MINISTRY OF RESOURCES AND ENVIRONMENT
**VIETNAM INSTITUTE OF METEOROLOGY, HYDROLOGY AND CLIMATE CHANGE**

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# RESEARCH ON EVALUATING ECONOMIC LOSS BY ECOSYSTEM DEGRADATION IN TERRITORIAL SEA AND ISLAND OF PHU QUOC UNDER THE IMPACT OF CLIMATE CHANGE

Major: Climate change
Code: 9440221

SUMMARY OF DOCTORAL THESIS IN CLIMATE CHANGE

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The thesis is completed at:

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Referee 1: ……

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Referee 3: ……

The thesis will be examined by Examination Board of Vietnam Institute of Meteorology, Hydrology and Climate Change

# INTRODUCTION

## 1. The rationale of the research

Phu Quoc island is located in the Southwest Sea, an area with an important position in terms of national security and great potential for economic development. The sea and island of Phu Quoc is also an area with many potential natural disasters, especially climate change. The complex developments of climate change not only cause anomalies in weather, affecting many aspects of human life, but also negatively impact the ecosystems.

Phu Quoc has a high biodiversity compared to other islands with typical ecosystems such as forests, mangroves, seagrass beds and coral reefs. Climate change will reduce the area and cover of forests as well as the role and function of ecosystems. These ecosystems not only play an important role in regulating the climate but also bring many great values and benefits in terms of socio-economics. However, when the ecosystems in Phu Quoc are degraded due to climate change, it will cause significant losses in the economic value that these ecosystems bring, especially for Phu Quoc which is an island district and also a special administrative-economic zone. Therefore, in order to evaluate the economic losses of typical ecosystems in Phu Quoc due to climate change, the PhD student chooses "*Research on evaluating economic loss by ecosystem degradation in territorial sea and island of Phu Quoc under the impact of climate change*" is the topic of the doctoral thesis.

## 2. The objectives of the research

Assessing economic loss due to ecosystem degradation in Phu Quoc under the impact of climate change based on theory and practice,

thereby proposing solutions to reduce economic loss in this area caused by climate change.

**3. The subjects and scope of the research**

Research Research subjects are economic loss due to ecosystem degradation under the impact of climate change include: direct use values (aquaculture, tourism); indirect use values (protection, $CO_2$ absorption; providing habitat, aquatic seed source); and non-use value.

Research scope:

- Regarding space: territorial sea and island of Phu Quoc.
- Regarding time: from 2018 and forecast to 2050.
- About academic content: Theory of evaluating economic loss caused by climate change is based on the consideration of total economic value.

**4. Research questions**

What problems and challenges have/are/will the ecosystems in Phu Quoc faced/facing/face under the impact of climate change?

How to forecast ecosystem degradation level and evaluate economic loss under the climate change scenario?

What solutions are there to reduce economic loss due to ecosystem degradation under the impact of climate change?

**5. Defensive argument**

Argument 1: The total value of economic loss due to the degradation of ecosystems under the impact of climate change in Phu Quoc can be estimated from the values of the component economic loss (direct use value, indirect use value and non-use value) with the help of highly reliable econometric methods.

Argument 2: It is possible to base on the value of loss due to ecosystem degradation in Phu Quoc under the impact of climate change to have appropriate solutions.

## 6. Research contents

Clarifying the theoretical basis, methods of recession prediction and economic loss assessment of the ecosystem in Phu Quoc.

Forecasting the typical ecosystem degradation level in Phu Quoc (coral, seagrass, mangrove, forest) under the impact of climate change.

Estimating economic loss due to typical ecosystem degradation in Phu Quoc under the impact of climate change.

Proposing solutions to reduce economic loss due to typical ecosystem degradation in Phu Quoc.

## 7. Scientific and practical significance of the research

Scientific significance: The thesis contributes to the theoretical basis for assessing economic loss due to ecosystem degradation under the impact of climate change, specifically the case in Phu Quoc.

Practical significance: The thesis is a reference document on the economic value of loss due to climate change according to the scenario RCP4.5; RCP8.5 to 2050 for management and awareness raising of people, communities, some economic sectors, tourist areas, seafood, conservation in Phu Quoc.

## 8. New contributions of the research

The thesis contributes to building a theoretical basis and evaluation process of economic loss due to the ecosystem degradation under the impact of climate change.

The thesis has predicted the level of ecosystem degradation in Phu Quoc under climate change scenarios.

The thesis has evaluated the economic loss due to the degradation of ecosystems in Phu Quoc under climate change scenarios.

The thesis has proposed solutions to reduce economic loss due to ecosystem degradation under the impact of climate change.

**9. The contents of the research**

Introduction

Chapter 1. Theoretical basis, review of studies on the evaluation of economic loss due to ecosystem degradation under the impact of climate change.

Chapter 2. Approach, research methods and characteristics of the research area.

Chapter 3. Results of the evaluation of economic loss due to the ecosystem degradation in Phu Quoc under the impact of climate change.

Conclusions and recommendations.

# CHAPTER 1. THEORETICAL BASIS, REVIEW OF STUDIES ON THE EVALUATION OF ECONOMIC LOSS DUE TO ECOSYSTEM DEGRADATION UNDER THE IMPACT OF CLIMATE CHANGE

## 1.1. Theoretical basis

### *1.1.1. Some related concepts and terms*

### *1.1.2. The scientific basis of climate change*

*1.1.2.1. Causes of climate change*

Climate change can be caused by natural processes (changing parameters of the earth's orbit; variations in the emission of the sun and the absorption of radiation by the earth; volcanic activity) and human activities cause excessive emission of greenhouse gases into the atmosphere [7].

*1.1.2.2. Manifestations of climate change*

The manifestations of climate change include: The warming of the atmosphere and the Earth; Changes in the composition and quality of the atmosphere are harmful to the habitat of people and organisms on the Earth; Sea level rise due to melting ice; The movement of climate zones persists for thousands of years in different regions of the Earth.

In Vietnam, in the period of 1958-2018, the average temperature tended to increase across the country with an increase of 0.89$^{o}$C; annual rainfall tended to increase slightly by 2.1%. The number of hot days tended to increase across the country. The number of days of intense cold and damaging cold tended to decrease in the northern climates. The number of strong storms tended to increase slightly. Sea level rise in Vietnam's coast at a rate of about 3.6 mm/year [8].

*1.1.2.3. Climate change scenario*

The climate change scenario is developed based on a new approach to emission scenarios, which is Benchmark emissions scenarios or Representative Concentration Pathways (RCP). There are four RCP scenarios as following: RCP2.6, RCP4.5, RCP6.0, and RCP8.5.

### *1.1.3. Theoretical basis for assessing economic losses related to climate change*

*1.1.3.1. Distinguishing between loss and damage*

The UNFCC does not distinguish between “loss” and “damage”, but some scientists have also tried to separate the two concepts. “Loss” refers to an irreversible loss, for example, death from a heat-related disaster or the permanent destruction of coral reefs, while “Damage” is considered as a loss that is can be mitigated or repaired, such as damage to buildings (Boyd et al. 2017).

*1.1.3.2. Economic loss due to climate change*

Economic loss caused by climate change is understood as the loss in quality/quantity of environmental resources, goods and services that cannot be recovered after implementation of mitigation and adaptation measures. Loss may be the result of transient extreme weather events such as storms, floods, droughts, …; or processes that evolve slowly

over time such as temperature rise, sea level rise, saline intrusion, ... Loss and damage to people (such as damage to health, livelihoods, ...) and to natural systems (such as loss of biodiversity, ecosystems...).

*1.1.3.3. Existing approaches to total economic value of ecosystems value*

Gordon (1954), Barbier (1994), Tietenbery (2003) studied the relationship between economic system and ecosystem. From there, it was agreed to divide the total economic value of the ecosystem into two main groups: use values and non-use values.

The formula for total economic value is as follows:

TEV = (UV + NUV) = [(DUV + IUV + OV) + (EV + BV)]

## 1.2. Literature review

### *1.2.1. International study*

*1.2.1.1. The studies about ecosystem degradation due to climate change in the world*

Studies by Dyer (1995), Amthor (1995), Short (1996), Gilman (2007), Inkyin and Su (2014), ... have shown that climate change is one of the important causes of ecosystem degradation. However, most of these studies only focus on analyzing the causes and effects of climate change on ecosystem degradation in general, the extent of impacts of climate change on ecosystem degradation under climate change scenarios has not been assessed.

*1.2.1.2. The studies about the evaluation of economic loss due to ecosystem degradation in the world*

Studies on economic loss assessment and eco-economy calculation have been interested in by scientists and organizations around the world since very early, such as the works of H. Jack Ruitenbeek (1994), Desvousges (1998), Sathirathai and Barbier (2001), ... These studies

have a significant contribution to the management of natural resources & ecosystem environment in countries around the world, but also serve as a diverse reference source for many future studies.

### *1.2.2. Overview of studies in Vietnam*

*1.2.2.1. The studies about ecosystem degradation due to climate change in Vietnam*

The domestic research works of the authors Nguyen Huy Yet (2010), Pham Anh Cuong (2011), Nguyen Dai An (2015), Pham Van Thanh (2015), ... have synthesized research methods, assessment and prediction of ecosystem degradation under climate change scenarios. However, the studies have not been updated according to the latest climate change scenario of the Ministry of Natural Resources and Environment.

*1.2.2.2. The studies about the evaluation of economic loss due to ecosystem degradation in Vietnam*

Some research works Nguyen The Chinh and Dinh Duc Truong (2011), Tran Dinh Lan (2015), Nguyen Ngoc Thanh (2015), Tran Thu Ha (2020), ... have flexibly selected many loss assessment methods and calculated the results in VND. However, studies have not assessed the economic loss of ecosystems associated with climate change scenarios. In Phu Quoc, there is no research on this issue.

## 1.3. Sub-conclusion of chapter 1

Research works in the world have drawn the process of economic evaluation, environmental resources as well as economic damage to ecosystems. In Vietnam, the number of studies assessing economic loss due to ecosystem degradation is still small. New studies are mostly interested in the aspect of ecosystem loss due to environmental

pollution by human exploitation activities, climate change factors are rarely mentioned. In addition, the studíe have not yet assessed the ecosystem economic loss associated with climate change scenarios.

In Phu Quoc, studies on ecosystem degradation have not been updated according to the new scenario. In addition, there are no studies to evaluate the economic loss of the degraded Phu Quoc ecosystems due to climate change.

# CHAPTER 2. APPROACH, RESEARCH METHODS AND CHARACTERISTICS OF THE RESEARCH AREA

## 2.1. Approach

The main approaches being used: Systematic approach, Historical-perspective approach, Market-based approach, Integrated approach, combination of qualitative and quantitative assessments, Approach based on total economic value and total damage value, Approach based on current practice in the study area.

## 2.2. Research methods

### *2.2.1. Method of collecting documents and secondary data*

Collect documents from management agencies such as Kien Giang Department of Natural Resources and Environment, Phu Quoc National Park Management Board, Phu Quoc Marine Protected Area Management Board, Economic Office of the People's Committee of Phu Quoc District and scientific research projects and topics related to the thesis.

### *2.2.2. Methods of fact-finding survey*

The questionnaire survey process is as follows: Constructing survey forms; Organize fact-finding; Processing questionnaires.

### *2.2.3. Consulation with experts method*

Collaborate with experts to develop research content and process collected documents, especially in selecting climate change scenarios, and assessing causes of ecosystem degradation at present and in the future.

***2.2.4. The weighted measurement method predicts the level degradation of ecosystems under the climate change scenario***

The weighted measurement method to forecast the degradation level of the ecosystem based on the current degradation rate includes the following steps: Assessment of the degradation status of the ecosystem; Identify factors causing ecosystem degradation; Determine the weighted scores for the degrading factors; Calculate the level of ecosystem degradation over the forecast time.

***2.2.5. Group of methods to estimate economic loss due to ecosystem degradation***

*a. Market Price Method*

*b. Travel Cost Method*

*c. Contingent valuation Method*

**2.3. Characteristics of the study area - Phu Quoc**

***2.3.1. Characteristics of natural condition***

*2.3.1.1. Geographical location*

Phu Quoc island is located in the Southwest Sea, with an area of 567.88 $km^2$ with a coastline of about 150 km.

*2.3.1.2. Topographical features*

Phu Quoc island has a triangular shape, the terrain is lower from North to South and from West to East with continuous high hills and mountains.

*2.3.1.3. Climatic, hydrological - hydrographic characteristics*

- Climate: tropical monsoon.

- Hydrology: A network of rivers and streams with a length of 281.5km; in which, there are 3 river systems over 10km, 5 stream systems with catchment area over 10km².

- Oceanography: The diurnal tide regime is irregular, the number of days with semi-diurnal tides in the year is very few, the wave regime forms two distinct seasons, the salinity of seawater is 30.3‰.

*2.3.1.4. Features of ecosystems*

- The forest on Phu Quoc island is mainly evergreen forest and melaleuca forest with characteristics of tropical monsoon climate.

- Mangroves have an area of about 17.9 ha, mainly growing on sandy soil and distributed in narrow bands along estuaries and canals with medium to low density. The species composition has 103 species/ subspecies of higher vascular plants. Mangroves are located in Phu Quoc National Park, so it is less prone to degradation [33].

- Seagrass beds with an area about 10,000 ha are commonly distributed in the East and Northwest in shallow water along the island's tidal zone. The composition of seagrasses is quite diverse with 9 species. Seagrass beds are still relatively well maintained with the average coverage of seagrass reaching 54.8%. However, the resources of fish and large benthic animals in the ecosystem decreased, leaving only groups of less value and small size [14], [26].

- Coral reefs are distributed in the south of An Thoi archipelago and the northwestern islands with an area of 473.9 ha. The composition is diverse with 260 species. The status of coral reefs is still relatively well maintained with an average coverage of live coral reaching 49.3%. However, the resources of fish and large benthic

animals in the ecosystem are exhausted, the rest are groups of little value and small size [14], [26].

*2.3.1.5. Characteristics and trends of climate factors in Phu Quoc*

In the period 1979-2018, the temperature tends to increase at a rate of about 0.02$^{o}$C/year, the average annual rainfall tends to decrease at the rate of 0.9mm/year. The average temperature in Phu Quoc is about 27.5$^{o}$C; annual rainfall is about 2,831 mm. In recent years, the temperature is higher than the average of many years and the rainfall is lower than the average of many years [36].

Climate change scenario for Phu Quoc:

- Temperature: According to the RCP4.5 scenario, the average annual temperature will increase by 1.2 $^{o}$C at the middle of the century and 1.7 $^{o}$C at the end of the century. According to the RCP8.5 scenario, the average annual temperature will increase by 1.5$^{o}$C at the middle of the century and 3.2$^{o}$C at the end of the century [36].

- Annual rainfall: According to the RCP4.5 scenario, the annual rainfall will increase by 6.7% at the middle of the century and 12.8% at the end of the century. According to the RCP8.5 scenario, the annual rainfall will increase by 12.2% at the middle of the century and 16.5% at the end of the century [36].

- Sea level rise: At the middle of the century, Phu Quoc will have sea level rise under the RCP4.5 and RCP 8.5 scenarios of 23 cm and 28 cm, respectively. In Phu Quoc, the risk of flooding due to the impact of sea level rise and climate change will also increase. In the scenario RCP4.5 in 2050, the risk of flooding is about 391.88 ha (about 0.68% of the area). In the scenario of RCP8.5 in 2050, the risk of flooding is about 434.63 ha (about 0.76% of the area) [36].

### *2.3.2. Socio-economic characteristics*

*2.3.2.1. Infrastructure and population*

By 2018, the island's population is over 125 thousand people, with an average density of 211 people/km². There are 60,117 workers with age from 15 to higher, accounting for 48% of the population [9].

The infrastructure is developed synchronously and modernly with a full system of electricity, water, traffic, and healthcare.

*2.3.2.2. Current status of economic development*

Phu Quoc's economy in recent years has grown quite stably with a fairly high speed. The structure of the economy has been shifting in a positive direction, gradually promoting the strengths of key manufacturing industries such as industry, fisheries, and tourism, etc.

## 2.4. The process of assessing economic loss due to degradation of typical Phu Quoc ecosystems under the impact of climate change

The assessment of economic loss due to the ecosystem degradation of in the context of climate change is based on two states: the economic value of the ecosystems at the present time (when the ecosystems are being developed stably) and the economic value of the ecosystems at the time of degradation in respect to climate change scenarios. Loss can be calculated as a percentage of the loss of economic value of the ecosystem due to area degradation (equivalent to % of the area of typical ecosystems that are degraded).

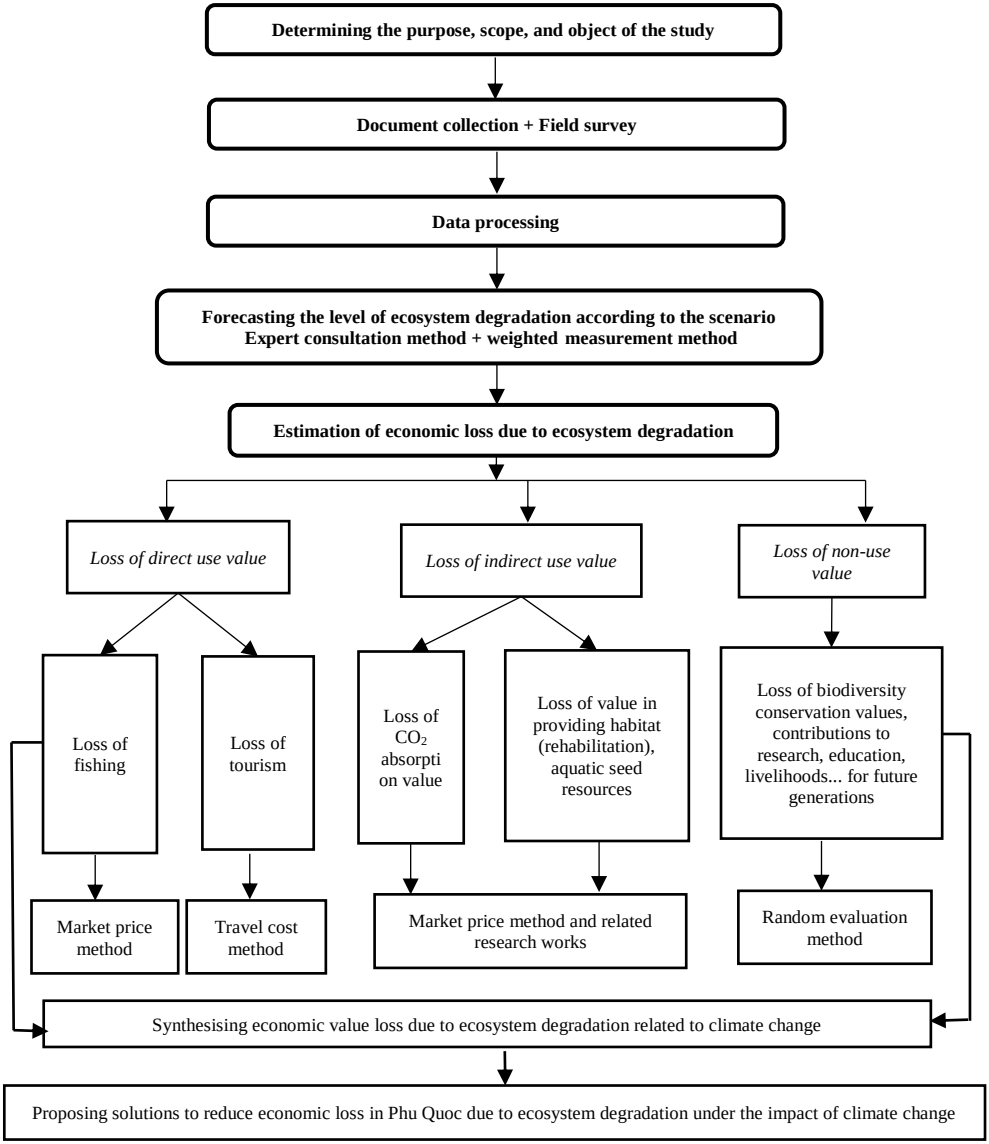


*Figure 2.3. Logical framework of the thesis to assess economic loss due to degradation of typical ecosystem in Phu Quoc under the impact of climate change*

## 2.5. Sub-conclusion of chapter 2

In this chapter, the author has shown the approach of the thesis. On the theoretical basis, the author selected the methods used to estimate the loss due to the ecosystem degradation in Phu Quoc under the impact of climate change. The prediction of the degradation level of the ecosystem is carried out by weighted measurement method and expert consultation. Calculation methods to estimate economic loss due to the ecosystem degradation in Phu Quoc under the impact of climate change include: market price method, tourism cost method, replacement cost method, market method and related research works, random evaluation method. Thereby, the author also builded a process to evaluate economic loss due to the ecosystem degradation in Phu Quoc under the impact of climate change.

# CHAPTER 3. RESULTS OF THE EVALUATION OF ECONOMIC LOSS DUE TO THE ECOSYSTEM DEGRADATION IN PHU QUOC UNDER THE IMPACT OF CLIMATE CHANGE

## 3.1. Forecasting the ecosystem degradation level in Phu Quoc under the impact of climate change

### *3.1.1. Forecasting the forest ecosystem degradation level in Phu Quoc according to the climate change scenario*

According to the author's assessment, based on the forest status in Phu Quoc, combining with expert consultation about the causes of forest degradation and scores for each cause corresponding to the climate change scenario, the author predicted the forest degradation level as follows: According to the RCP4.5 scenario, the forest will be degraded by 15.36%, of which climate change factor accounts for 1.92%. According to the RCP 8.5 scenario, the forest will be degraded by 17.28%, of which climate change factor accounts for 3.84%.

### *3.1.2. Forecasting the level of mangrove ecosystem degradation in Phu Quoc according to the climate change scenario*

According to the research of Pham Anh Cuong and Do Cong Thung [14], combining expert consultation about the causes of mangrove degradation and scores for each cause corresponding to the climate change scenario, the author predicted the mangrove degradation level as follows: According to the RCP4.5 scenario, mangrove will be degraded by 19.2%, of which climate change factor accounts for 6.4%. According to the RCP 8.5 scenario, mangrove will be degraded by 22.4%, of which climate change factor accounts for 9.6%.

### *3.1.3. Forecasting the seagrass bed ecosystem degradation level in Phu Quoc according to the climate change scenario*

According to research by Pham Anh Cuong and Do Cong Thung [14], Nguyen Van Long [26], combining expert consultation about causes of seagrass bed degradation and scores for each cause corresponding to the climate change scenario, the author predicted the seagrass bed degradation level as follows: According to the RCP4.5 scenario, seagrass will be degraded by 16.8%, of which climate change factor accounts for 4.8%. According to the RCP8.5 scenario, seagrass will be degraded by 21.6%, of which climate change factor accounts for 9.6%.

### *3.1.4. Forecasting the coral reef ecosystem degradation level in Phu Quoc under the climate change scenario*

According to the research of Pham Anh Cuong and Do Cong Thung [14] combining with expert consultation about the causes of coral reef degradation and the score for each cause corresponding to the climate change scenario, the author predicted the coral reef

degradation level as follows: According to scenario RCP4.5, coral reef will be degraded by 21.12%, of which climate change factor accounts for 3.84%. According to the RCP8.5 scenario, coral reef will be degraded by 24.96%, in which climate change factor accounts for 7.68%.

## 3.2. Economic loss due to ecosystem degradation in Phu Quoc under the impact of climate change

### *3.2.1. Economic loss of fishery direct use value*

The fishery direct use value in Phu Quoc is 2,351,042 billion VND/year. From the results of forecasting ecosystem degradation under climate change scenarios, the study has estimated the loss of economic value of fishery as follows:

(1) In the RCP4.5 scenario in 2050, the area of seagrass bed will be degraded to 4.8%; coral reef will be degraded to 3.84%; on average, the entire area of marine ecosystem decreased about 4.32%, equivalent to a loss of 4.32% of the direct use value of Phu Quoc's fisheries of 101.57 billion VND/year.

(2) In the RCP8.5 scenario in 2050, the seagrass bed will be degraded by 9.6%; coral reef will be degraded to 7.68%; on average, the entire area of marine ecosystem decreased about 8.64%, equivalent to a loss of 8.64% of the direct use value of Phu Quoc's fisheries of 203.13 billion VND/year. *(Undiscounted values as of 2018).*

### *3.2.2. Economic loss of direct use value of tourism*

Tourism value of Phu Quoc is derived from the services of ecosystems. The amount of potential tourism value of Phu Quoc is the overall value of ecosystem services. In order to estimate tourism loss in Phu Quoc, it is necessary to determine the percentage of visitors reduced due to the ecosystem degradation under climate change

scenarios. The author interviewed to investigate the behavior change of tourists. Accordingly, the larger the degradation, the larger the number of non-returning tourists, specifically: according to the climate change scenario RCP8.5, the percentage of domestic and international tourists do not return is much larger than in the climate change scenario RCP4.5. And the trends in both scenarios demonstrate that domestic tourists have a higher percentage of non-returning visitors than international tourists.

With the decrease in tourist arrivals, it will cause economic loss to the tourism industry in Phu Quoc. The loss of Phu Quoc tourism value under the RCP4.5 and RCP8.5 scenarios is 361,012 million VND and 1,081,937 million VND, respectively.

### *3.2.3. Economic loss of biodiversity values, habitats, and breeding grounds for marine biomes*

From the calculated results of the economic value obtained from the exploitation of aquatic resources in Phu Quoc is 2,351,042 billion VND/year and selected the calculation method by Alan White, research applied and calculated the ecological benefits of marine ecosystems such as biodiversity, breeding grounds, spawning grounds of aquatic species with economic value equivalent to the amount of 470.21 billion VND/year. This is the basis for forecasting the loss of biodiversity values, breeding grounds and spawning grounds of aquatic species due to marine ecosystem degradation under climate change scenarios.

(1) In the RCP4.5 scenario, in 2050 mangroves will be degraded by 6.4%; seagrass will be degraded by 4.8%; coral reef will be degraded by 3.84%; on average, the entire area of marine ecosystem

is lost about 5.01%, equivalent to a loss of 5.01% of biodiversity value, breeding grounds and spawning grounds of aquatic species. The amount of loss is: 470.21 billion VND/year * 5.01% = 23.56 billion VND/year.

(2) In the RCP8.5 scenario in 2050, mangrove will be degraded by 9.6%; seagrass will be degraded by 9.6%; coral reef will be degraded by 7.68%; on average, the entire area of marine ecosystem is lost about 8.96%, equivalent to a loss of 8.96% of biodiversity value, breeding grounds and spawning grounds of aquatic species. The amount of loss is: 470.21 billion VND/year * 8.96% = 42.13 billion VND/year.

*(Undiscounted values as of 2018)*

### *3.2.4. Loss of carbon absorption value of Phu Quoc forest ecosystem*

The value of the forest 's $CO_2$ absorption is calculated based on the direct market price method. According to the scenario RCP4.5 in 2050, the forest will be degraded by 1.92%, the value of carbon storage and absorption will be decreased by 1,262.94 thousand USDs in the world market and 2,210.14 thousand EURs in the European market. The mangrove will be degraded by 6.4%, the value of carbon storage and absorption will be decreased by 1.59 thousand USDs in the world market and 2,79 thousand EURs in the European market. According to the scenario RCP8.5 in 2050, the forest will be degraded by 3.84%, the value of carbon storage and absorption will be decreased by 2,525.88 thousand USDs in the world market and 4,420.29 thousand EURs in the market Europe. The mangrove will be degraded by 9.6%, the value of carbon storage and absorption will be decreased by 2.39 thousand USDs in the world market and 4,19 thousand EURs in the European market. Thus, the loss of carbon storage and absorption

value in the Phu Quoc forest ecosystem according to scenario RCP 4.5 in 2050 will range from 29.4 - 58.42 (billion VND/year). According to scenario RCP 8.5 in 2050 will range from 58.78 - 116.8 (billion VND/year) (*values have not been discounted to present value at the base time of 2018*).

### *3.2.5. Loss of non-use value due to ecosystem degradation*

The total value that people are willing to pay for the restoration, conservation and development of biodiversity is the non-use value of typical ecosystems. With an average willingness to pay per household of approximately 87,000 VND /year, the thesis estimates the non-use value of typical Phu Quoc ecosystems to be 2.41 billion VND /year.

Combining with the biodiversity loss based on the rate of degraded area under the climate change scenarios RCP4.5 and RCP8.5 for 2050 to determine the total loss of non-use value.

- According to the RCP4.5 scenario, the loss of biodiversity and resources of typical ecosystems corresponds to the average area of degraded ecosystems of 4.24%. The loss is 102.2 million VND/year.

- According to the RCP8.5 scenario, the loss of biodiversity and resources of typical ecosystems corresponds to the average area of degraded ecosystems of 7.68%. The loss is 185.1 million VND/year.

(V*alues have not been discounted to present value at the base time of 2018*).

### *3.2.6. Summary of loss of economic value due to typical ecosystem degradation in Phu Quoc*

*Table 3. 34. Summary of economic losses due to ecosystem degradation in Phu Quoc under climate change scenarios RCP4.5 and RCP8.5*

Unit: billion VND/year

| STT | Economic loss | Climate change scenario RCP4.5 in 2050 | Climate change scenario RCP8.5 in 2050 |
|---|---|---|---|
| ***I*** | ***Economic loss of direct use values*** | | |
| 1.1 | Loss of fishery | 101,57 | 203,13 |
| 1.2 | Loss of tourism | 361 | 1.081,94 |
| ***II*** | ***Economic loss of indirect use values*** | | |
| 2.1 | Loss of $CO_2$ absorption value | 29,4 – 58,42 | 58,78 – 116,8 |
| 2.2 | Loss of value in providing habitat (residential), aquatic seed resources | 23,56 | 42,13 |
| ***III*** | ***Economic loss of non-use value*** | 0,102 | 0,185 |
| Total economic loss (undiscounted value as of 2018) | | 515,63 – 544,65 | 1.386, 16 – 1.444,19 |
| Total economic loss (discounted value as of 2018). Take r = 10% | | 24,42 – 25,8 | 65,65 – 68,4 |

Thus, in respect to the climate change scenario RCP4.5 in 2050 the economic loss will be in the range of 515.63 - 544.65 billion VND/year (the discounted value in 2018 is 24.42 - 25.8 billion VND/year). According to the scenario RCP8.5 in 2050 the economic loss will be in the range of 1386.16 - 1444.19 billion VND/year (the discounted value in 2018 is 65.65 - 68.4 billion VND/year).

### 3.3. Proposing solutions to reduce economic loss due to the ecosystem degradation in Phu Quoc under the impact of climate change

#### *3.3.1. Conserving and restoring ecosystems being affected by climate change*

Ecosystem protection and restoration is one of the highly effective solutions in response to climate change. Some solutions to protect ecosystems can be mentioned as follows: Setting up a background database and monitoring the changes of ecosystems; Apply science

and technology to restore degraded ecosystems; Strengthen international cooperation; Improve staff capacity….

### *3.3.2. Improving the efficiency of management and use of ecosystems being affected by climate change*

The results of the evaluation can be used to improve the efficiency of management and use of the ecosystem as follows: Integrating evaluation results into the development planning process of economic sectors; Integrating evaluation results into the conservation planning process; Integrating evaluation results into the process of developing a payment mechanism for environmental services.

### *3.3.3. Education propaganda to raise public awareness*

Some methods of propaganda and education are highly feasible such as: Organizing contests to propose ideas and create eco-preservation activities; Propaganda in the mass media; Raise awareness for local high school students.

## 3.4. Sub-conclusion of chapter 3

Applying the process of synthesis and assessment of economic losses due to climate change causing ecosystem degradation, the thesis has evaluated the total economic loss due to the degradation of ecosystems in Phu Quoc according to climate change scenario RCP 4.5 about 515, 63 - 544.65 billion VND/year (discount value in 2018 is 24.42 – 25.8 billion VND/year) and according to climate change scenario RCP 8.5 about 1,386.16 – 1,444.19 billion VND/year (discount value in 2018 is 65.65 - 69.4 billion VND/year). In which, the economic value loss of the tourism and fishing industry is very large, the non-use value loss is the lowest. Three groups of solutions have been proposed to reduce economic losses due to the ecosystem degradation in Phu Quoc

including: Conserving and restoring ecosystems being affected by climate change; Improving the efficiency of management and use of ecosystems under the impact of climate change; Education propaganda to raise public awareness.

## CONCLUSIONS AND RECOMMENDATIONS

### 1. Conclusions

Research on the assessment of economic losses due to ecosystem degradation under the impact of climate change is of great significance in scientific research and management in order to effectively and sustainably use ecological resources. Based on the research results, the author made some conclusions as follows:

Firstly, the thesis has reviewed domestic and foreign studies on ecosystem degradation and economic loss evaluation due to ecosystem degradation under the impact of climate change. From this, provide approaches and research methods suitable to contents of the thesis to create highly reliable research results. The thesis has contributed to build the theoretical basis and the process of assessing economic losses due to climate change to apply to Phu Quoc.

Secondly, applying the process of assessing economic losses due to recession, the thesis has determined the total value of economic losses due to ecosystem degradation under 2 climate change scenarios: According to scenario RCP4.5 in 2050, the forest will be degraded by 1.92%; mangrove will be degraded by 6.4%; seagrass will be degraded by 4.8%; coral reef will be degraded by 3.84%. The total economic loss is in the range of 515.63-544.65 billion VND/year (the discounted value in 2018 is 24.42-25.8 billion VND/year). According to the scenario

RCP8.5 in 2050, the forest will be degraded by 3.84%; mangrove will be degraded by 9.6%; seagrass will be degraded by 9.6%; coral reef will be degraded by 7.68%. The total economic loss is in the range of 1,386.16 - 1,444.19 billion VND/year (the discounted value in 2018 is 65.65 - 69.4 billion VND/year). The total economic loss due to the ecosystem degradation in Phu Quoc is not small, in which, the biggest loss is in tourism and fishing, the lowest loss is non-use value.

Thirdly, the thesis has proposed solutions to reduce economic loss due to ecosystem degradation under the impact of climate change, including: Conserving and restoring ecosystems being affected by climate change; Improving the efficiency of management and use of ecosystems under the impact of climate change; Education propaganda to raise public awareness. These solutions are all towards the goal of sustainable development of ecosystems.

Thus, the thesis has assessed the economic loss of the ecosystem in Phu Quoc due to climate change, thereby proposing solutions to reduce economic loss in this area. However, because the research object of the topic is quite wide, the total loss value of the ecosystems has not been fully and in detail evaluated.

## 2. Recommendations

The research results of the thesis can be used aa references for local authorities to make decisions regarding the effective use of ecosystems taking into account climate change factor. Therefore, when building a socio-economic development plan, investing and paying for ecosystem services, management units can refer to the research results of the thesis.

During the research process, due to limitations of in scale and time for the survey, there reamains some difficulties and shortcomings as following:

- The collection of documents is not easy due to high barriers of copyright; secondary data collected from local management agencies is not always complete; the primary data also has errors due to the difference between the respondents and the ratio of the number of successful interviews to the total number of interviews, but this error level is relatively small, at acceptable level.

- Seagrass ecosystem plays an important role in Phu Quoc, however its values have not been fully evaluated, especially the value of $CO_2$ absorption.

- Some solutions to reduce economic loss of ecosystems under the impact of climate change have been proposed, but have not been verified.

The above shortcomings of the thesis are the basis for recommending the directions for future research:

- Continue to study more deeply about the loss of values of seagrass ecosystem, especially the value of $CO_2$ absorption.

- Research to evaluate economic loss after implementing solutions, thereby calculating the difference between "yes" and "no" solution.

## LIST OF WORKS RELATED TO THE THESIS HAS BEEN PUBLISHED

1. Dao Huong Giang, Bach Quang Dung, Dao Manh Tri (2019), *Overview of Investigations in Economic Loss by Ecosystem Degradation Relating to Climate Change*, Vietnam journal of hydrometerology, Volume 2-1-10/2019, pp.12-20.
2. Dao Huong Giang, Ngo Thi Bich Ngoc, Bach Quang Dung (2022), *Research on assessment of the decrease in the coverage of typical ecosystems in territorial sea of Phu Quoc city corresponding to the climate change and sea level rise scenarios*, Journal of Science Climate Change, No. 21-3/2022, pp.24-32.
3. Dao Manh Tien, Pham Van Thanh, Dao Manh Tri, Dang Thi Huong, Dao Huong Giang, Pham Thai Nam (2020*), Integrated Structure and Specific Solutions for Sustainable Development of Islands' Special Economic Zone: A Practice in Phu Quoc Island, Vietnam*, Journal of Sustainable Development, 13 (5), pp. 31-45.
4. Đao Huong Giang (2023), *Economic valuation of tourism for typical ecosystems in Phu Quoc*, Journal of Science Climate Change, No. 25-3/2023, pp.11-21.