B-12.4 Study on method of assessment for effects of sea level rise and integration of regional data (Final Report)

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Total Budget for FY1997-FY1999, 35,830,000 Yen (FY 1999; 10,845,000Yen)

Abstract: The coastal zone, where population and economic activities are concentrated, has swamps, coral reef, mangroves and so on, which are important places concerning to natural environment. Sea level rise will cause serious problems in various social and environmental systems; submergence of land, flood of river, salinity intrusion to river, ground water level rise, and so on. They must be important research subjects on global environment problems in the future to grasp various impacts of sea level rise and climatic variation in the coastal zone beforehand and to examine countermeasures against them. This study, by constructing database to support impact assessment for sea level rise in Asia-Pacific region, tries to evaluate economic impact of sea level rise and to assess physical impact.

Key Words: Sea level rise, impact assessment, economic impact, and physical impact

1. Introduction

Because many low islands and deltas are distributed in Asia-Pacific region, it seems to be suffered serious damage due to sea level rise and climatic change. However results of its impact assessment is not open and the assessment scenario at a country level is also not described, due to insufficient accuracy of prediction of sea level rise and climatic variation. And the comprehensive assessment technique is not developed though natural and socioeconomic systems are composed of various elements in coastal zone. Because sea level rise is a serious environmental problem, it is necessary to evaluate impact of sea level rise not only in global scale but also in regional scale. Objective of this study is to make a guideline (or manual) for impact assessment of sea level rise. This study integrates individual assessment results in Thailand and makes a foothold for appropriate impact assessment of sea level rise in Asia-Pacific region.

This study employs two approaches. One is evaluation of economic impact of sea level rise, by constructing and using the quasi-SCGE (spatial computable general equilibrium) model. The other is integrated assessment of physical impacts of sea level rise.

2. Evaluation of economic impact of sea level rise

2.1 The quasi-SCGE model

The quasi-SCGE model of this study is based on Ueda-Morisugi's macro economic model [Ueda et al. (1996), Morisugi et al. (1997)], and has some assumptions as follows.

(1) The land consists of 5 regions: Bangkok, Central, Northern, Northeastern, and Southern regions.
(2) The industry consists of 16 sectors: Crops, Livestock, Fisheries, Forestry, Agricultural services, Simple agricultural processing, Mining and quarrying, Manufacturing, Construction, Electricity and water supply, Transportation and communication, Wholesale and retail trade, Banking, insurance and real estate, Ownership of dwellings, Public administration and defense, and Services sectors.
(3) The economy consists of 2 sectors: Labor, and Private firm sectors.
(4) There are 3 markets: Labor, Land, and Commodity markets.
(5) There are unemployed persons.

2.2 Impact of sea level rise

The model of this study expresses sea level rise as decrease of available land in coast area. Changes in available land should be propagated into markets. Land rent and other market prices in coast area will change, and the utility level of people will change, then people may migrate to other regions. In these regions immigration of people will change markets. So, those changes in coast area should be expanded to other regions through the market mechanism. The flowchart of this model is shown in figure 1.

2.3 Definition of damage

By comparing the market equilibrium condition "without sea level rise" (without-case) with the condition "with sea level rise" (with-case), the social net damage due to sea level rise can be shown. This study employs two definitions as damage due to sea level rise: (1) decrease of production and (2) equivalent variation.

2.4 Land loss due to sea level rise

Because data of land loss due to sea level rise in Thailand is under measuring, provisional data is assumed in table 1. Table 1 is based on an estimate that the coastline will go up 300m inland due to sea level rise of 1m.

2.5 Measurement of damage

The results are shown in table 2, which indicates production will decrease 11,463 and 21,777 million baht per year (0.361 and 0.685% in comparison with GDP) due to sea level rise of 50 and 100cm, respectively. By using definition of equivalent variation, on the other hand, damages are estimated as 1,906 and 3,780 million baht per year (0.060 and 0.119% in comparison with GDP). However difference between results by two definitions of damage is not clear theoretically yet. This point should be studied.

Tables 3 and 4 indicate production change in each region and each industry, respectively. In northern and northeastern regions production will increase due to sea level rise because labor will migrate from coastal area to inland. Damages in Bangkok and central regions are almost equal to total damage in Thailand. On the other hand, manufacturing sector suffers the most damage, about 40% in comparison with total damage, of all industrial sectors. The second is wholesale and retail trade sector; the third is service sector and so on.

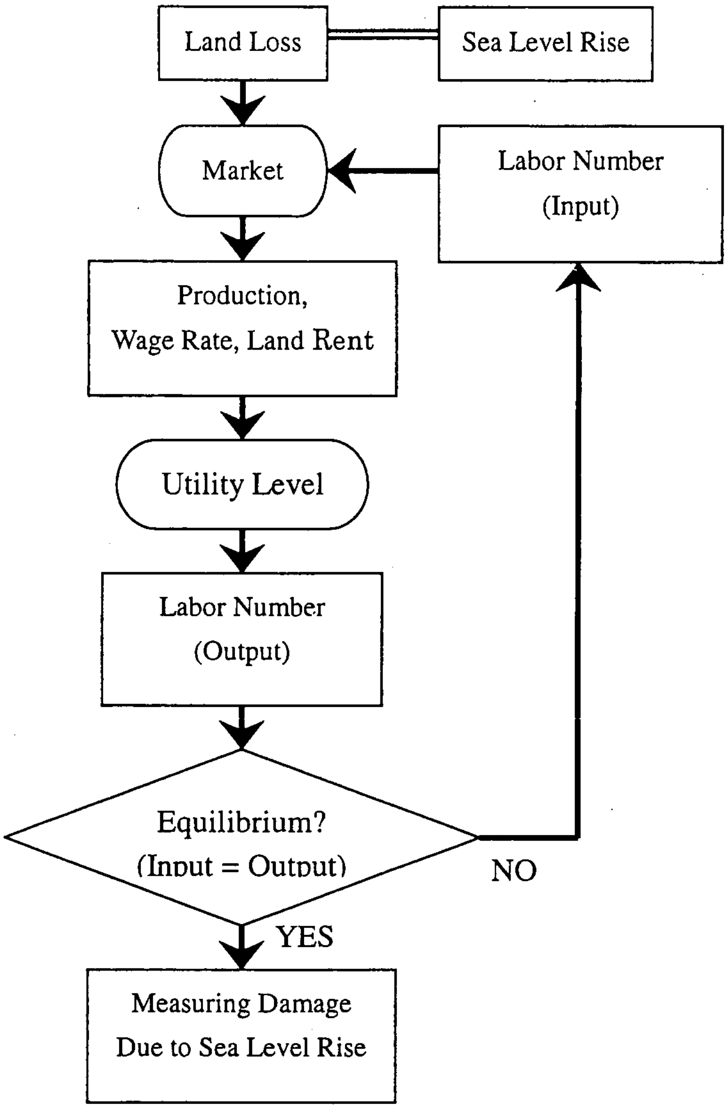

Figure 1. Flowchart of the model

Table 1. Land Loss due to Sea Level Rise

Region	50cm up	100cm up
Bangkok	9.000 [0.276]	18.000 [0.553]
Central	50.985 [0.126]	101.970 [0.252]
North	-	-
Northeast	-	-
South	88.980 [0.323]	177.960 [0.647]
Whole Kingdom	148.965 [0.071]	297.930 [0.142]

Note) unit: square km [% ratio to each area]

Table 2. Damage due to Sea Level Rise

	50cm up	100cm up
Production Change	-11,463 [-0.361]	-21,777 [-0.685]
Equivalent Variation	-1,906 [-0.060]	-3,780 [-0.119]

Note) unit: million baht per year [% ratio to GDP in 1993]

Table 3. Change of Production in Each Region

Region	50cm up	100cm up
Bangkok	-7,062	-13,305
Central	-5,063	-9,360
Northern	296	529
Northeastern	911	1,203
Southern	-545	-844
Whole Kingdom	-11,463 [-0.361]	-21,777 [-0.685]

Note) unit: million baht per year [% ratio to GDP in 1993]

Table 4. Change of Production in Each Industry

Industry	50cm up	100cm up
Crops	-152	-361
Livestock	-51	-109
Fisheries	-53	-71
Forestry	-12	-21
Agricultural services	7	3
Simple agricultural processing	-116	-234
Mining and quarrying	-302	-603
Manufacturing	-4,354	-8,355
Construction	-616	-1,071
Electricity and water supply	-381	-751
Transportation and communication	-915	-1,740
Wholesale and retail trade	-1,832	-3,489
Banking, insurance and real estate	-940	-1,793
Ownership of dwellings	-201	-390
Public administration and defense	-230	-435
Service	-1,313	-2,358
Whole Kingdom	-11,463 [-0.361]	-21,777 [-0.685]

Note) unit: million baht per year [% ratio to GDP in 1993]

3. Integrated assessment of physical impact of sea level rise

This part of the study consists of three components; development of assessment guidelines, integration of physical impact assessment by GIS, and case study for Thailand. The case study for Thailand is an application of the developed method of the integrated assessment.

3.1 Development of assessment guidelines

In the present study, the occurrence and propagation of the impacts of sea level rise are formulated by three stages, such as external forces, primary impacts, and secondary and higher ordered impacts on natural environment and human society. The major external force for this study is changes in mean sea level, therefore, mean sea level rise by global warming, tide, and storm surge caused by tropical cyclone are considered.

The primary impact means physical changes of coastal zones. Permanent inundation by sea level rise and episodic flooding are taken in this study, for which high tide level on the increased sea level, and storm surge level on it are the respective external forces. The secondary and higher ordered impacts are those which appear on natural and social systems in the coastal zones. The exposure units taken in this study are sandy beach, delta(erosion, flooding by storm surge, river flooding, salt water intrusion), coastal lagoon, wetlands, mangroves, coral reef for the natural system, and potential of natural disasters, economic damages, industry and social activities (affected areas and population).

A table was formed to summarize the guidelines for the assessment of the above impacts. The table indicates the combination of the needed data and assessment methods, including scenarios for the external forces, past and present data for the exposure units, and frameworks and procedures of the impact assessment. Two major gaps identified in the application of the guidelines are lack of data and models for the prediction of responses of the target exposure units. For many of them, the present methodology is still in the stage of analogy of the past behaviors rather than quantitative prediction, therefore the further development of predictive models is urgent.

3.2 Integration of physical impact assessment by GIS

This part of the study followed the same structure of the assessment shown in the guidelines. The target area of this part is the whole Asia and Pacific region, i.e. E30°～W165° and N90°～S60°.

(1) External forces

A scenario for the future sea level rise was given on the basis of the IPCC Second Assessment Report. For the IS92a emission scenario, IPCC indicated that mean sea level would rise 48cm with a possible range of 15cm to 90cm until 2100. A sea level rise of 1m by 2100 was assumed for simplicity in this study.

Tide is another factor to change the influence of sea level. The tide data, i.e. tidal range and high tide level, are digitized from the Tidal Chart published by Hydrographic Department, Maritime Safety Agency, Japan. The number of tidal observation stations is 1852. The variation of the high tide level is interpolated to each segment of the all coastlines on the 1' x 1' grid system.

Storm surge is the most influential factor to change the sea level in a short period of time. It is caused by sucking-up of seawater and wind set-up by tropical cyclones. Though set-up by high waves is another mechanism of storm surge, it is not considered here. The height of storm surge was calculated taking into account of the two mechanisms for each 1'x

1' segment of all the coastlines. The strength and tracks of the historical typhoons were taken from World-Wide Consolidated Tropical Cyclone Data Set published by U.S. NOAA. In the present study, cyclones of the past 40 years, from 1949 to 1989, are used for the calculation.

(2) Integration of the assessment by GIS

The areas subject to the permanent inundation and episodic flooding are identified for the whole region by GIS. Data for the regional distribution of the exposure units, such as population, wetlands, and coral reefs, were also incorporated into the GIS database. By overlaying the affected areas and exposure unit data, distribution of the secondary and higher ordered impacts were calculated.

Regarding the permanent inundation, severely affected areas distributes in the New Guinea Island, and Mekong River Delta in Vietnam. The areas widely affected by the storm surge are found in Bangladesh and Chinese coasts, such as Shanghais area. In summary, the area below the present high tide level is 310 thousand km^2 or 0.46% of the total land area of the region, and those for 1m sea level rise and the episodic flooding are 620 thousand km^2 or 0.92%, and 850 km^2 or 1.27%.

The difference in the affected areas between the simple inundation and storm surge flooding is 10 times for China, 5 times for Thailand, and 3 times for Bangladesh. In Bangladesh, the area affected by storm surge may amount to 1/3 of the whole country.

3.3 Case study for Thailand

Similar approach was made for Thailand. The external forces ate the same for the whole Asia and Pacific region. As for the exposure unit data, Thailand on a Disc, a GIS database published by Thailand Environment Institute was used. This database covers a wide range of the geographic and environmental parameters, such as administrative boundary, climatic conditions, topography, geology, land use and land cover, forest, agriculture, infrastructures, and socioeconomic conditions.

Most data are presented according to town and village. Therefore, the results are primarily summarized on such basis. The affected quantities are interpolated by proportion of the inundated or flooded areas of each town or village.

According to the present case study, the areas affected by the inundation by 1m sea level rise and storm surge flooding are 2,400 km^2 or 0.47% of the national land, and 12,000 km^2. This means that the threatened areas by storm surge is five times larger that that of the simple inundation. The populations in these areas are 330 thousand and 3.9 million, respectively. The most affected land use was coastal forest(mangroves), coconuts plantation, rice paddy, and coastal cities.

4. Conclusion

(1) Evaluation of economic impact

This study constructs a quasi-SCGE model, employs two definitions as damage due to sea level rise: (1) decrease of production and (2) equivalent variation, and evaluates economic impact of land loss due to sea level rise in Thailand by using this model. As a result, production will decrease 11,463 and 21,777 million baht per year (0.361 and 0.685%119% in comparison with GDP) due to sea level rise of 50 and 100cm, respectively. By using definition of equivalent variation, on the other hand, damages are estimated as 1,906 and 3,780 million baht per year (0.060 and 0.119% in comparison with GDP). However difference between results by two definitions of damage is not clear theoretically yet. This point should be studied.

(2) Integrated assessment of physical impact

In this study, three major results were obtained. (1) Guidelines for the assessment was developed in a form of table to summarize the combination of the needed data and assessment methods. Two major gaps identified in the guidelines are lack of data and models for the prediction of responses of the target exposure units. (2) An integration system covering the whole Asia and Pacific region was developed for physical impacts. The effects of storm surge superposed on 1m sea level rise are considerable. It was confirmed that the Asia and Pacific region is one of the most vulnerable regions in the world. (3) A case study for Thailand was performed using the same framework of the integrated assessment. Thailand is not the most vulnerable to the present climatic condition. However, if climatic changes, such as changes in cyclone tracks, occur, the effects of storm surge could be serious because of the low-lying nature of the Thai coastal zones.

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