

Assessment procedure for sea level rise economic damage due to climate change in agricultural land use: case study in Nam Dinh province

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Abstract:

Nam Dinh province is located in the Red river delta with a relatively flat terrain. The North East of Nam Dinh is bordered by the Red river and the southwest by the Day river and has a coastline of approximately 80 km. Given the geographical location, Nam Dinh has favourable conditions for agricultural and aquaculture production. Climate change creates a large number of potential risks for Nam Dinh. This includes sea level rise, typhoons, flood tide, etc. According to the climate change and sea level rise scenario in 2016, if the sea level rises by 100 cm, the flood risk area in coastal districts such as Hai Hau would be 67.34%, Giao Thuy 64.6%, Nghia Hung 81.61% and Xuan Truong 59.3% [1]. According to the monitoring data from Vietnam Institute of Meteorology, Hydrology and Climate Change (IMHEN), the salinity intrusion area due to sea level rise is likely to widen, which degrades and affects the area of the mangrove ecosystem [2]. In addition, the sea level rise may reduce the resilience of irrigation system due to the changes in estuarine and coastal dynamics such as water levels, flows, waves, etc. Through synthesising the local and international guidelines and in combination with expert consultation and field surveys, this paper develops an assessment procedure for sea level rise that causes economic damage to agricultural land use in order to quantify the impact of sea level rise in 4 coastal districts of Xuan Truong, Giao Thuy, Hai Hau and Nghia Hung in Nam Dinh province.

Keywords: agricultural land, climate change, coastal district, damage assessment procedure, Nam Dinh province, sea level rise.

Classification number: 6.2

Introduction

The Climate change and sea level rise scenarios 2016 of the Ministry of Natural Resources and Environment (MONRE, Vietnam) estimated that if the sea level rises by 100 cm, approximately 16.8% of the Red river delta area would be in danger of flooding. Accordingly, Nam Dinh is one of the two provinces (together with Thai Binh province) to have the highest flood risk with approximately 58.0% (in area) of the province facing flood risk.

Nam Dinh is located in the Red River delta with a relatively flat terrain. The North East of the province is bordered by the Red river and the southwest by the Day river and has a coastline of nearly 80 km. Nam Dinh has favourable conditions for agricultural and aquaculture production. Climate change creates a great number of potential risks including sea level rise, typhoons, flood tide, etc.

Previous studies on assessing socio-economic damages caused by climate change, especially sea level rise, have been carried out at the regional and global scale, or for national group, sector or specific countries such as the United States, Singapore, Indonesia, etc. Specially, the study by Susmita Dasgupta, et al. (2007) [3] on the impact of sea level rise on developing countries have listed 10 countries where sea level may rise by 1 m. According to this study, the affected land area of Vietnam is estimated to be 5.17%, which equates to 10.79% of the population being affected and a loss of 10.21% GDP. In Vietnam, MONRE has developed and updated three climate change and sea level rise scenarios for Vietnam from 2009 to 2016 [1]. In addition, there exists a great number of researches on the impact of climate change on different sectors, fields and regions such as the impact of climate change on the economy, or research on the impact of climate change - sea level rise in specific coastal provinces such as Ca Mau and Thua Thien - Hue. However, these researches only performed qualitative impact assessment. Only a few studies have quantified the extent of damage,

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yet the scale is too wide for the sea level rise scenarios to be suitable for Vietnam conditions; moreover, the land use changes are not included in these studies.

In fact, there are different methods of calculating economic losses due to climate change, in general, and sea level rise, in particular. These methods have been widely applied in the world. However, the application of such methods is still limited to the case of Vietnam (such as the extent of damages for different target groups and areas due to the impact of sea level rise). Therefore, identifying the objects affected by sea level rise, selecting and using appropriate methods of economic damage calculation to assess the economic damage of the sea level rise because of climate change is important and should be realistic to improve the scientific basis of research assessment of economic damage to agricultural land due to the sea level rise caused by climate change.

This study seeks to establish assessment procedures for economic damage caused to agricultural land use in Nam Dinh. The results of this study form an important basis for the selection of methods to assess the economic damage caused by the sea level rise to the agriculture land use in the Nam Dinh province and can be applied to other areas with similar conditions.

Materials and methods

In order to build an economic damage assessment procedure of sea level rise, the development and standardisation of the database is necessary. Three main methods of research were used:

- (i) Collect document and data of the world, in general, and of Vietnam, in particular.
- (ii) Use the Delphi method to collect opinions from expert groups on the selection of evaluation scenarios and the impacts of sea level rise on agricultural production.
- (iii) Conduct field surveys and community consultation to identify the objects and areas likely to be impacted by sea level rise.

The databases for developing the assessment procedure for damage caused by sea level rise are described in detail below:

- a) Documents on climate change and sea level rise:

This document includes: The 1st and 3rd Report of the Intergovernmental Panel on Climate Change (IPCC) [4]; IPCC Technical Guidelines on assessing the impact of climate change and adaptation [5]; Scenario of Climate change and sea level rise of MONRE in 2012, 2016 [1, 6]; Sea level data from the Hydrographic Data and Information Center be long to Viet Nam Meteorological and Hydrological Administration; Guidebook for Assessing

the Impacts of Climate Change and Identifying Adaptation Measures of the IMHEN [7]; Climate Change Action Plan for Nam Dinh provincial People's Committee [8]; Irrigation planning to 2020 and orientation to 2030, etc [9].

- b) Data on agricultural land in the Nam Dinh province:

Statistical yearbook of Nam Dinh province from 2010 to 2015 [10]; Land use data in 2010, 2015; Land use planning map to 2020 and vision to 2030 (General Department of Land Administration be long to MONRE); Report on socio-economic development of four research districts: Report on development planning for agriculture, fisheries and salt production in 2010-2020, vision to 2030 in the Nam Dinh province; Research and dissertation related to land use in the area, etc.

- c) Documents and data on economic damage assessment:

Documents and data on economic damage assessment includes the theory of total economic value (TEV) and the theory of methods used in estimating the economic value commonly used; The researches in the world, areas and in Vietnam on the impact of climate change, sea level rise on land resources, especially on agricultural land; Document on the valuation of economic value of related subjects have been implemented in Vietnam and the Nam Dinh province.

The paper utilises the results from previous researches such as doctoral dissertation, national-level research projects, ministerial-level research project and organisational-level research project that have been conducted on the Nam Dinh area.

Results and discussion

The database supports the framework of the procedure of assessing the economic damage caused by sea level rise

Delphi consultation results:

From two independent rounds of the consultative panel, the synthesised results of the consultation are as follows:

- a) Selection of climate change and sea level rise scenarios:

Climate change and sea level rise scenario for Nam Dinh with greenhouse emission level equivalent to RCP 6.0 is used to assess the impact of sea level rise on Nam Dinh land use. On the one hand, the rationale behind the selection of the scenarios from local scientists and officials is due to the potentially high level of impacts of climate change and sea level rise on the Nam Dinh province. On the other hand, the selection of the RCP 6.0 scenarios is also a conservative selection to improve the ability to cope with climate change and sea level rise of the locals in the future.

- b) Identification of areas and objects affected by sea level rise:

The study identified four districts and four groups of agricultural land in Nam Dinh with a high risk. The four groups of agriculture land include: paddy land, aquaculture land, salt land and special-use forest land, including protection forest and production forest (since the coastal area of Nam Dinh province only has mangrove forest, thus, mangrove forest the identify name is mangroves forest replaces all other protection and production forest category).

c) Determine the damage level (K):

To assess the economic damage, under the guidance of Inter-ministerial Circular No. 43/2015/TTLT-BNNPTNT-BKHDT [11] on guidelines for statistics and assessment of damages caused by natural disasters and in consultation with local officials and economic experts, the study determined the damage level of agriculture land due to sea level rise for two areas namely the inside and the outside of the dyke protection area (as shown in Table 1).

Table 1. Damage level in two areas inside and outside the dyke protection area.

Areas inside the dyke protection area	Areas outside the dyke protection area
Seriously damaged K = 0.5	Completely damaged K = 1
Partially damaged K = 0.3	Very serious damaged K = 0.7
Mangrove forest ecosystems damaged in the period of 2020-2030 K = 0.2	
Mangrove forest ecosystems damaged in the period of 2020-2030 K = 0.4	

+ The area outside of the dyke protection area is likely to be completely damaged or seriously damaged.

+ The area inside the dyke protection area is less likely to be flooded and the level of impact of the sea level rise is not as direct (due to the dyke system); the level of damage is categorised as seriously damaged and partially damaged.

+ For mangrove forest: based on expert consultation at the Mangrove Forest Research Center - Hanoi Pedagogic University, officers at Xuan Thuy National Park, Nghia Hung Biosphere Reserve and from reference research projects such as Thi Kim Cuc Nguyen (2012) [12], Gilman Eric, et al. (2007) [13], the authors have selected the following damage level: Damage level of 0.2 for from 2020-2030 (corresponding to the sea level rise between 12 and 18 cm) and damage level of 0.4 for from 2040 to 2050 (corresponding to the sea level rise between 24 and 32 cm).

Survey results and community consultation:

The results of survey and community consultation were fairly similar to the applied Delphi method with specific results as follows:

a) Identification of four districts with high risk of sea level rise in Nam Dinh:

Results from consultation and survey of four districts affected by sea level rise include: Nghia Hung, Hai Hau, Giao Thuy and Xuan Truong, of which there are three districts adjacent to the sea. Xuan Truong, although not a coastal district, yet due to terrain conditions and the similarity of irrigation systems with Giao Thuy (the shared irrigation system with Xuan Thuy district) faces the impact of climate change and sea level rise, which could be seen in serious salinity intrusion.

b) Identification of agricultural land groups affected by sea level rise:

The study identified four groups of affected agricultural lands from a total of eight types: paddy land, aquaculture land, salt land and special-use forest land including protection forest and production forest in the four research districts directly affected by sea level rise. In addition, consulted opinions suggested that the dyke systems and drainage sluices and drainage ditches in these four districts will be affected by sea level rise. Summary of affected objects in four districts divided into two areas inside and outside the dyke protection area is as follows:

Table 2. Affected objects located inside and outside of the dyke protection area in four districts.

Area	Affected objects outside the dyke protection area	Affected objects inside the dyke protection area
Nghia Hung, Hai Hau, Giao Thuy	- Area of aquaculture - Area of mangrove forest - Area of salt production	- The sea dyke system - Salinity warning system and Salinity prevented system (not yet invested) - Area of paddy land - Area of aquaculture - Area of salt production
Xuan Truong	- Not affected	- Salinity warning system (investment enhancement) - Area of paddy land

The assessment procedure of economic damage caused by sea level rise

The procedure of determining the economic damage caused by sea level rise has been created in a scientific manner based on domestic and international guidelines from renowned agencies and organisations. The applicability of the guideline is also tested during consultations with experts, administrators and communities in conjunction with the field survey.

Scientific foundation to create the procedure:

To develop a procedure for assessing economic losses due to sea level rise, the study utilised collected documents on climate change, sea level rise, information on the assessment of economic value globally and in Vietnam, which includes ‘Technical Guidelines on Impact Assessment of Climate Change and Adaptation’ by IPCC (1994) [5] and ‘Guidelines for Impact Assessment of Climate change and Identification of Adaptive Measures’ by the IMHEN [14].

Foundation to create the procedure:

In addition to using documents in the world and in Vietnam, the research is also based on expert opinion through the application of the Delphi method, the field survey and community consultation. The study has developed a procedure for the assessment of damage caused by sea level rise on the Nam Dinh province. The detailed procedure of assessing economic damage are presented in Fig. 1 with seven main steps:

(1) Select sea level rise scenario under RCP 6.0 by the Delphi method and community consultation.

According to the Delphi Expert Consultation method and community consultation, the selected scenarios are RCP 6.0, representing a high average GHG emission. The reason is for enhanced prevention. Sea level rise of 12, 18, 24 and 32 cm were selected from the scenarios in the period 2020 to 2050.

(2) Create a flood risk map according to the sea level rise according to RCP 6.0 scenario.

- Use the DEM model, topographic data, cross section, slope... and spatial interpolation analysis from the ‘decision tree’ approach to map the flood risk and the impact of sea level rise to agriculture land.

- Estimate the level of flooding due to sea level rise according to the climate change scenario. Digitise attributed data (sea level rise inundation level) into the basic map based on the ‘water surface elevation’ method at a selected value.

- Use topographic data, cross-section and slope as inputs for the DEMs model to construct the digital elevation model for four coastal districts of the Nam Dinh province, including:

+ Field survey data: coastal topography, sea level rise, saline intrusion within the last 10 years in four districts Xuan Truong, Giao Thuy, Hai Hau and Nghia Hung; Community surveys on changes in agriculture land use, focusing on the conversion of paddy land, salt land and mangrove forest into aquaculture land (by local people).

+ Map data and statistics: input data for spatial analysis to establish a flooding risk map, including the impact of

natural-human relationships: background map topography of four districts with a 1:10,000 scale; Thematic maps on land use status in 2010, 2015 and Nam Dinh land use planning map in 2020 with a scale of 1: 50,000 [15-17]; Area of natural land of four districts according to the statistics of Nam Dinh province by General Statistics Office of Vietnam (GSO) in 2010, 2015.

Identification, description of different wetlands (in dykes, outside dykes) as a basis for map overlays (spatial analysis, floodplain interpolation by decision tree method).

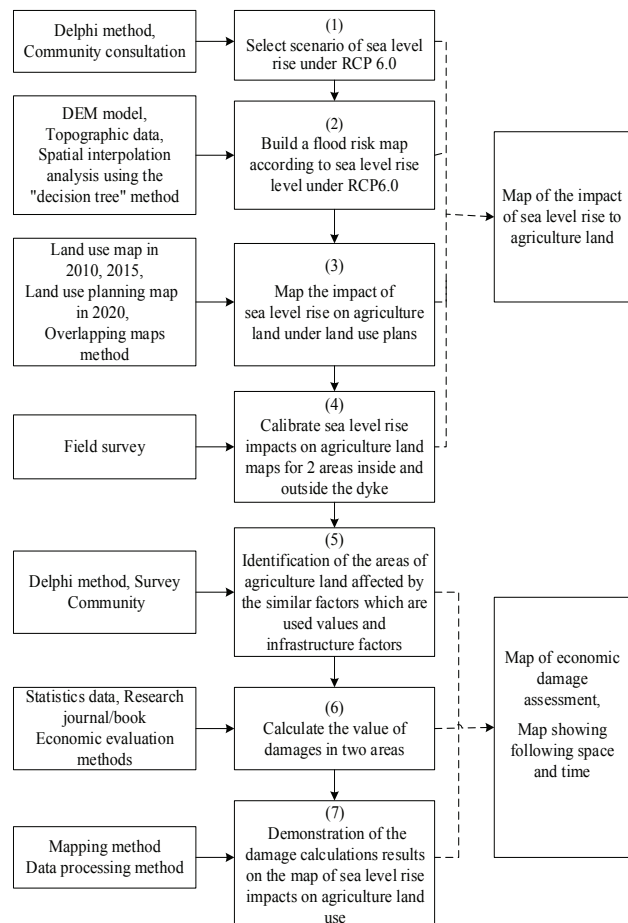


Fig. 1. Economic damage assessment procedure.

(3) Build the map of the impact of sea level rise on agriculture land under land use plans such as land use status map in 2010, 2015 and planning map of 2020.

- Using the method of overlapping maps from the flood risk map in step 2 with three land use maps including land use status map of 2010, 2015 and land use planning map to 2020 vision to 2030 (The use of three maps as three land use scenarios may occur from 2020 to 2050 for more options for local review when the impact of the sea level rise occurs).

- Map of flood risk caused by sea level rise to agriculture

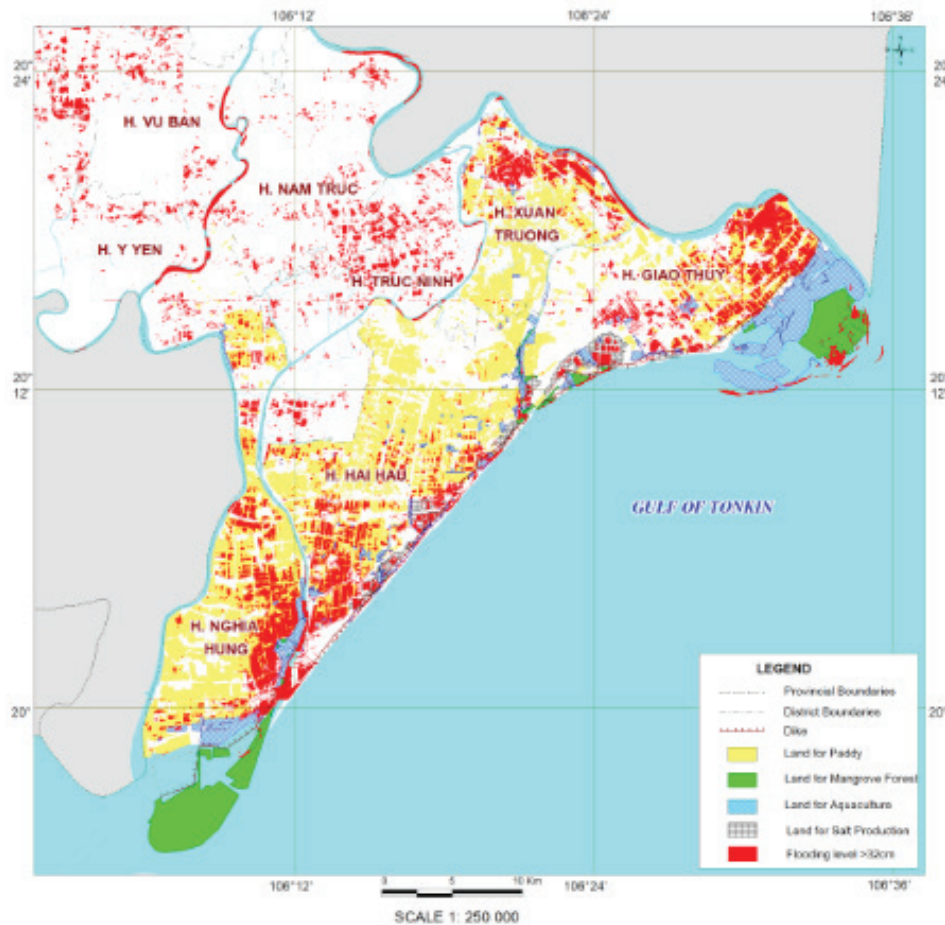


Fig. 2. Map of flood risk caused by sea level rise to agriculture land use for four districts by 2050 according to the land use planning map of 2020.

land use was established by combining floodplains in sea level rise inlays (interpolation on ArcGIS software based on DEMs) and submerged areas according to current land use map (Fig. 2). Overlapped floodplains will be pooled into flooded areas. Calculation of the flood risk area (S_i) was adjusted according to the survey data in four districts of Xuan Truong, Giao Thuy, Hai Hau and Nghia Hung.

The map of flood risk caused by sea level rise to agriculture land use for four districts shows that the total area of the agriculture land use was impacted by sea level rise, the proportion of agriculture land use that was most affected by the sea level rise and the object most affected by the sea level rise.

(4) Calibrate maps of sea level rise impacts on agricultural land for two areas inside and outside the dyke protection area.

- Calibrate flood impact maps due to sea level rise in order to correct the area and the flood risk area to eliminate errors of the DEMs model. Calibrate the map according to the actual survey data from suspected points due to

spontaneous conversion of land use purpose of local people or errors in interpolation.

- Comparing the methods of mapping the impact of flood risk caused by sea level rise to agriculture land use in the Nam Dinh province and the method of developing flood risk maps from the MONRE scenario includes the additional step of investigating the reality date to develop flood risk maps that are most appropriate. This is a new contribution in the method of mapping the impacts of flood risk caused by sea level rise to agriculture land use in the Nam Dinh province in order to accurately determine the vulnerable area of land types in the area protected by the dyke system.

(5) Identification of the agricultural area (including paddy area, aquaculture area, salt area, special-use forest land and mangroves forest) affected by the used values and infrastructure factors such as dykes and system to prevent salty.

The use of supporting tools in Arcgis and Mapinfo software to calculate the area affected by sea level rise in the four districts of the agriculture land group include:

Table 3. Area of agricultural land affected by sea level rise in both areas inside and outside the dyke from 2020-2050 according to the planning map of 2020.

District	Type of land	Area of land use master plan 2020 (ha)	Flooded area outside the dyke affects to each type of land (ha)				Flooded area inside the dyke affects to each type of land (ha)			
			2020 12 cm	2030 18 cm	2040 24 cm	2050 32 cm	2020 12 cm	2030 18 cm	2040 24 cm	2050 32 cm
Nghia Hung	Area of paddy land	8599.4	0.0	0.0	0.0	0.0	599.0	1031.5	1483.3	2160.0
	Area of aquaculture	4639.3	6.2	6.5	7.1	7.5	97.9	129.5	163.4	211.5
	Area of salt production	31.0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Area of mangrove forest	2213.7	51.1	57.7	64.3	72.8	7.8	8.5	9.1	9.8
Hai Hau	Area of paddy land	8014.4	0.0	0.0	0.0	0.0	494.6	792.3	1126.6	1633.2
	Area of aquaculture	3090.6	7.9	18.7	31.0	49.5	14.7	29.9	51.7	78.9
	Area of salt production	213.7	2.7	5.2	7.8	13.1	20.2	40.1	67.6	111.2
	Area of mangrove forest	84.5	0.2	0.3	0.3	0.6	0.4	2.9	4.8	7.0
Giao Thuy	Area of paddy land	6561.0	0.0	0.0	0.0	0.0	290.5	694.4	1054.6	1508.4
	Area of aquaculture	5647.7	41.6	90.7	124.4	161.1	3.3	17.6	37.3	69.6
	Area of salt production	305.3	2.2	8.9	13.4	23.0	1.4	14.6	48.9	103.7
	Area of mangrove forest	2178.4	21.4	59.8	100.8	169.1	0.7	1.7	3.3	7.0
Xuan Truong	Area of paddy land	4608.8	0.0	0.0	0.0	0.0	138.7	277.2	412.3	577.4
	Area of aquaculture	1196.2	0.0	0.0	0.0	0.0	7.5	11.0	14.0	16.1
	Area of salt production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Area of mangrove forest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

mangrove forest, aquaculture land, salt land and paddy land. This supports the identification of the risk area affected in the two areas inside and outside of the protection area of the dyke system of the four districts. In addition, the study considered the system of sea dykes and the system of salty water drainage for two areas inside and outside the sea dykes.

Table 3 is a typical spreadsheet of the area of agricultural land affected by the sea level rise in both areas inside and outside the dyke. It shows the details of the agricultural land affected by sea level rise. In Hai Hau and Giao Thuy districts, the proportion of the area of salt production affected is extremely high, equivalent to 58.2% and 41.5%

of total area of salt production in the two districts by 2050.

(6) Calculate the value of damages in two areas inside and outside the dyke.

The procedure to determine the value of damage caused by sea level rise to agriculture land in 4 districts of Nghia Hung, Hai Hau, Giao Thuy and Xuan Truong consists of 3 main components:

- Determine the average economic value (Gj) of the objects affected by conducting field surveys, collecting data from Nam Dinh Statistical Yearbook and reviewing the literature (journal/book). The affected objects include agriculture land, the dyke systems and the salinity

prevention system. The TEV of Bolt, Pearce and the system of valuation according to Babie are used [18-20].

- Select the discount coefficient (r) to calculate the value in 2010 (the comparative price being applied in statistics in Vietnam).

- Calculate the value of economic damage to agriculture land, dykes and salinity prevention system in 4 districts according to formula (1):

$$TH_{DNN} = \sum(S_i \times G_j) \cdot K \quad (1)$$

where: TH_{DNN} : damage value of agriculture land caused by sea level rise in one area; S_i : area of agriculture land type i affected by sea level rise. In this study, the agriculture land consists of four main categories: aquaculture land, mangroves, salt land and paddy land; G_j : average economic value j of 1 unit of agricultural land; K: damage level.

(7) Map the damage calculations result on the map of impact of sea level rise on agriculture land use.

Through mapping of the results, it could be observed that there are changes in the degree of impacted level to agriculture land caused by the sea level rise in space (study area) and time (from 2020 to 2050). The mapping of the calculated results proved to be significant in rapidly assessing the objects, locations and the difference between the affected objects and the affected area.

Conclusions

This study has created the procedure of evaluating the economic damage of sea level rise due to climate change to agriculture land use in the coastal area of Nam Dinh province with seven main steps. The process of assessing the economic damage of sea level rise due to climate change is scientifically supported by the guidelines of prestigious agencies in the world and in Vietnam in the field of climate change and sea level rise. Besides that, the procedure also ensures the practicality and the possibility of replication when consulting experts and councils and combined with the actual survey.

When the economic damage assessment procedure for the coastal area of Nam Dinh is completed, the data set for assessing the economic damage of sea level rise due to climate change in the coastal area of Nam Dinh province will include:

+ Database on climate change scenarios, sea level rise, data on agricultural land use and related documents on economic valuation of Nam Dinh province.

+ The flood risk map system and maps of the impact of

sea level rise on agricultural land use in 4 districts of Nghia Hung, Hai Hau, Giao Thuy and Xuan Truong at four time points from 2020 to 2050 for three other land use plans.

+ The dataset on the flood risk area affected by sea level rise for four districts was separated into two areas inside and outside the dyke, which showed that the area of flood risk was affected by sea level rise in four districts.

This dataset has not only significant scientific value but also practical value for local government and scientists in the context of climate change and sea level rise, which have an impact on the local conditions that are becoming increasingly serious.

The procedure of assessing the economic damage of the sea level rise due to climate change to the agricultural land use in the coastal area of Nam Dinh province can be applied to areas with similar terrain and database.

Recommendations and outlook from the results

This study hypothesised that the flood risk area will be economically affected by four different levels of damage to the two areas inside and outside the dyke.

In order to assess the impact of sea level rise on more accurate and efficient use of agricultural land, there should be an agreement on the databases collected for the calculation from the local statistical yearbook, data from land use status maps and land use planning maps, local research works.

In the future, the application of the economic damage assessment method will be widely used, as, in addition to determining the value of ecosystem management services, it can also be applied to determine compensation for damage in conflicts, environmental conflicts, etc. Therefore, there will be more research on assessing the economic value of ecosystem in the field of natural resources and environment to continue improving the methodology, unify the process of assessment for specific objects and moving towards institutionalising legal documents that regulate ecological economic valuation.

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