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Full Paper

IMPACT EVALUATION OF SEA LEVEL RISE ON INDONESIAN COASTAL CITIES -MICRO APPROACH THROUGH FIELD SURVEY AND MACRO APPROACH THROUGH SATELLITE IMAGE ANALYSIS-

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Abstract

This Research aimed to quantitatively evaluate the impact of sea level rise on coastal cities in Asia-pacific region, through studying 7 Indonesian various coastal cities. Loss of materials and human time was identified from measurement and interview of 84 sample houses, while total area of each land use type and contour zone identified through analyzing satellite image. Finally, total impact on each city was measured for several assumed cases. For this purpose, not only the "price" or "cost" as the final summary, but also "amount of resources lost" per hectare will be useful and appropriate for international comparison and summing up in the field of human settlements as a semi-ecological process.

KEYWORDS: *sea level rise, Indonesian coastal cities, field survey, satellite image, GIS*

1. Introduction

Sea Level Rise (hereinafter, referred as SLR), attributed to Global Warming, is estimated to be 90cm in A.D.2100 at the maximum case (Mimura and Harasawa, 2000). Various countermeasures are under discussion to reduce green house gases (GHGs), including international co-operation scheme.

On the other hand, impact of SLR is concerned in various aspects, including geography, natural ecosystem, human settlements and social systems. Especially in Asia-Pacific region where large population concentrate in coastal wetlands the strategies for adaptation would be important.

However, detailed features of impact of SLR on densely populated coastal cities in developing countries have not been studied yet. Even though key-note addresses in the international congresses on global environmental issues usually underline the fear of serious damage to coastal human life, many following reports refer to e.g. coral leafs or mangrove forests (Global Change and Asia Pacific Coasts, 2000). Several economical analysis have mentioned about housing area, however, they paid more attention to the industrial and commercial area, while housing area is merely referred in terms of land price and population

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infected (Mimura and Harasawa, 2000).

In the near future, more detailed evaluation of magnitude and extent of impacts on urban settlements will become urgent. Moreover, evaluation with regarding the best adaptation strategies should be undertaken, considering the total cost for adaptation.

The global sum of the net impact needs to be compared with the total cost for reducing emissions.

This paper reports the result of studies in Indonesia between 2000-2002, where the total length of coast line is estimated as more than 80,000km. The reasons for selecting this country are: (1) various types of cities are included and methodology developed here is expected to be highly replicable to other Asia-Pacific cities, (2) vast "unknown" area of islands in Asia-pacific vulnerability map has to be investigated. Also in future, discussions for adaptation strategy, regarding international co-operation scheme, will be needed.

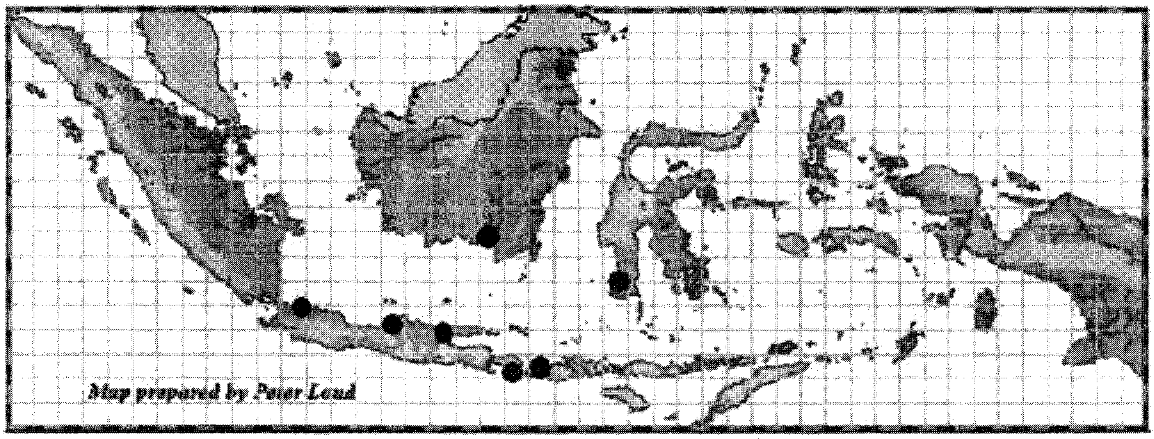


Fig. 1: Location of target cities (In FY2001, sampled typical houses were measured)

2. Methodologies

2.1 Fact finding survey (Zubaidah et al., 2001)

In the first fiscal year (FY2000), 6 cities were observed through field survey, in order to list-up the possible phenomena caused by the future SLR. Types of urban districts and urban houses were listed. Contents of damages caused by flood and high water (inundation) were recorded. Especially the situation in land subsidence zone was quite suggestive for identifying what will happen after SLR. And also, various forms of adaptation to high water were recorded, including re-location, reclamation, reconstruction of houses, provision of polder and pumps, etc.

2.2 Microscopic measurement of sampled houses for identifying the basic unit of damages (Zubaidah et al., 2002)

In next year (FY2001), 84 houses were sampled from 7 cities containing different district types, and measured precisely in order to know the amount of materials used for those houses and man-days for construction. Through field survey, physical measurement was recorded in the form of drawing with scale, including furniture. At the same time, in-depth interview was carried out to know the frequency, extent and contents of damages caused by inundation. It was rather difficult to ask the "price" for reconstructing or repairing buildings. Therefore, amount of materials and manpower invested for construction, or lost through disasters were also more reliable indexes to measure the quantity.

These indexes were utilized as basic units for evaluating stocked resources and damage for average building unit, and they were multiplied by building density of each district type to obtain the basic units per hectare.

2.3 Macro analysis of satellite image on GIS (Kobayashi 2003,2004b,Nakajima 2003)

Geographical maps provided by Indonesian *National Coordinating Agency for Surveys and Mapping* (BAKOSURTANAL), with scale of 1:25,000 for Jawa Island and 1:50,000 for other islands, were scanned and saved in GIS system, based on the UTM coordinates noted on these maps.

Throughout 3 years, several kinds of satellite images available, including LANDSAT7, SPOT and IKONOS were monitored and compared, from viewpoint of quality (mainly rate of clouds), resolution for identifying building/district type and land use, etc. The original satellite images were converted to orthogonal images, through several obvious objects whose locations are identified on geographical maps. Finally, those images are stored into GIS system and the following analysis was carried out:

(1) Boundaries among different land-use, building typology were identified. Each area of land-use/building type was stored in the form of polygon, so that the total area of each land-use could be summed up.

(2) Altitude zones were identified, based on singular points on geographical maps noted with altitude (1m, 2m etc.). Coast lines are also referred for this identification.

(3) Cross-tabulation between land use zones and altitude zones was executed on GIS in order to know the configuration of land-use in the area where the land will be submerged after SLR.

(4) Each segment of land-use was multiplied by the index, that show the basic unit per hectare, in order to calculate the total loss caused by SLR as for whole city.

2.4 Consideration of adaptation strategies (Zubaidah et al. 2003, Research Institute for Human Settlements, Bandung-Indonesia, 2003)

The assessed damage will occur if no adaptation will be applied. However, through the field survey, several kinds of adaptation applied by communities, or by individual inhabitants, were already identified. These efforts reduce the damage, while requiring additional expenditure to their daily life. Most typical adaptation takes forms of (1) reclamation, (2) re-construction (3) relocation, (4) provision of polder and pumps and (5) introduction of high-rise apartments etc. The application of these strategies is described as changes of land-use or changes of altitude zone on GIS. The costs are evaluated through field interviews or reviews of project documents. The adaptation was discussed in the last workshop (2003.3) (Zubaidah et al., 2003).

3. Results

3.1 General observation through fact-finding survey

(1) Land-use and building types (Kobayashi, 2000)

Urban districts were classified into (a) un-planned housing area, (b) planned housing area, (c) market and commercial area, (d) public buildings, (e) factories, (f) Open spaces/greenery, (g) rivers and ponds, etc. Among these, un-planned housing areas, which have been developed in vernacular way without any formal planning, and identified by narrow and irregularly shaped streets through satellite images, is dominant in the coastal low-wet areas, and large impact from SLR is expected. Usually, this type is identical to the traditional houses in surrounding rural area and different from city to city.

In short, houses in un-planned area in Indonesian cities are classified into three categories, namely

(T1) Landed house: 1 or 2 story, usually made of bricks, typical in Jawa island.

(T2) Platform house above land: single story with a raised floor on house lot, usually made of timber, typical in Sumatera, Kalimantan and Sulawesi islands. This type is also popular in other Asia-pacific countries, including Japan.

This type suffers less from inundation than (T1), however sometimes, the lower part was modified for rental rooms or shops in urban densely inhabited condition, causing more damage by inundation.

(T3) Platform house above water: single story with raised floor without house-lot, usually made of timber. This appears in any cities in the areas along rivers or seacoasts.

Modernized houses in planned housing areas, commercial area, factory and public building areas are rather common to all the surveyed cities, in contrast to the un-planned housing area.

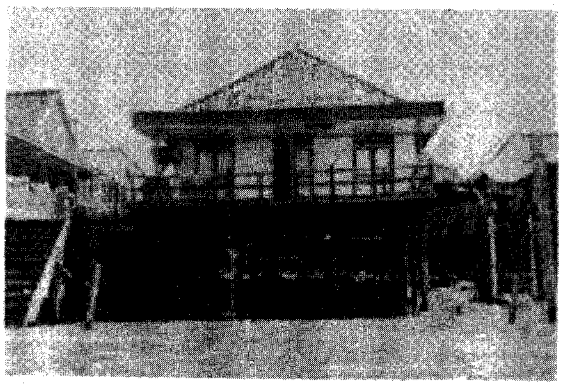


Photo 1 Platform house above water, Palembang

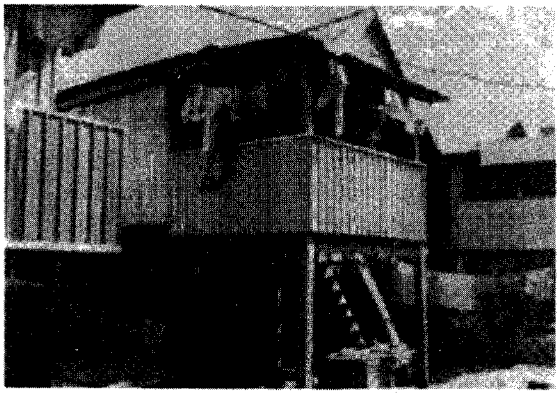


Photo 2 Platform house above land, Makassar

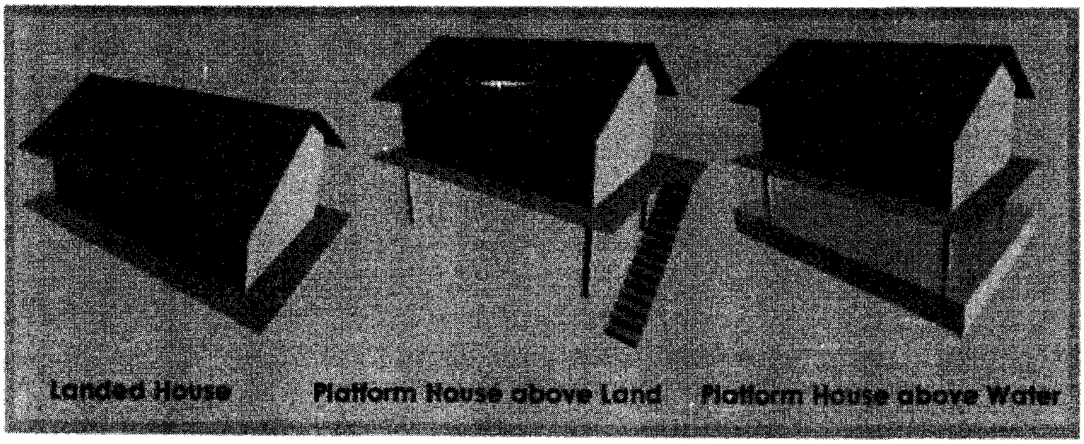


Fig. 2: Three basic types of popular houses

(2) Phenomena forerunning impact of SLR

Land subsidence is occurring in several cities, most drastically in Semarang city, where the speed of subsidence exceeds 20 cm per year at several districts. In those cases, landed houses are suffering very frequent damage of high water, and some of the housing areas are abandoned and becoming ghost towns (Photo3).

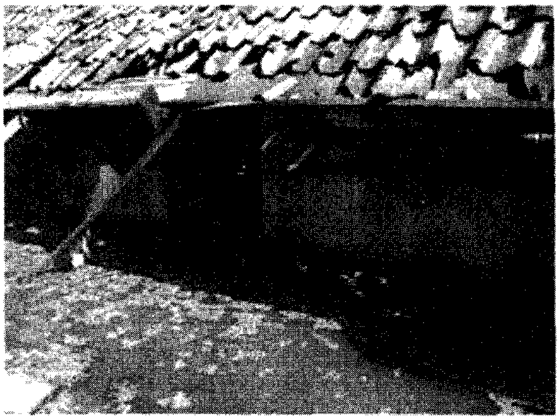
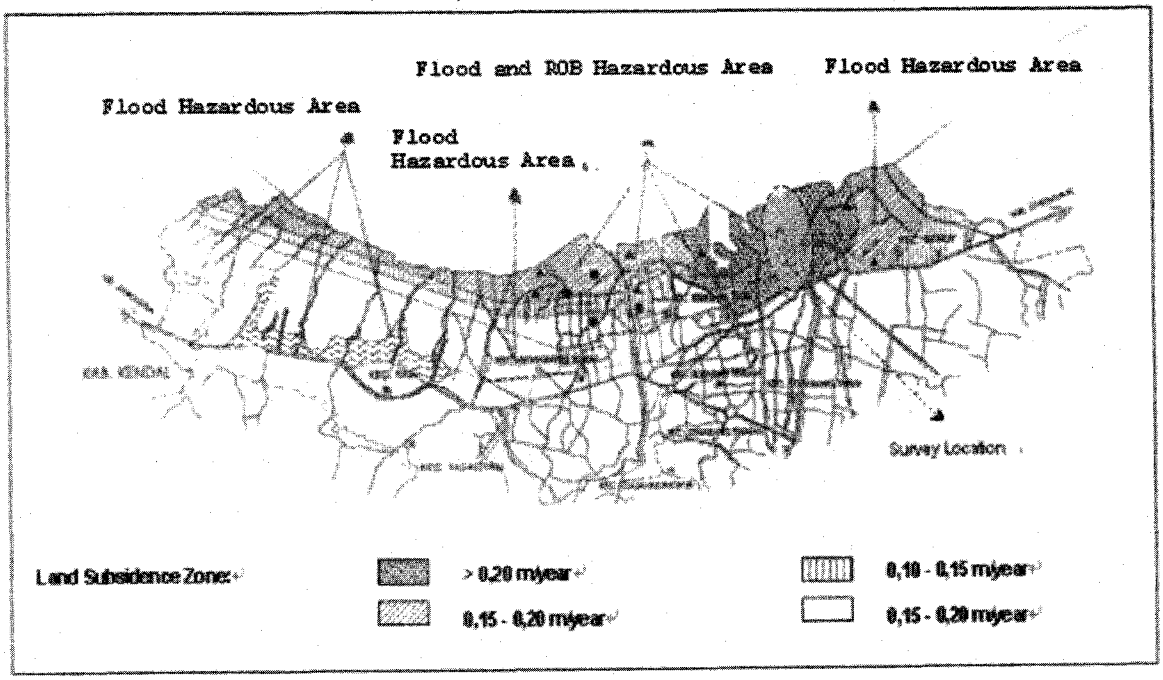


Photo 3 Abandonned house, Semarang

Photo 4 Inundated road, Semarang

In the remaining houses, inhabitants pay efforts to carry sand onto the ground floor by their expenditure (Photo 5, 6). Some capable families demolish the damaged houses, reclaim the land and re-construct higher houses on the enhanced house-lot (Photo 7).



Source: Agency for Regional Development, Semarang City (2002)

Fig. 3: Distribution of land subsidence, Semarang

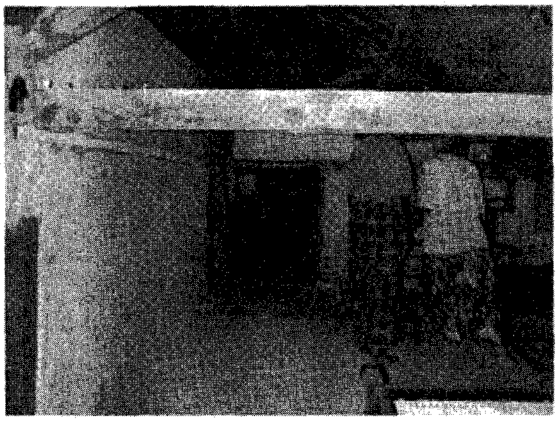



Photo 5, 6 Adaptation, by heightening the ground floor by sand, Semarang

(3) Adaptation by local communities

In addition to this, several forms of more social adaptation were observed. For example in Semarang city, the open space in front of a railroad station was converted to a spatially designed retaining pond, provided with pump, in order to reduce the depth and duration of inundation, that is to be operated at expenditure of the local community. Public rental houses with 5 stories were also tried out (Photo 8). Planned housing area on the reclaimed land is also developed. These show the possible alternative ways for the adaptation to SLR in future.

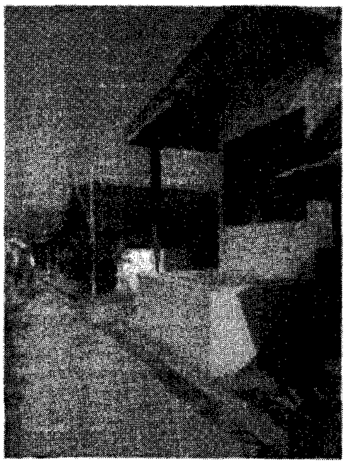


Photo 7 Re-constructed house

Photo 8 Flat apartment with pilotis, Semarang

(4) Damage caused by inundation

Inundation causes damage of physical houses. This includes (1) structural damage (2) aesthetical damage (3) damage of furniture, and (4) acceleration of deterioration (or shortening the length of life).

Social damage caused by inundation was also identified, including stop of business and schools (income opportunity), etc. That means, the total impact of SLR is not confined in the area where the land level will become lower than the seawater level, but also covers the area where the frequency and depth of inundation will be higher.

3.2 Quantitative evaluation of impacts

(1) Typology of urban districts

Methods for classifying urban districts should be significant in terms of evaluating total impact of SLR, and also should be distinctive on satellite images. In case of satellite image with rather low resolution (LANDSAT 7, or SPOT), very rough classification of land-use or building type is available, while in case of that of high resolution (IKONOS), identification of each building is possible. For that purpose, pan chrome image is enough and color information is not essential. In this study, high-resolution satellite images were tried only in Semarang and Jakarta. In the best case (Jakarta, northern coastal area), such classification was possible to apply, as:

(a) un-planned housing areas (streets are narrow and inaccessible for automobiles)
(b) planned housing areas (streets are accessible for automobiles, and they are identified on streets)
(c) multi-story housing areas (apartments and condominium etc. with more than 3 stories)
(d) public buildings (large buildings whose site planning is identical on satellite image)
(e) commercial areas (market, or linear continuous series of shop houses)
(f) factories and storages
(g) Highway / wide streets (with no less than 6 lines, including fly-over)
(h) open space (including public buildings under construction)
(i) water surface(pond, river, etc.)

(2) Identification of basic unit

In this study, most efforts were paid for identifying the basic units for (a) un-planned housing areas and (b) planned housing areas, because they covered the wide areas of coastal zone. Another reason is that the contents of them are rather homogeneous within a city, but different among the studied cities. For other types of land use, an index common to all the cities seems to be applicable, and still under investigation.

As mentioned above, "direct enquiry about the price of buildings" was difficult to be reliable, or even difficult to be answered. Moreover, there is a great diversity of the prices among cities and unstable change of the price. Therefore, in this study, we measured the buildings and summed up the amount of each building material. The price could be calculated through applying the basic price at the time of evaluation.

The measurement of houses was undertaken in FY2001, through selecting 84 sample buildings from 7 target cities. Random sampling was impossible, because of lack of the basic record or statistical data. We chose the areas where inundation is occurring frequently, and requested to the local communities to select households ready for our survey. We measured the buildings and furniture, and also interviewed to the family about the experiences of past inundation using questionnaire. The result of the identification of the materials and measurement of size of the major parts of the buildings was tabulated in tables 1 and 2. Based on these data, basic unit of resource investment per hectare are calculated, for macro analysis.

(3) Zone identification through satellite image analysis

Fig. 4 and 5 show the result of identification of zones of land-use, through the method mentioned in 3.
The result was tabulated as area (hectare) for each land-use and altitude zone (Table 3).

Table 1 Major materials for each part of building, for each city

City Part ob bdg	Jakarta	Semarang	Surabaya	Denpasar	Mataram	Makassar	Banjarmasin
Type	landed, mostly 2 storied	landed 1 storied	landed mostly 1 storied	landed 1 storied	landed 1 storied	platform on land, with ground floor converted to rooms	platform on land & on water 1 storied
Foundation	brick, stone	Brick	stone	coral stone	brick	column on stone	Timber underground
1st floor	tile, plaster	cement +soil	plaster, etc.	cement	plaster	plaster etc.	timber
2nd floor	tile, timber	-	-	-	-	timber	-
Wall of 1st floor	Brick	brick, timber	brick	brick	brick, timber	brick(infill),tim ber	timber
Wall of 2nd floor	brick, timber	-	-	-	-	plywood, iron	-
Sash	Timber	timber	timber	timber	timber	timber	timber
Door panel	Timber	timber	plywood	timber	timber	timber	timber
Ceiling, hanging	Timber	timber	timber	timber	timber	timber	timber
Ceiling, finishing	plywood asbestos	plywood, asbestos	plywood, asbestos	bamboo-m at, plywood	bamboo-mat	plywood, plastic	plywood
Roof structure	Timber	timber	timber	timber	timber	timber	timber
Roof finishing	Roof tile, asbestos	Roof tile	roof tile	roof tile	zinc plate	zinc plate	zinc plate

Table 2 Average size of major parts of buildings, for each city

city→	Jakarta	Semarang	Surabaya	Denpasar	Mataram	Makassar	Banjarmasin
Age(years)	27.2	22.6	27.4	14.1	9.8	22.3	36.7
1st fl. area(m^3)	51.2	74.2	78.2	89.0	44.7	47.7	89.3
2nd fl. area(m^2)	38.3	0.0	3.8	0.0	0.0	27.3	5.9
Foundation(m^3)	24.2	24.1	32.2	89.0	7.4	46.1	3.1
Wall of 1st fl.(m^2)	122.1	120.3	166.3	225.7	123.9	120.3	172.6
Wall of 2nd fl.(m^2)	90.3	0.0	11.4	0.0	0.0	73.3	20.4
Door & window (m^2)	12.1	14.5	15.4	13.9	12.4	10.1	26.7
Sash (m^2)	7.7	3.5	8.2	10.4	5.3	5.5	8.9
Ceiling (m^2)	84.5	30.2	39.0	89.0	13.7	44.15	75.3
Roof area(m^2)	89.5	107.9	103.8	108.9	82.1	75.0	unknown

(4) Identification of the total influence

For simple assessment, as proposed by SURVAS (Global Change and Asia Pacific Coasts, 2000) to the whole coastal countries in the world, the area lower than 1m could be summed up as (Table 3) in case of Semarang city. In case of Makassar, all the areas under 1m above average sea level are classified as "Un-planned housing area". They are expanding into the low-wet area, and consist of platform houses above land. Therefore, the total loss will be summed-up as Table 4.

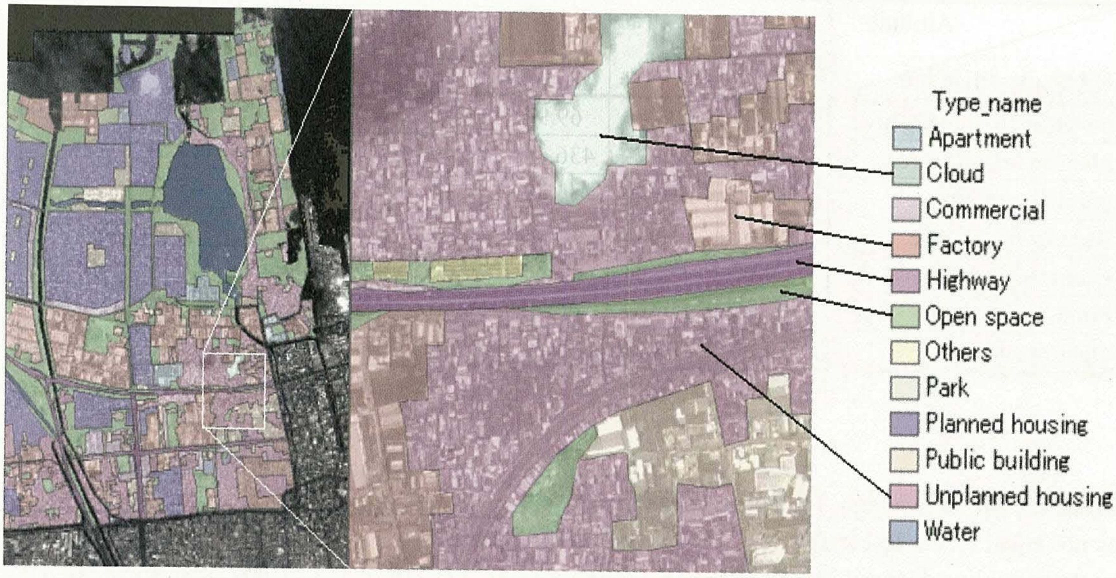


Fig. 4, 5: Examples of identified land-use/building type from satellite image (IKONOS) on GIS, Jakarta.

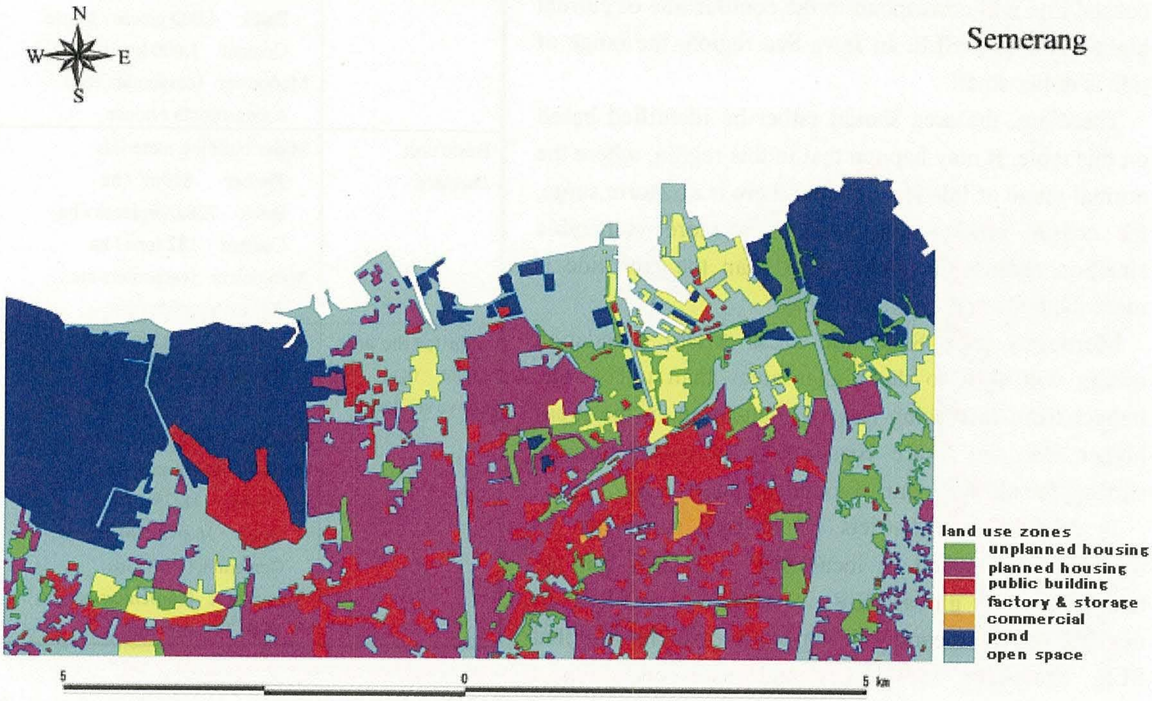


Fig. 6: Identified land use zones, Semarang

Table 3 Cross distribution for land use – altitude in the area, Semarang

Altitude / Urban classification	0-1m	1-2m	2-3m	3-4m	4-5m	5-10m	10-12.5m	12.5m-
un-planned housing area	171.37	128.06	69.94	11.07	8.93	22.07	26.04	11.88
planned housing area	314.40	316.79	436.64	68.59	39.76	140.43	118.91	128.46
public buildings	69.80	216.76	133.52	21.14	14.95	70.79	47.52	25.92
Factory/warehouse	150.62	56.42	17.53	1.04	2.01	16.94	9.01	20.04
Commercial area	0.00	3.41	13.83	0.00	0.00	0.00	0.00	0.00
Pond	607.89	114.64	64.70	66.54	69.55	217.87	5.37	0.00
Open space	584.80	199.39	315.36	73.39	53.00	115.65	72.22	95.42

However, the area under 1m above mean sea level does not equal to the lost area after SLR of 1m, as the current coastal line does not corresponds to the mean sea level, but to the "highest level" of normal tide. Future coastal line will correspond to the contour line of current highest tide plus SLR. In Jawa Sea region, the range of tide is rather small.

Therefore, the area should rather be identified based on this table. It may happen that in this region, where the normal range of tide is small and there is no storm surge, the coastal environment will result more vulnerable situation against the global SLR than the area tide is more dynamic and un-stable today.

Moreover, after SLR, the areas where inundation occurs will shift to the higher areas than today. The impact from increasing risk of inundation in the areas higher than the future coastline is estimated through shifting the altitude zone of inundated areas today.

In the cities or districts where land subsidence is occurring, the speed of local SLR is higher, but the contribution of global SLR is relatively small (even negligible). The meaning of impact assessment of global SLR excluding the local land subsidence needs discussions. The partial contribution of SLR among the total damage should be evaluated. In future, it might be possible to reduce the local land subsidence through e.g. regulating factories for usage of ground water, along with alternative provision of water supply from dams, as discussed and studied by Semarang City now.

Table 4 Total loss for Makassar city

Density	182 houses / ha 255 households / ha
Basic unit / house	Major building materials Timber 4.5 m^3 / house Brick 4,000 pieces / house Cement 1,000 kg / house Manpower (carpenters etc.) 4 man-month / house
Basic unit / hectare	Major building materials Timber 819m^3 / ha Brick 728,000pieces / ha Cement 182 tons / ha Man power (carpenters etc.) 728 man-month / ha
Sum for the area, lower than 1m above sea level	Lost land 22.9ha Affected population 5,840 households Affected buildings 4,168 houses Major building materials Timber 18,755 m^3 Brick 16,672,000 pieces Cement 4,167.8 tons Man power (carpenters etc.) 16,672 man-month

Table 5 Estimation of contour line after SLR, regarding tidal index

City	(1) M2	(2) S2	(3) K1	(4) O1	Sum of (1)-(4)	After SLR
JAKARTA	0.05	0.05	0.25	0.13	0.48	1.38 m
SEMARANG	0.10	0.08	0.22	0.03	0.48	1.38
SURABAYA	0.35	0.21	0.47	0.26	1.29	2.19
BANJARMASIN	0.31	0.05	0.59	0.32	1.27	2.17
MAKASSAR	0.08	0.11	0.28	0.17	0.64	1.54

(Data: Japan Hydrographic Association)

3.3 Discussions in Local Seminars and Workshops

In the end of every fiscal year between 2000-2002, we held a seminar in Bandung, where the results of the field survey and analysis of satellite were reported together, and discussed with attendance of Indonesian resource persons and governmental officials in charge (coastal engineering, geology, and urban planning etc.). Especially in the last seminar (March 2003), after the presentation, we had an intense workshop on the adaptation. The participants were subdivided into three groups and discussed on the the adaptation at (1) city wide scale, (2) community scale and (3) individual scale. In the workshop, members noted each idea and opinion onto a small piece of paper and put it on the panel in front, to obtain the structural understanding of the issues (Photo 9).

Photo 9 Workshop in Bandung, on adaptation (2003.3)

4. Discussion

4.1 Method for assessment (toward more accuracy and reality)

For the time being, total view of extent and magnitude of the impact of SLR is requested, even though rough and less accurate. However, if we start discussions on the actual adaptation for each coastal city, we need more realistic scenario. In case of urban human settlements, it will never happen that inhabitants passively suffer from the rising sea without any countermeasures, if the rising occurs very slowly for the long time. Therefore, the net impact will be assessed with assumption that they choose the best efficient way of adaptation. The impact will include not only reduced loss from SLR, but also cost for the adaptation.

However, the communities might not easily select the most appropriate. There are many constraints, related to institutional, or cultural aspects of the local community, and it will be a long process to reach to the consensus. For that reason, we had held series of discussions in the local workshop.

As a result, we realized that a basic paradigm of urban planning and urban development is difficult to change drastically, even when we take SLR into account, and many opinions were to strengthen the past approaches, which were oriented to better safety, health and security, etc. However, at least, it has become clear that many inhabitants of the coastal zone are in the position to suffer from the global environmental problem, and they came to the concept that "urban development needs good balance with the nature"(Title of a column in a local newspaper, which introduced that workshop). They realized that the un-rational development or un-controlled urban extension would result the most vulnerable areas.

4.2 Amount of resource and human time, as basic unit for measurement and description

In case of Makassar, the estimated damage was 4,168 houses or 4,840 households. If describe this as price, approximately equals to 11 million US$, and equivalent to the price of merely 20~30 units of Japanese average urban detached houses. This is because of the very low local price of labor (carpenters etc.), which is 1~2% of Japanese one. Therefore, if we simply sum-up the price of materials and manpower costs, the actual damage will be hidden away. This basic price is not stable and will change. There are several methods for calibrating this value. However, in order to compare among countries, or to sum-up impact for many countries, our method of using more original quantitative amount of the related resources and manpower will help us for better understanding of the actual situation. Moreover, the unit of manpower or human time (mandate) for re-constructing the damaged houses has the same dimension with human time loss due to the inundation, or even with the time of rest life of the victims.

4.3 Assessment of vulnerability, based on the discussions on adaptation

As for initial rough assessment, we simply assumed 'vulnerability' as amount of loss caused by SLR. It may be useful for that purpose. However, this will be far different from actual scenario. We should assess a case as "vulnerable", only when the urban land and estates on it will not be kept safe by any countermeasures against SLR with reasonable costs.

If some countermeasures will be implemented to save the simple loss (total assets in the area where the altitude will be under the future sea level), then the net loss will be readjusted to the "reduced loss + cost for adaptation" (Fig.7). If some countermeasure can effectively reduce the loss at reasonable cost, the situation will be evaluated as "adaptable" (Fig.7[1]), while any effective countermeasures cannot reduce the loss or will require huge cost, the situation will be evaluated as "vulnerable" (Fig.7[2]).

From another point of view, even though level of SLR is a continuous parameter, impact to a city will drastically rise after certain level. In such case, we can identify a certain limit of adaptation and call it "threshold for vulnerability".

For example, among cities we studied, Banjarmasin is located on a low, wet and flat land, comprising "platform" type timber houses. Until certain level of SLR, no change will happen to their daily life, however if SLR will exceed the threshold, the total city may disappear or have to move to distant place.

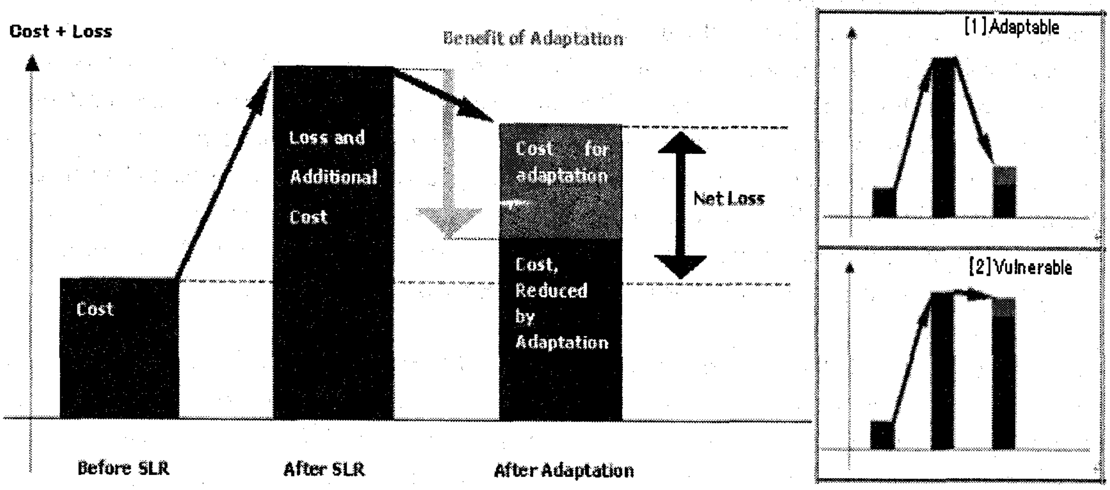


Fig. 7: Concept of Net loss, with best efficient adaptation

4.4 Socio-economical constraints

As mentioned before, the possible alternative adaptation will be in the form of re-settlement, reclamation, or change of building type, in the form of "project". However, the project will be accompanied with change of life style of inhabitants, and needs social adaptation, that may include change of income source.

Field survey reports and following discussions in the workshop suggested the difficulty of changing life style in low-income groups. Even if "re-settlement" is the best efficient way of adaptation, they cannot choose it being afraid of losing job opportunity, or being inaccessible to initial capital for investment. They might remain in the current site and will continue to pay for expensive rehabilitation, staying at very low level of daily life, accompanied with frequent inundation. They have to buy new cheap furniture frequently. They will continue to pay for frequent repair of their houses. This kind of socio-economical constraint will lower the limit of the adaptation, or threshold of vulnerability of the city.

In the global relationship, assistance from countries causing the problem to the suffering countries will be the primary solution, as a kind of international compensation. However, loan may have another effect.

The World Bank is making effort for establishing small-scale loan system for low-income groups. If the desired kinds of system will be established in the vulnerable areas, and help low-income people to choose the rational solution, it will create another channel for international co-operation.

5. Conclusions

This study clarifies the following.

(1) We observed and identified possible features of urban problems related to SLR in various coastal cities. Especially in the cities where land subsidence occurs, we have already observed phenomena that will occur after future SLR, as a kind of field simulation.

(2) We obtained several basic units per hectare for evaluating the impact of SLR, as for several different types of coastal cities. That will be useful for evaluating similar cities in Asia-pacific region.

(3) We developed a method for macro analysis by using high-resolution satellite images on GIS, that

enables summing up the total loss that will occur. This method is applicable to the cities in developing countries where secondary data is difficult to refer.

(4) Actual (net) loss after SLR should assume efficient adaptation taken by individual, community or local government. By this assumption, net loss will be the amount of loss reduced through the adaptation and the cost for the adaptation. The adaptation will be alternatively, (a) reclamation, (b) relocation or re-settlement, (c) re-construction or changing the building type, (d) provision of polder and pump, etc.

(5) Sosio-economical conditions, or even cultural condition, etc. might be barriers for choosing and implementing the best efficient way for adaptation. Therefore, in order to choose the practical way for adaptation, local seminars and workshops involving related stakeholders will be inevitable.

In the next stage (FY 2004-2006), the team will be funded from the Ministry of Environment, Japan for another research. In that activity, we will study about the future urban form considering climate change, and propose to several cities, regarding not only adapting to the impact of global warming and SLR, but also minimizing the emission, while keeping the conventional purpose of safety, health and comfort.

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