A GLOBAL VULNERABILITY ASSESSMENT: VULNERABILITY OF COASTAL AREAS TO SEA-LEVEL RISE

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ABSTRACT

Assessment of the global vulnerability (GVA) of the various resources of the world's coastal zones to an acceleration of sea-level rise (ASLR) and related climate change effects requires detailed global information on the distribution, density and state of the resources and on the impacting hazardous events. For many resources, such as ecosystems for instance, data on a global scale are not readily available. Another complication is that in order to assess the consequences of hazardous events the response of coastal systems and their response time scales need to be known at a sufficient level of accuracy, which is not generally the case. Within the limits of these constraints the GVA study (DELFT HYDRAULICS/Rijkswaterstaat, 1993) considers the following three resources of the coastal zone and accompanying impacts:

- population at risk (i.e. the number of people subject to regular flooding) on a global scale;
- wetlands at loss (i.e. the ecologically valuable coastal wetland area under a serious threat of loss) on a global scale;
- rice production at change (i.e. the potential changes in coastal rice yields due to less favourable conditions) in South, Southeast and East Asia.

INTRODUCTION

Scope of this study

The Intergovernmental Panel on Climatic Change (IPCC) in its First Assessment Report (1990) concluded that, if emissions of greenhouse gasses continue to grow as currently projected (a so-named Business-as-Usual scenario), then global mean temperatures will increase by 0.2°C-0.5°C per decade over the next century. One of the most important

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impacts of this global temperature change for the coastal zone is expected to be an accelerated sea level rise (ASLR). IPCC Working Group I (Climatic Change Group) projects a rise in global sea level of 30 cm to 110 cm by the year 2100, due principally to thermal expansion of the ocean and melting of small mountain glaciers.

Within IPCC Working Group III (Response Strategy Group) the Coastal Zone Management Subgroup (CZMS) contributed to the IPCC First Assessment Report by producing a CZMS Report on Strategies for Adaptation to Sea Level Rise. As a result of significant participation from developing countries at two major international workshops held in Miami (November 1989) and Perth (February 1990), this report identified the response strategies for coastal areas: to retreat, to accommodate, or to protect from the potential adverse impacts associated with ASLR. Each response strategy has different implications for different coastal resources and can be implemented within a framework of integrated coastal zone management planning.

Early 1991, the CZMS developed "The Seven Steps to the Assessment of the Vulnerability of Coastal Areas to Sea Level Rise - A Common Methodology". The objectives of the Common Methodology are:

- to provide a basis for coastal countries to assess the vulnerability of their coastal areas to ASLR;
- to provide a basis for a worldwide comparative assessment of vulnerability of coastal areas;
- to provide a mechanism for identifying priority needs of developing coastal countries; and
- to provide a basis for decisions on responsive measures.

The Common Methodology utilizes a step-wise approach, such that a country is helped to identify the actions needed to plan for and cope with the impacts associated with potential ASLR. These steps will help a country to define its vulnerability; to examine the feasibility of response options, including their institutional, economical, technical and social implications; to identify needs for assistance in order to apply the response options.

So, the Common Methodology is primarily intended to be used in country case studies, so that each case study produces comparable vulnerability profiles on the distinguished aspects. Structuring country case studies along these lines will greatly help the integration of the case study results made available prior to the UNCED conference in Brazil (June 1992). The evaluation of vulnerability to ASLR is being undertaken in a number of countries. As of January 1, 1992, studies were either completed, in progress or in planning in 27 countries by members of the CZMS with an additional 14 cases being sponsored through the UNEP Regional Seas Programme.

Objectives of this study

As each coastal country undertakes vulnerability assessment studies, that information will assist in providing a better global picture of the potential problems of ASLR on coastal resources and level of effort that may be required in response. One of the aims of the CZMS is to provide a worldwide estimate of socio-economic and ecological implications of ASLR, based on the information made available through the case studies, questionnaires, and additional fact finding. Waiting for a sufficient number of country case studies to be completed would take too long in view of the UNCED conference. The primary objective of this study is therefore to generate some first vulnerability results on a global scale. Secondary objectives are to provide a reference for country case studies, and to investigate the feasibility of some of the steps suggested in the Common Methodology.

In assessing vulnerability, three levels of boundary conditions and scenarios are incorporated in the methodology recommended by the Common Methodology. First this concerns the rate of ASLR as the primary external condition imposed by nature, including the human factor. The Common Methodology suggests to consider a rise of 0.3 m and 1.0 m by the year 2100 versus the present situation. In the present study only the 1.0 m scenario is considered versus the present situation. Secondly, the socio-economic development scenario for the considered coastal region is introduced as a main external variable. Since it is virtually impossible to make a reliable prognosis over 100 year a 30-year development prediction is suggested, which was also adopted for the present study. Finally, the Common Methodology introduces the response options for coastal defence as a scenario variable. Here, only the two extremes of the range of response options are adopted, viz. no measures versus full protection.

Vulnerability assessments made

The assessment of the risks, losses or changes for all relevant resources of the world's coastal zones requires detailed global information on the distribution, density and state of the resources and on the relevant hazardous events and corresponding probability distributions. For many resources, such as ecosystems for instance, data on a global scale are not available. Another complicating factor is that in order to assess the consequences of hazardous events the response of the various systems and their response time scales are not always known at the same level of 'proven technology', and sometimes not known to a sufficient degree of accuracy at all.

In consideration of these constraints and of those related to budget and time constraints, it was finally decided to limit this study to the following three resources of the coastal zone and accompanying impacts:

- *population at risk* on a global scale;
- *coastal wetlands of international importance at loss* on a global scale;
- *rice production at change* in South, Southeast and East Asia.

Next to these impact subjects, a set of measures were developed to be able to compare the 'with- and without measures' situation in case of ASLR. Unit costs of such measures were derived and combined with the results of the "Worldwide Cost Estimate" (WCE-study) prepared by the CZMS for IPCC in 1990. The ability to bear the costs of protection also constitutes an important aspect of the notion of 'vulnerability'. One may be vulnerable to adverse conditions; if one can defend oneself rather easily, then there is hardly any cause for concern.

The choice of these elements is also encouraged by the idea to describe at least some factors along the axes: people, land use, environment and economy. This enables to elaborate and depict the consequences of development and the limits of adaptation.

Its needs hardly to be stressed that many of the underlying data and many of the assumptions about physical processes, physical and socio-economic boundary conditions limit the accuracy of the results. It is therefore necessary to aggregate the results to a level where the accuracy of the data presented is real, but still interesting enough as a result. So, although the results are presented in detail in the report for reference purposes, it should be borne in mind that the detailed results have only limited accuracy and validity.

METHODOLOGY

Values at risk, at loss and at change

In order to define and assess the vulnerability of a coastal zone to ASLR, uniform procedures are needed, so that regional and national studies on impacts of ASLR can be compared and integrated. As mentioned earlier the Common Methodology suggests a number of these procedures. Crucial to these procedures are the concepts of values at risk, values at loss and values at change, which help to determine impacts in measurable and objective terms. These concepts are also used in the present study.

In the present context, the concept of risk is defined as the consequence of natural hazardous events times the probability of the occurrence of these events, without taking the system response into account. The concepts of loss and of change are defined as the consequences of natural hazardous events times the probability of the occurrence of these events, with taking the system response into account. The natural hazardous events vary from global events as eustatic sea level rise, to regional events as subsidence, changing rainfall or increase of storm surges. The socio-economic or physical response and the intrinsic time response scale of the relevant "system" (people, agriculture, ecosystems) determine the type of hazardous event which is relevant.

The concept of risk is considered to be appropriate in the context of assessing the consequences of ASLR and related climatic changes to the coastal zone population and nearby economic values. The short-term consequence of flooding events to population varies obviously from minor effects such as flooding of peoples' goods to the possibility of loss of life. It is considered not realistic to predict any changes these events may have on the behaviour of the population in the longer term. It is for instance likely to assume that frequent flooding leads to migration, but this is certainly not true for countries, such as Bangladesh, where migration is no realistic alternative. Therefore the concept of risk rather than the concept of loss or change is applied to indicate the impact on the populations of the coastal zone.

The concepts of loss and of change are considered essential in the context respectively of ecosystems and of agricultural production. In these cases it is not so much the short term flooding events that determine the consequences on these resources, but rather the persistence of the average longer term hydraulic changes, of which the eustatic forcing and in some cases including the regional forcing of ASLR are the most important. The probability of the occurrence of ASLR is assumed to be 100%, only the rates of change are subject to discussion.

As indicated, the determination of values at loss or at change requires taking account of the system response in assessing the consequences of the hazardous event or combination of events. This in its turn requires the introduction of the time rates of change of the events. With respect to coastal wetlands at loss we only have considered the rate of change of eustatic plus local sea level rise to be of importance (for a period of 100 years) for the analysis of the ecosystem response. With respect to rice production at change we only have analyzed the impact of ASLR as if it would happen over-night (instantaneous ASLR).

Delineation of the coastal zone area

For the determination of the impacts on the coastal zone resources which are the topic of the present study (population, ecosystems and rice production), it is necessary to delineate the coastal zone areas in which the risks, losses or changes will occur. With respect to ecosystems and rice production the delineation is based on the information given by the consulted databases themselves. For the population at risk the information was generated for this study, which implied especially difficulties since account has been taken of a detailed zonation in terms of areas and accompanying flooding frequencies, including those due to storm surges.

Boundary conditions and scenarios

In line with the requirements of the Common Methodology a comparison of the different impacts is made for different scenarios of the determining boundary conditions. As discussed, these conditions concern the three main variables:

- the rate of ASLR, for which here only the current rate compared to a 1 meter rise per century is adopted;
- the socio-economic development, for which here 'no development' (=present situation) versus a predicted development over a period of 30 years is adopted (Note that the Common Methodology purposely chooses for a different time scale for the various scenario variables: for ASLR 100 years is assumed, for development 30 years and for measures 0 year);
- the response strategy, for which here only the minimum versus maximum option is considered, i.e. no measures versus full measures.

Only in the assessment of values at change and at loss the timescale is relevant, since for the prediction of the response of the system the timescale is required. It must be noted that lack of data and lack of knowledge of the system response do limit the accuracy of the estimate of resources at change and at loss.

POPULATION AT RISK

Specification of methodology

As mentioned above, the concept of risk is considered to be most appropriate for the assessment of the vulnerability of population in the coastal zone, since it indicates the consequences of the impact without taking the response into account. It is considered not realistic to make a prognosis of population response to increased flooding.

In line with the Common Methodology, population at risk is defined as the product of the population density in a certain risk zone and the probability of a hazardous flooding event in this risk zone, which products are to be summed over the risk zones. The resulting number is to be interpreted as the expected number of people subject to flooding events per unit time. This "risk value" is able to reflect both changes in the population in the risk zone and the changes in flooding frequency due to ASLR.

It was attempted to make a rather detailed estimate of the population at risk, so that effects of changes in the boundary conditions can be made explicit. Therefore, account has been taken of a detailed zonation in terms of areas and accompanying flooding frequencies, including those due to storm surges. For instance, first order storm surge calculations were performed for the world's coastlines, producing flood levels for the 1 in 1, 1 in 10, 1 in 100 and 1 in 1000 years storms, which were increased with ASLR, subsidence, and pressure effects. The determination of the areas subject to these flooding events requires both the availability of detailed area information and of the physical process of flooding. Obviously, all of these items could only be considered to a limited degree. Some of the consequences are discussed further on.

As mentioned earlier, for the population at risk a systematic variation of the boundary conditions is considered. In effect, the present study makes a comparison of the vulnerability for the following situations (future state refers to a development scenario of 30 years; ASLR refers to 1m per 100 years; measures refers to full protection):

- the present state of the countries without ASLR;
- the present state of the countries with ASLR without measures;
- the future state of the countries with ASLR without measures;
- the present state of the countries with ASLR with measures;
- the future state of the countries with ASLR with measures.

In fact, assessing the population at risk for the present state of the countries with ASLR presumes an instantaneous rise of the sea level with 1 meter, in other words, what would happen if the mean sea level would be one meter higher as of today.

In summary, the following steps were undertaken to determine the population at risk for the various scenarios:

(1) Assessment of maximum height contour of the floodprone coastal zone taking into account present and future hydraulic conditions;
(2) Calculation of surface area captured between the coastline and the maximum height contour (maximum potential impact zone);
(3) Calculation of surface area of risk zones with accompanying flooding frequencies, accounting for the inundation process;
(4) Assessment of present state of protection to flooding in the low-lying countries;
(5) Calculation of population densities for the present and the future state;
(6) Calculation of population at risk for the different scenarios considered.

Each of these steps is discussed in detail in the present study report. As stressed above, the detailed country-by-country results have only limited accuracy and validity. Therefore aggregated results for the various coastal regions of the world are presented, but first a discussion of some of the assumptions and associated effects is in order.

Some assumptions and their effects

- Limitations of data sources: The global data sources which were used allowed only for a limited spatial resolution of a number of variables, e.g. population distribution, height contours, surface areas between height contours. This introduces inaccuracies and requires assumptions, which all lead to inaccurate results on the scale of countries itself. Verification has shown that averaged results on the scales of regions are accurate.

- No physical system response: In the assessment of population at risk any physical changes of the coastal environment in the course of time are ignored. Although this does seem in many cases to be a realistic assumption because of the human restrictions of sediment availability (river regulation, river damming, coastal protection), it is not generally true (cf. Ganges delta in Bangladesh). The effects on the level of the population at risk are however, estimated to be of second order.

- Hydraulic conditions and regional effects: Necessarily so assumptions had to be made about the additional, often very local, effects increasing the storm surge levels (e.g. subsidence, tides, barometric pressure). These estimate will again limit the accuracy of the results on the scale of countries, but less so on the scale of regions.

- Estimate of present protection status: Since there is no global information on the present protection status of the world's coastlines, it was assumed that the estimate could be based on per capita Gross National Product.

Aggregated results Population at Risk

(i) A considerable amount of the coastal population (ranging from 200 to 250 million people) lives below the height contour corresponding to the once per year storm surge level. *

(ii) In case of a 1 meter ASLR and ignoring any physical or human responses to this effect, the number of people experiencing flooding or inundation will increase with 50%. Under the adoption of a 30-year population growth rate, this figure will be more than double the present number.

(iii) Because of differences in the regime of extreme water level events (especially due to differences in decimating height levels) the increase of flood risk in low-lying coastal regions due to ASLR is larger than average for the Asian region (especially the Asian Indian Ocean coast), the South Mediterranean coast, the Africa Atlantic and Indian Ocean coast and the coasts of the Caribbean and many of the small islands states.

(iv) Another manifestation of climate change, i.e. storm frequency and intensity, may significantly increase these figures in those regions of the world where the storm frequency and intensity increases.

COASTAL ECOSYSTEMS AT LOSS

Specification of methodology

As mentioned above, the concept of loss is considered to be most appropriate for the assessment of the vulnerability of ecosystems in the coastal zone, since it indicates the consequences of the impact with taking the response of the system into account. It is namely not of interest to indicate any increases in flooding, without quantifying the impacts this has on the coastal ecosystem. Furthermore, since it is difficult to quantify changes, e.g. with respect to biodiversity, only (the chance of) habitat area losses are estimated. The response mechanisms taken into account are only limited (mainly horizontal shifts of habitats). Thus, it is better to use the connotation of potentially at loss, as actual future loss may be counteracted by other feedback mechanisms of the physical and biological system.

In line with the Common Methodology, ecosystems at loss is defined as the area of special ecological value (here: of international importance) which is expected to be lost over the indicated time horizon for a variation of the boundary conditions. In effect,

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* There exist various estimates of "the coastal population", such as *"two-thirds of the world population lives in the coastal zone"* or *"by the year 2000 six billion people live within 60 km from the coast"*. Here, however, it was attempted to keep to the very strict definition of people below the mentioned height contour.

the present study makes a comparison of the vulnerability for the following situations:

- the expected loss of coastal wetlands due to ASLR, without measures and without socio-economic development;
- the expected loss of coastal wetlands due to ASLR, with measures and without socio-economic development;
- the expected loss of coastal wetlands due to ASLR, without measures and with socio-economic development;
- the expected loss of coastal wetlands due to ASLR, with measures and with socio-economic development.

In summary, the following steps were undertaken to determine the coastal wetlands at loss for the various scenarios:

(1) Inventory of special ecological areas (coastal wetlands);
(2) Global typology of coasts, based on morphogenesis;
(3) Overlay of inventory and typology, classification of response types;
(4) Analysis of historic and current trends;
(5) Specification of responses according to:
   - physical conditions (subsidence, tidal range, etc)
   - human development factors (population density);
(6) Estimate coastal wetland areas at loss.

Each of these steps is discussed in detail in the present study report. As stressed above, the detailed country-by-country results have only limited accuracy and validity. Therefore aggregated results are presented, but first a discussion of some of the assumptions and associated effects is in order.

Some assumptions and their effects

- Limitations of data sources: There exists a large variety of literature and databases describing coastal wetlands. Yet, some countries with extensive coastal wetland areas (e.g. Canada) could not be included because of lack of data. Furthermore, the inventoried data sources present the information non-uniform, and some data sources present contradictory information. These limitations indicate that only conclusions on a regional basis are in order.

- Coastal wetland response: The causes of coastal wetland decline rates under present conditions are a complicated mix of human-induced and natural causes. In order to estimate the decline rates on a regional scale including the additional effect of ASLR, simplifying assumptions had to be made, e.g. mangrove forests on low islands will disappear by definition contrary to those on high islands, and, countries will follow a preservation scenario for the coastal wetlands in those regions where wetlands are declining rapidly.

Aggregated results for coastal wetlands at loss

(i) Worldwide over 900,000 km^2 of coastal area can be classified as 'areas of international importance', indicating that their character is in accordance with the criteria set by the RAMSAR Wetlands convention. One-third of these coastal areas consists of coastal wetlands (salt marshes: 15%, intertidal areas: 10%, and mangroves: 8%). While these coastal wetlands are recognized to be of high ecological and economic value, they seem to be particularly vulnerable to ASLR.

(ii) Coastal wetlands are presently being lost at an increasingly rapid rate worldwide. The increase in loss rates is closely connected with human activities such as enhanced subsidence and shoreline protection, blocking sediment sources for wetlands, and development activities, e.g., land reclamation and aquaculture development.

(iii) ASLR would increase the rate of net coastal wetland loss. In combination with human activities a 1 meter ASLR over the next century would threaten with loss half of the world's coastal wetlands of international importance. In some areas, coastal wetlands could be virtually eliminated, because their ability to migrate inland would be limited over such short timescales. Taking account of increasing human development (the development scenario) will increase this expected loss in the order of 5%.

(iv) The indicated coastal wetland decline is expected to be larger than average for the coasts of the United States, the coasts of the Mediterranean Sea, the African Atlantic coast, the Asian Indian Ocean coast, and the coasts of Australia and Papua New Guinea.

RICE PRODUCTION AT CHANGE

Specification of methodology

The concept of change is considered to be most appropriate for the assessment of the vulnerability of agriculture in the coastal zone. With production at change the consequences of increased flooding and other climatic change factors on the floodprone agricultural area are considered in terms of changes in the crop yields. It is assumed that it is not so much the actual loss of agricultural area that is dominant, but rather the production changes due to less favourable hydraulic and climatic conditions.

In line with the Common Methodology, rice production at change is defined as the production quantity which is expected to be lost over the indicated time horizon for the various scenario conditions. However, in the present study a more limited indication is given, i.e. the total production in the area impacted by more frequent flooding with an indication of the order-of-magnitude changes that may occur in this production.

These order-of-magnitude changes are based on a simple, hypothetical model which assumes yield changes because of a shift of each crop type towards the next wetter type, due to the 'worsening' hydraulic conditions. Because of the limited accuracy of this approach it is not realistic to specify these order-of-magnitude changes for the various scenarios.

In summary, the following steps were undertaken to determine the rice production at change:

(1) Inventory of mapping of rice production in Asia;
(2) Estimate of the production in floodprone areas;
(3) Hypothetical response exercise.

Each of these steps is discussed in detail in the present study report. Aggregated results as well as country results are presented, the latter have only an indicative validity.

Some assumptions and their effects

- Limitations of data sources: The current production figures which are based on the literature, have a limited accuracy both because of the limited spatial resolution and because of the relatively old production figures (late seventies).

- Crop production response: The determination of the response of rice crops to changing conditions requires rather sophisticated approaches, e.g. those used in the context of the analysis of climate change impact on crops in uniform regions which combine computer models with actual observations. The present approach must therefore be considered as a hypothetical approach, which is found to produce figures of the same order-of-magnitude as found for some individual regions with the more sophisticated climate change approaches.

Aggregated results for rice production at change

(i) Approximately 85% of the world's rice production takes place in South and Southeast Asia, and of this production about 10% is located in areas which are estimated to be vulnerable to ASLR, such that the hydraulic conditions in these areas become less favourable for the rice production. The amount of rice cultivated in this area is enough to feed more than 200 million people.

(ii) Less favourable hydraulic conditions may cause lower rice production yields if no adaptive measures are taken. Especially in the large deltas of Vietnam, Bangladesh and Myanmar (Burma) serious production reductions may be expected.

(iii) A simple, hypothetical model indicates that up to 40% of the rice cultivated in the areas vulnerable to ASLR may be affected (at loss). This could mean that about 75 million people may lose their main food source.

SUMMARY OF SOME RESULTS

The results of the GVA on a world scale are presented in Table 1 according to the format of the vulnerability profile of the Common Methodology. The first impact category shows the impacts of ASLR on the socio-economic system. The people living in the Risk Zone (the impact area below the maximum height contour) increase from

Table 1 Impacts of ASLR on the global coastal system

Impact category	Present situation		1 METER ASLR			
			NO MEASURES		WITH MEASURES	
			No development	30 year development	No development	30 year development
Socio-econ. system:						
- World Population [million]	5,100		5,100	7,600	5,100	7,600
- People in Risk Zone [million]	210		260	400	260	400
- Population at Risk: [million]	47		61	100	7	12
Coastal ecosystem: [km^2*1000]						
- Coastal Wetlands *remaining unaffected:*	302		133	122	122	112
. salt marsh	75		33	31	30	28
. intertidal	94		42	38	38	34
. mangroves	134		58	53	55	50
- Wetlands at loss through development:	-		-	26	-	26
. salt marsh	-		-	6	-	6
. intertidal	-		-	8	-	8
. mangroves	-		-	11	-	11
- Wetlands potentially at loss (ASLR):	-		169	154	180	164
. salt marsh	-		41	38	44	41
. intertidal	-		52	47	56	51
. mangroves	-		76	69	79	72
Rice production:	World	Asia				
- area [km^2*1000]	1,450	1,250	-	-	-	-
- production [million tonnes]	485	418	-	-	-	-
- people equivalents [million]	2,200	1,900	-	-	-	-
Potentially at change in Asia:						
- area [km^2*1000]			160	-	-	-
- production [million tonnes]			47	-	-	-
- people equivalents [million]			214	-	-	-

210 million to 260 million due to ASLR. Without taking any adaptive measures, the population at risk per year increases from 47 million to 61 million. With projection of the population over a 30-year period (30 year development), the population at risk per

year would more than double (100 million). When a set of defence measures are applied, the population at risk per year would decrease considerably to a level of 7 million without development and 12 million with development.

The vulnerability of a selected group of coastal regions has been analyzed using the concordance analysis technique. Concordance analysis is based upon a pair-wise comparison of the scores of alternatives (coastal regions) for each criterion. When a coastal region scores more vulnerable for a specific criterion, the coastal region is given the weight of this criterion. By summing the weights given to the coastal region in case of dominance and subtracting the sum of the weights if the region is found to be dominated by others, the net concordance dominance value can be found.

The following sets of weights have been used (Table 2):

Table 2 Sets of weights for multi criteria analysis

CRITERIA	Weight set 1	Weight set 2	Weight set 3 (socio-econ. system oriented)	Weight set 4 (ecosystem oriented)
Population at Risk	0.333	0.30	0.40	0.25
Annual costs as a percentage of GNP	0.166	0.20	0.20	0.15
Wetlands at Loss	0.375	0.40	0.35	0.45
Sensitivity of wetlands for protection measures	0.125	0.10	0.05	0.15

For almost all weight sets the same coastal regions are ranked among the top 4:
- o Asia Indian Ocean Coast;
- o Africa Indian Ocean Coast;
- o Southeast Asia;
- o Southern Mediterranean.

With respect to the socio-economic system and ecosystem it can be safely concluded that, based upon the data gathered in this study, these regions are the most vulnerable (Table 3).

Table 3 Ranking of most vulnerable coastal regions

	WEIGHT SETS							
	1		2		3		4	
	net conc. dominance	rank	net conc. dominance	rank	net conc. dominance	rank	net conc. dominance	rank
Asia Indian Ocean Coast	1	1	1	1	1	1	1	1
Africa Indian Ocean Coast	0.67	2	0.52	3	0.53	3	0.51	4
Southeast Asia	0.64	3	0.59	2	0.67	2	0.60	3
Southern Mediterranean	0.47	4	0.48	4	0.38	5	0.79	2
Indian Ocean Small Islands	0.36	5	0.30	5	0.44	4	0.06	8
East Asia	0.20	6	0.09	7	0.00	6	0.39	5
Caribbean	0.12	7	0.11	6	-0.07	7	0.37	6
South America Atlantic Ocean	-0.20	8	-0.16	8	-0.37	10	0.07	7
Pacific Ocean Small Islands	-0.20	9	-0.18	9	-0.07	8	-0.46	11
Africa Atlantic Ocean Coast	-0.33	10	-0.23	10	-0.21	9	-0.30	10

Although East Asia rank among the middle range of over-all vulnerability, the potential loss of more than 70% if its total wetlands is of great ecological concern, a percentage that is surpassed by the United States, the Mediterranean coast and Australia/Papua New Guinea, only.

With respect to the three small island regions in the ranking list, the Indian Ocean Small Islands are the most vulnerable. It has to be emphasized that in case of the Indian and Pacific Ocean small islands, no wetland data were available and medium vulnerability is assumed.

The African Atlantic Ocean coast seems to be the least vulnerable coast of these 10 regions marked as vulnerable in both respects. With respect to these region another aspect should be taken into consideration when assessing the vulnerability of this coastal region, that is the rapid growth of its coastal population (cf. Table 6.5). This growth constitutes problems for both the socio-economic system and the ecosystems: increase of population at risk, rising costs in relation to GNP, and population pressure on the coastal wetlands which further reduces the capability of the coastal ecosystems to adapt to ASLR. A similar remark can be made for the Southeast Asia coast.
Although highly sensitive to measures, the ecosystem vulnerability of the Africa Indian Ocean Coast is low indeed: only 7% is potentially at loss.

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