangroves in Xuan Thuy National Park is relatively low, which means mangroves are resilient to climate change.

However, according Van Maren [4], the coastline in the area of Xuan Thuy National Park was unstable because erosion and sedimentation occurred intensively in this area (Figure-2). This could significantly affect the mangrove development and distribution. On the other hand, results from field survey also showed that the vulnerability to climate change of mangroves in Xuan Thuy National Park can increase in near future due to the serious impacts and pressures from local people, environmental and climate change. The increase of vulnerability could be expected through the observations of seaward margin erosion and rapid development of

aquaculture in landward margin which prevent mangrove expansion (Figure 3(a), 3(b)).

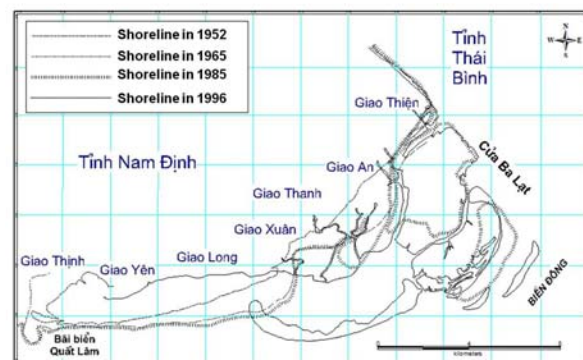


Figure-2. The shorelines of Xuan Thuy National Park from 1952 to 1996 (Edited from Van Maren [4]).

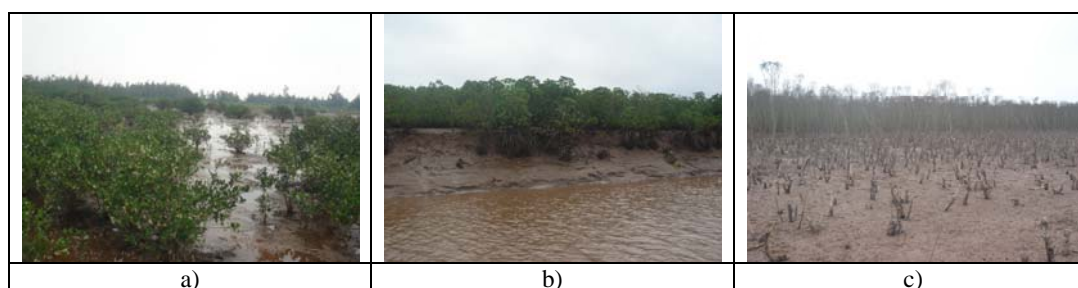


Figure-3. Mangroves in Xuan Thuy National Park: a) degradation due to rapid sedimentation; b) seaward margin erosion; c) illegal deforestation

Trends of climate change and sea level rise

Analysis of climate data back to the 1970s shows that in the coastal area of Nam Dinh province, including Xuan Thuy National Park, the temperature is increasing at a rate of about $0.013^{\circ}\text{C}/\text{year}$ (Figure-3a) and the precipitation is reducing at a rate of $4.145 \text{ mm}/\text{year}$

(Figure-3b). The temperature increases and precipitation decline could produce drier condition thereby reducing productivity and biodiversity. Some species such as *Sonneratia caseolaris* (L.) Engl., *Bruguiera gymnorhiza* (L.) Lam and *Avicennia marina* (Forsk) Vierh are very sensitive to the increased salinity due to dry conditions [5].

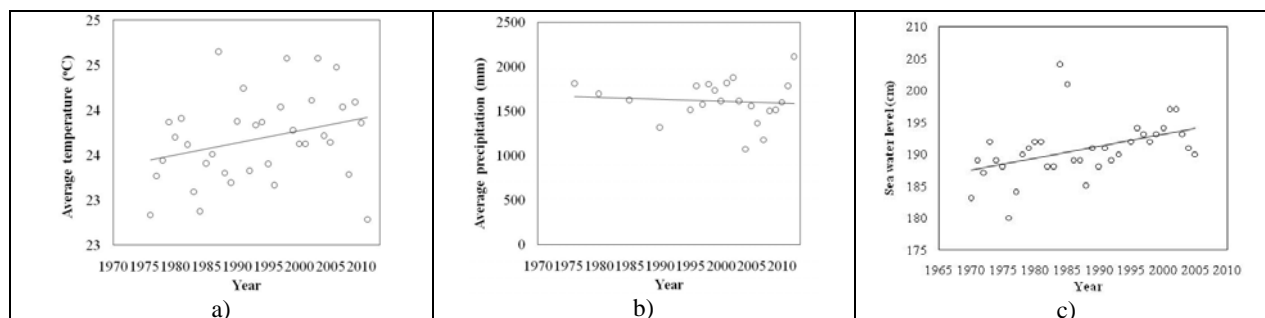


Figure-4. (a) Trends of temperature (b) precipitation (c) and sea level in coastal area of Nam Dinh (Source: Hydrometeorological Data Center).

Analysis of sea level data indicates that sea level at Xuan Thuy National Park is rising at a rate of about $1.9 \text{ mm}/\text{year}$ (Figure-3c). Sea level rise is the result of many natural phenomena such as the thermal expansion of sea water, the loss of land-based ice due to increased melting and so on. Along with increased salinity, sea level rise is also a huge threat to the growth, development and distribution of mangroves, which could increase the vulnerability of mangroves.

Ministry of Natural Resources and Environment (2012) has developed scenarios of climate change and sea

level rise for Vietnam according to scenarios of greenhouse gas emissions: low (B1), medium (B2) and high (A2, A1FI). Scenario B2 is recommended to be used in Vietnam. Accordingly, in 2050 temperature, precipitation changes and sea level rise in the coastal area of Nam Dinh province was 1.2°C , 4.1% and 30 cm respectively. Compared to the period 1980-1999 in 2100 those changes are 2.4°C , 7.9% and 74 cm , respectively (Table-1).



Table-1. Temperature, precipitation changes and sea level rise in comparison to the period 1980-1999 in the coastal area of Nam Dinh according to scenario B2 (Source: MONRE [2]).

Time	Temperature change ($^{\circ}\text{C}$)	Precipitation changes (%)	Sea level rise (cm)
2020	0,5	1.6	12
2030	0,7	2.3	17
2040	0,9	3.2	23
2050	1,2	4.1	30
2060	1,5	5.0	37
2070	1,8	5.9	46
2080	2,0	6.6	54
2090	2,2	7.3	64
2100	2,4	7.9	74

As temperature, precipitation changes and sea level rise have occurred (Figure-4) and the scenarios of changes have predicted (Table-1), the coastal area of Nam Dinh province, including Xuan Thuy National Park, could be heavily impacted hence, threatening the existence and development of mangrove ecosystems. Mangroves are no longer able to develop and expand towards the sea, while theoretically the landward migration can be happened. However the development of seadikes and aquaculture can prevent the landward migration. Therefore, climate change is the factor affecting mangroves; it is also one of the causes of high vulnerability or low resilience to climate change of mangrove in Xuan Thuy National Park.

Sedimentation rate

Sedimentation rate measured at Xuan Thuy National Park from November 2013 to August 2014 was 10.4 mm/year in average (Table-2). However, the rates by seasons and locations were highly variable. In the dry season, the sedimentation rate was 13.2 mm/year, higher than the rate of 8.8 mm/year in the rainy season. This result can be explained by the fact that in the rainy season, this area is affected by strong waves generated from strong winds of tropical cyclones/storms causing more erosion and less sedimentation. On the other hand, Xuan Thuy National Park is located at the south of Red River estuary (Ba Lat Mouth), thus sediment load could be carried by fast moving water in rainy season to farther south of the Park. Therefore, the sedimentation rates measured along the transect GT3 and GT4 were greater than sedimentation rates along the transect GT1 and GT2 (Figure-1, Table-2).

Table-2. Sedimentation rates measured along transect lines in Xuan Thuy National Park.

Measurement location	Sedimentation rate (mm/year)		
	11/2013-3/2014	4/2013-8/2014	Average
GT1-A	1,5	1.1	1,3
GT1-B	2,1	1.8	1,9
GT1-C	2,7	2,3	2,5
GT2-A	4,7	1,5	3,1
GT2-B	20,1	10,7	15,4
GT2-C	7,9	3,3	5,6
GT3-A	12,7	6,3	9,5
GT3-B	51,1	39,7	45,4
GT3-C	5,2	1,8	3,5
GT4-A	4,8	0,6	2,7
GT4-B	32,3	18,5	25,4
GT4-C	13,1	3,1	8,1
Average	13,2	8,8	10,4



The obtained result is consistent with the results of other authors such as Hanh and Tuan [6]; Van Santen *et al.* [7], who studied at the same site, and in accordance with the observations of the role of mangroves in creating favorable conditions for the deposition of organic and inorganic matter.

Sedimentation rate was chosen as one of the criteria for assessing the vulnerability to climate change of mangroves because both the sedimentation rate and the rate of sea level rise restrict the intertidal, thereby affecting the distribution, growth and development of mangroves. At Xuan Thuy National Park, sedimentation rate was higher than the rate of sea level rise (10.4 mm/year and 1.9 mm/year, respectively). That result indicates that mangroves in Xuan Thuy National Park are more keeping pace with sea level rise. This result is also completely consistent with the results of Alongi [8] (Figure-5).

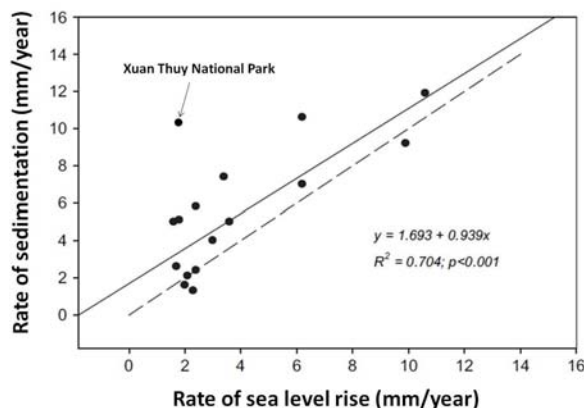


Figure-5. Relationship between sedimentation rate and sea level rise (Editted from Alongi [8]).

Community awareness and participation in mangrove conservation

Result from interviewing 100 people, managers in the buffer zone shows that Xuan Thuy National Park has good protection and management mechanisms with frequent and serious activities of mangrove management, monitoring and protection. The majority (90%) of interviewed people understood the roles of mangroves and benefited directly from the mangroves, thus they consciously protected mangroves and participated in mangrove development and conservation.

However, mangrove protection and development were not really effective, particularly illegal deforestation still occurred (Figure-3c) because the awareness about mangroves of a minority of people was not so good. In addition, the stakeholders such as management board, local people's committees, the women's union, youth union and so on have actively collaborated with each other in the protection and development of mangroves. However the collaboration was not really effective.

The above result confirms the importance of community involvement with the close cooperation of the

local government and organizations in development and protection of mangroves in the context of climate change.

CONCLUSIONS

The study demonstrated the ability to quantify vulnerability to climate change of mangrove ecosystems by analyzing climatic factors affecting mangroves, spatial distribution change, and community awareness and participation in mangrove development and conservation. Mangrove area in Xuan Thuy National Park increased about 600 ha in the period 1995-2010. Sedimentation rate were 10.4 mm/year much higher than the rate of sea level rise (1.9 mm/year). Moreover, Xuan Thuy National Park has good management mechanism with the participation of many stakeholders, including the communities living in the buffer zone, in the mangrove protection and development. The results confirmed that mangroves in Xuan Thuy National Park were less vulnerable to climate change.

The study also indicated that the vulnerability to climate change of mangroves in Xuan Thuy National Park likely increases in the future because the reforestation projects in this area have decreased while natural expansion of mangroves has been limited due to the development of seadikes and aquaculture, and seaward margin erosion.

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