B-10.1 The study on the sea level rise impacts to the land use suitability in coastal areas.

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Abstract

A rise in sea level induced by global warming has been predicted. According to the Summary of Second Assessment Report of IPCC (Intergovernmental Panel on Climate Change), fifty centimeter of the rise is predicted. Sea level rise itself and accompanying effects such as ground water rise or sea water intrusion will change the condition of suitability of land use in coastal regions.

The study dealt with the change of land use suitability by considering sea level rise and other related impacts. Then redistributed land use patterns were simulated by taking into account of these land use suitability, in two case study areas (Niigata in Japan and Bangkok in Thailand)

The study examined the applicability of the method for formulating the desirable spatial distribution of human activity in coastal areas, in responding to the requirements of mitigation of sea level rise and the utilization of land resource in a sustainable manner.

Key Words Sea Level Rise, Land use, Coastal Area, Niigata, Bangkok

1. Introduction

It has been predicted that global warming will cause sea level rise in coastal areas for more than several hundreds years in the future. According to the IPCC 1992 model, the predicted rise in sea level by 2100 will be 15 centimeters to 95 centimeters. The impacts of sea level is schematically described in Figure 1.

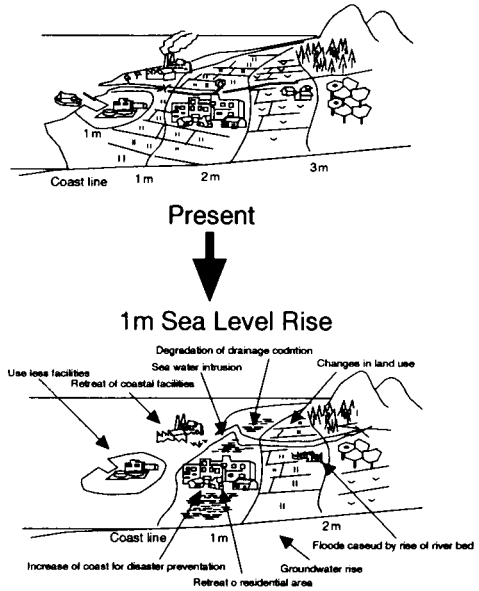

Fig. 1 Impacts of sea level rise

The sea level rise and other related impacts such as sea water intrusion and rises in river and ground water will change the basic conditions of land in coastal areas. Therefore the changes of land conditions and land use suitability after sea level rise should be predicted, in order for the adaption of coastal areas to sea level rise.

The study examined the change of land use suitability and simulated the suitable land use pattern after 1m sea level rise in two case study areas(Niigata in Japan and Bangkok in Thailand). The outline of the method for the study is shown in Figure 2. First, basic information such as ground elevation and land

use was digitized. Second, sea level rise and related impacts in case of 1 meter rise in sea level were estimated. Then, using the results of the estimation, land use suitability in the study areas after 1m sea level rise were estimated. Finally suitable land use pattern was simulated.

2. Niigata case study

Niigata area is located in the northern part of Japan as shown was in Figure 3. The study area is mostly lowlands and the central part of the area had been lagoon area before it changed into paddy field. Some of the areas are below sea level even now. East of the area is relatively urbanized, due to the expansion of Niigata city area. The method for Niigata case study is shown in Figure 4.

2.1 Digitization of basic information

In the first step in Figure 4, basic information was collected and digitized. As one of the basic information, present land use is shown in Figure 5.

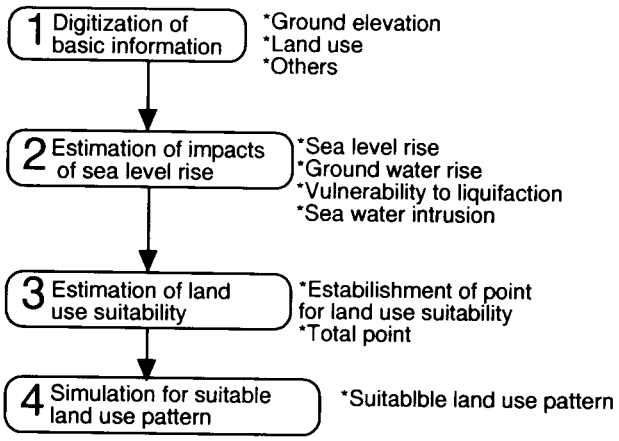

Fig. 2 Outline of method for the study

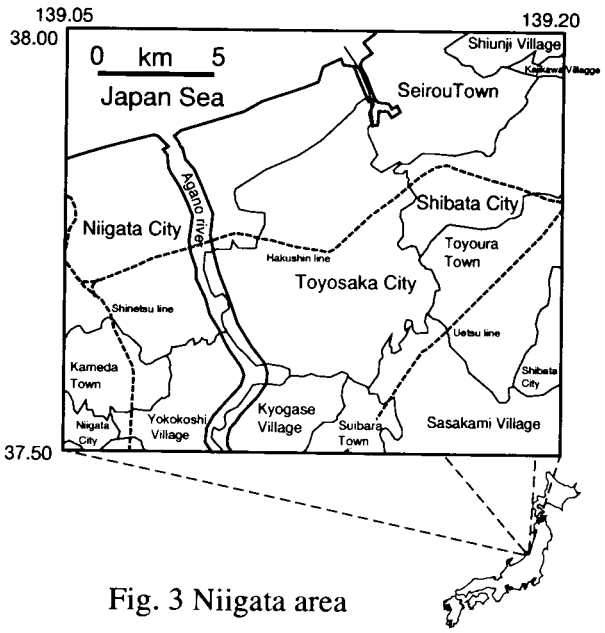

Fig. 3 Niigata area

2.2 Estimation of impacts of sea level rise

In the second step, two kinds of impacts by 1m sea level rise were examined other than sea level rise itself. One is ground water rise. The rise in ground water was estimated by the recursion method using the relationship between ground water height and ground elevation at present. The other impact is liquefaction caused by earthquakes. The vulnerability of liquefaction at Niigata 1964 Earthquake-level within the study area was estimated by neural network method. In the method, distribution of liquefaction caused by 1964 Niigata Earthquake was chosen as training data and ground elevation, present land use, land form, and estimated ground water

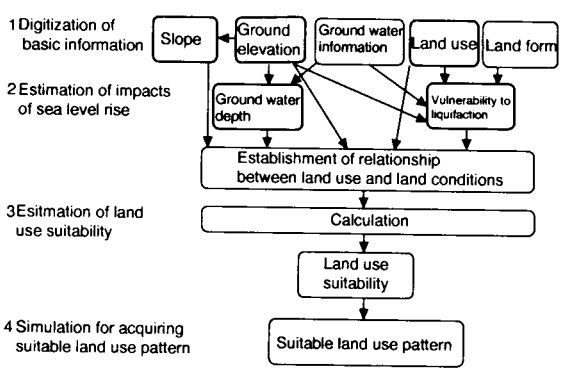

Fig. 4 The method for Niigata case study

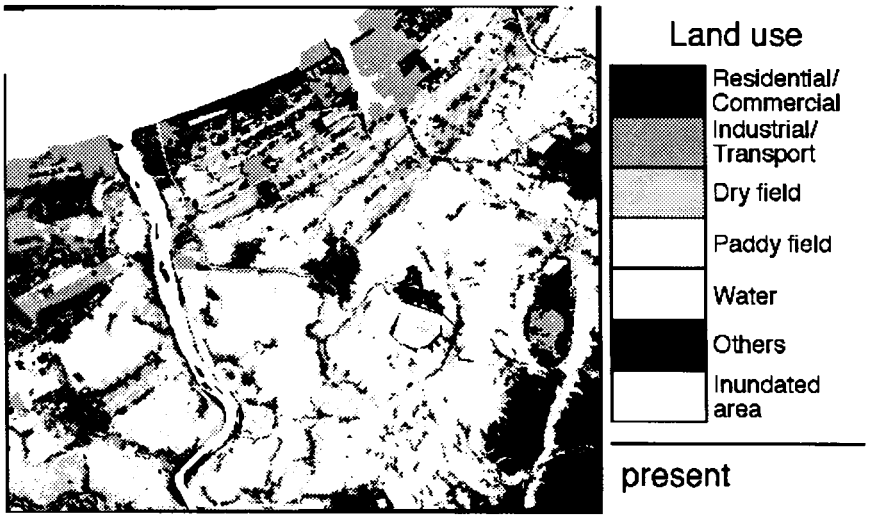

Fig. 5 Present land use

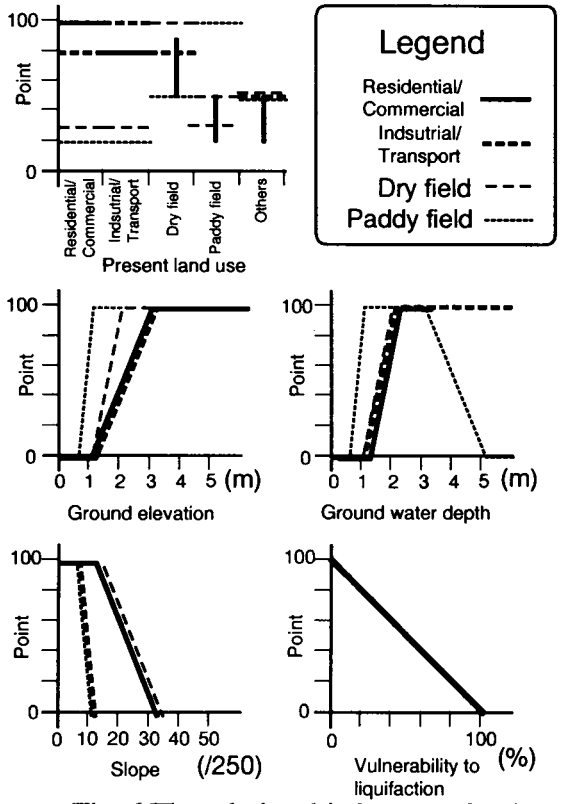

Fig. 6 The relationship between land condition and land use suitability

level were used as explanation variables.

2.3 The grasp of land use suitability

After the acquisition of basic information and the estimated impacts of sea level rise, the relationship between land conditions and its suitability to each land use species were established. In this case study, ground elevation, ground water height, land use, vulnerability to liquefaction and slope were chosen as land conditions that determine the suitability of land use.

The suitability of land use was denoted in figures whose range is from 0 to 100. The relationship between land use suitability and land condition by each land use was assumed as shown in Figure 6. For example, if the ground elevation is below 1m, the land use suitability as residential/commercial area is 0 and if the ground elevation is more than 3m the suitability becomes 100. As one of the land conditions, present land use is used for evaluating the convertibility from one land use to the other. In case of land use conversion from dry field, paddy field and others to residential/commercial area, the proximity of a locality to present residential/commercial area was taken into account, in considering to the cost for infrastructure investment

Then, the point of total land use suitability was acquired by the following equation.

Total point=((Plu*Wlu)+(Pwd*Wwd)+(Psl*Wsl)+(Plf*Wlf))*Pgl

where,

Plu:Point of land use suitability of present land use,

Wlu:Weight for Plu,

Pwd:Point of land use suitability of ground water depth,

Wwd:Weight for Pwd,

Psl:Point of land use suitability of slope,

Wsl:Weight for Psl,

Plf:Point of land use suitability of liquefaction,

Wlf:Weight for Plf, and
Pgl:Point of land use suitability of ground elevation.

The total sum of weight is 1 and the each weight is different from land use by land use as shown in Table 1.

2.4 The simulation of suitable land use pattern

In order to get the suitable land use pattern after 1 meter sea level rise, following method was considered. First, a certain area of the specific land use was assigned to the areas where the suitability of the land use is high. Then the next land use species was examined. If there is no vacant areas, the assignment is finished.

The ratio of areas assigned to each land use was assumed to be the same as the present ratio of land use. The considered land use species for redistribution was four: residential/commercial area , industrial/transport area, dry field and paddy field. The water areas was assumed to be invariable except the newly inundated area by sea level rise.

In this simulation, the amount of total demand of each land use was assumed to be 70% of the present areas of each land use, in considering to the future trend of population decrease in Japan.

Figure 7 shows the result of the simulation. By comparing to Figure 5, it was clarified that 1) many areas will be inundated, 2) most of low land will be suitable for paddy field in lowlands, 3) residential areas in plain become suitable for paddy field and 4) some of residential areas and industrial areas can be removed in the hilly areas in the south eastern of study area. The shore area became "others". No land use was assigned in this area because of the ill land condition. This area could be a kind of buffer zone between waterfront and inland areas.

Land use	Residential /Commercial	Industrial/ Transport	Dry field	Paddy field
Present land use	25	35	35	20
Ground water depth	25	25	20	30
Slope	25	20	25	35
Vulnerability to liquifaction	25	20	20	15

Table 1 The weight of each land condition

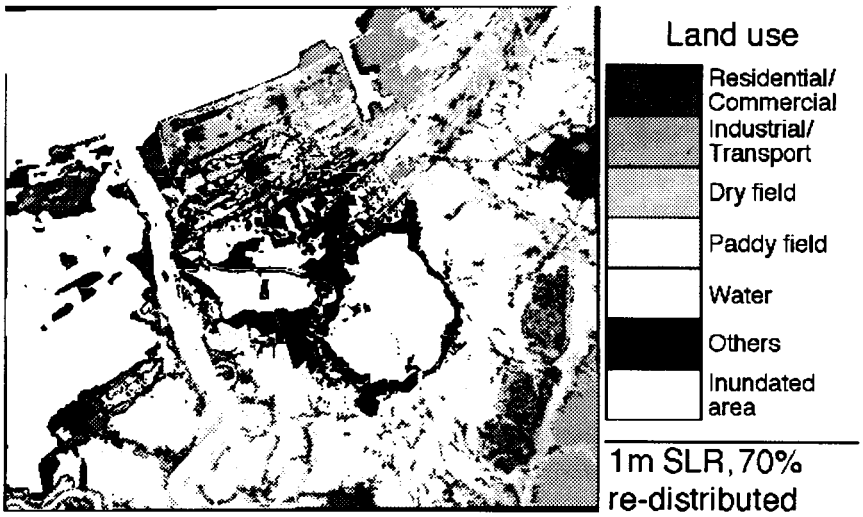

Fig. 7 Land use pattern in case of 1m sea level rise, Niigata area

3. Bangkok case study

Bangkok is the capital of Thailand. More than 6 million people live in the city. Bangkok area is shown in Figure 8. The Bangkok metropolitan area is located in the center of the area. Chaophraya river runs through the area from the North. The area is entirely a part of Chaophraya delta where the ground elevation is 3 meter at most. The delta has suffered flood in the late of rainy season. The method for the study area is shown in figure 9.

3.1 Digitization of basic information

First, basic information for the study was acquired. Unlike the Niigata case study, there is no land use map of the area so that satellite images were used as the land use information. Figure 10 shows the land use of the study area. The urban area is developing in the central part of the area. Coastal areas in the west side of Chaophraya river is used as fish pond and shrimp pond.

3.2 Estimation of impacts of sea level rise.

In the second step in Figure 9, impacts related to sea level rise were estimated. One impacts is the rise of ground water induced by sea level rise. The other is the salt water intrusion.

The rise of ground water was acquired by the extrapolation of estimated rise of water level of Chaophraya river. The rise of water level of Chaophraya river was estimated from the degree of tidal oscillation, observed at several stations along the river.

Salt water intrusion after 1 m sea level rise was estimated by the following method. First, distribution of salt water concentration within the area was estimated from the results of field survey and some documents. Then the distribution was shifted in accordance with the averaged progress of coast line after 1 m sea level rise.

3.3 Change of land use suitability

Referring to the results of the estimation stated above and other documents, the relationships between the ground water depth and land use suitability and salt water concentration and land use suitability were examined. Considered land uses spices are as follows; Public area, Commercial area, Residential area, Industrial area, Orchard, Paddy field and Fish pond. In case of salt concentration , Orchard, Paddy field and Fish pond were considered.

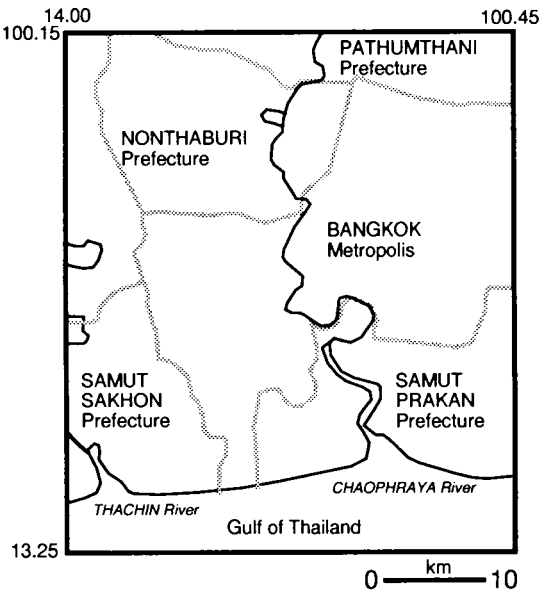

Fig. 8 Bangkok area

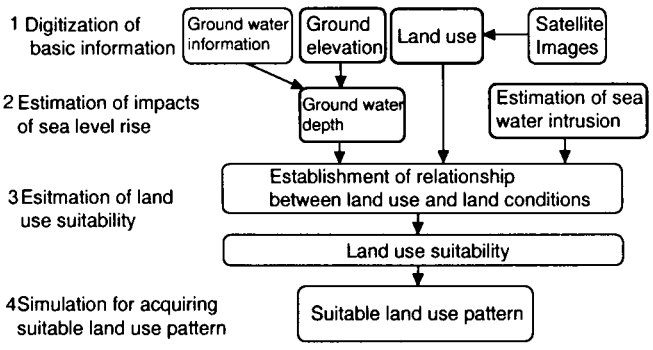

Fig. 9 The Method for Bangkok case study

Using the relationships, the land use suitability distribution was acquired. The distributions suggest that the suitability will alleviate in future sea level rise in most land use species. And applicability of paddy field cultivation become seriously decrease in case of 1m sea level rise in the study area. These results suggest the future measure implementation.

3.4 Simulation for suitable land use pattern

As one possibility of adaptation measures to sea level rise, redistribution of land use in the area was examined. The method was as follows: 1) Inundated area by each land use was calculated at 1m sea level rise. 2) The inundated area of public area was compensated by assigning the area to the remained area that is adjacent to present public area. 3) The commercial inundated area and commercial area replaced by the public area was compensated by the same method explained in 2). 4) Then, residential area, industrial, orchard and paddy fields was treated as the same way as that of commercial and public area. 5) Areas below 0.4 meter was converted into fish (shrimp) pond.

The results of the simulation was shown in Figure 11. The southern part of the land was broadly inundated even by 1m sea level rise. The compensated land use was assigned to northern areas.

4 Summary

Both in Niigata area and Bangkok area, redistributed land use pattern that is adaptive to 1m sea level rise was acquired, in considering to the several kinds of effects of sea level rise such as ground water rise or salt water intrusion.

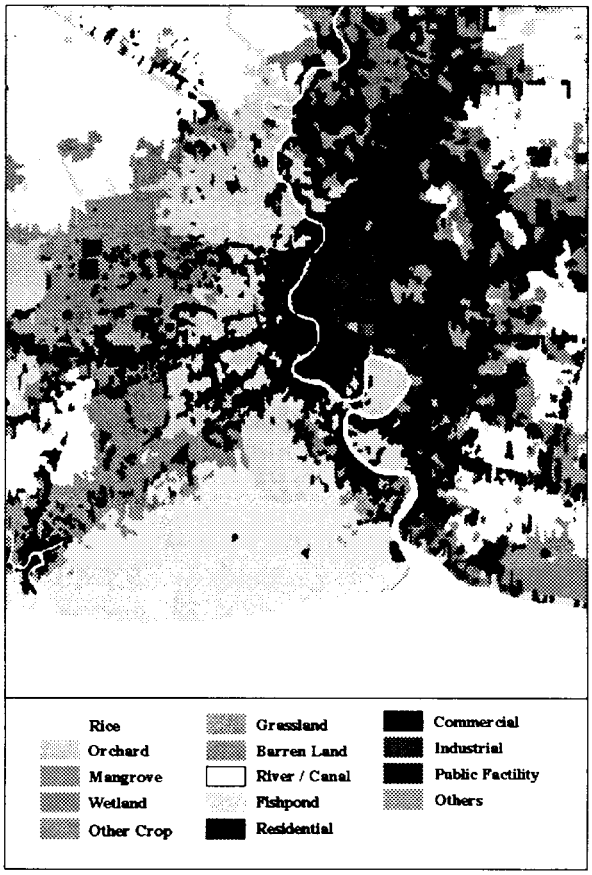

Fig. 10 Land use of Bangkok

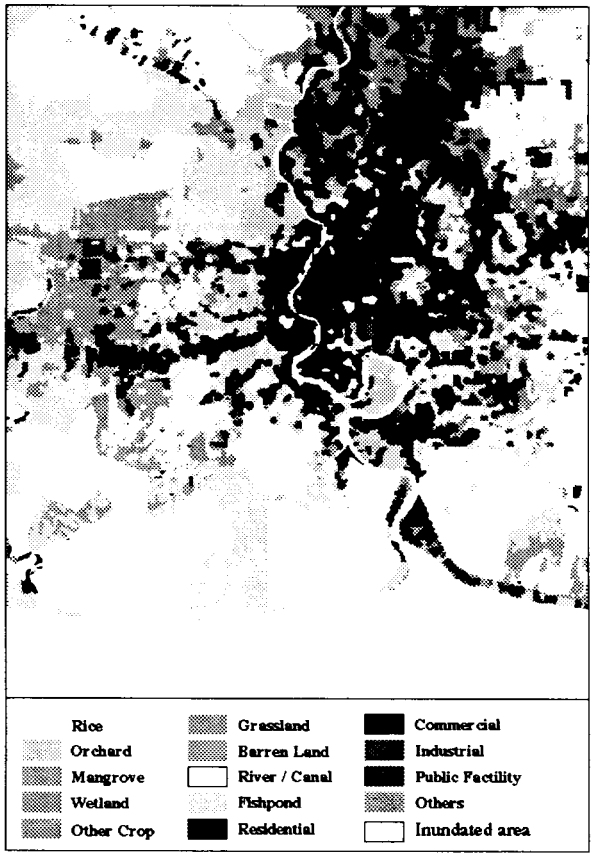

Fig. 11 Simulated land use of Bangkok

The results of the simulation of land use pattern shows the possibility of the conception of "land use redistribution strategy" as a measure to sea level rise. The strategy for the management of coastal land use differ place by place. The land use redistribution strategy will become important in the rural coastal area where the funding for maintaining present land use pattern is difficult. Also, the redistribution of land use is useful for the sustainable land use policy, in accordance with the potential of land use suitability that is determined by the natural condition in an area.

Although the method used in the study for redistribution was rather simple and sometimes shows unrealistic results, future development of the method is expected for more sophisticated natural resource management in coastal areas where future sea level rise would inevitably bring impacts.