

Comparative Merits of Adaptation Policies of Sea Level Rise and Their Potential Impacts on Coastal Settlements in Developing Countries

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SUMMARY

Climate change and global warming has been one of the most discussed and debated topics in Scientific Journals over the last two decades. There are considerable media and public pressures on governments, policy makers and international organisations such as European Union and United Nations to take measures to address global warming and its potential deleterious effects.

The biggest danger, many experts warn, is that global warming will cause sea levels to rise increasingly rapidly. The Inter-governmental Panel on Climate Change (IPCC) Third Assessment Report, published in 2001, projected that the global average sea level would rise between 9 and 88cm between 1990 and 2100. However, in February 2007, The Working Group 1 (WGI) of the IPCC published a summary of the first of the four reports, which is due to be published later this year as IPCC Fourth Assessment Report. WG1 Report has the following projections: Probable temperature rise between 3°C and 4°C (range 1.1°C to 6.4°C); Sea level likely to rise by 18-59cm, Arctic summer sea ice disappears in second half of century; increase in heatwaves very likely and increase in tropical storm intensity likely, the latter being likely to cause especially severe problems for developing countries. This report concluded that there was a greater certainty (at least 90% certain) that human emissions of greenhouse gases rather than natural variations are warming the planet's surface and most likely to cause sea level to rise.

The need to prepare adaptive responses to reduce impacts cannot be overlooked irrespective of the possibility of mitigating some of the more extreme effects through emissions controls. However, the policy making process required for effective adaptive action is very complex due to several limitations imposed by financial considerations and numerous physical, social, economic, legal and political factors. These limitations make developing countries more vulnerable because they have inadequate capacity in financial, planning, social, economic, legal and political considerations.

Three broad policy frameworks: *protection*, *accommodation* and *retreat* (IPCC, 2001) have evolved to deal with the impacts of sea level rise and climate change on coastal zone. This paper assesses the impacts of each policy option on coastal settlements and its resources in developing countries and then attempts to identify the likely applicability's of the alternative options, given the physical condition of a coast.

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1. INTRODUCTION.

This paper will be based on the IPCC, 2001 Third Assessment Report (TAR) on adaptation and vulnerability since the Fourth Assessment Report on adaptation and vulnerability is yet to be published. It could be identified from the Fourth Assessment Report (4AR) of WGI that, the key difference between the 2007 and the 2001 report may be the certainty of their scientific projections. It is important to note that the IPCC's WGI report looks at the science of climate change. The other reports yet to be published will look at: impacts, adaptation vulnerability and mitigation of climate change.

In 2001, WGI reported that it was "likely" that human activities lay behind the trends observed at various parts of the planet; "likely" in IPCC terminology means between 66% and 90% probability. However, in 2007, it reported that it was at least 90% certain that human emissions of greenhouse gases rather than natural variations are warming the planet's surface and most likely to cause sea level to rise by 18-59cm (IPCC, 2006).

Rising sea-levels can cause particular problems because a majority of the world's population lives in coastal areas. Nicholls and Mimura (1998) have estimated that 600 million people will occupy coastal floodplain land below the 1,000-year flood level by 2100. Quite apart from this, significant amount of the world's most diverse and productive resources are located in the coastal zone. This implies that a significant adverse effect of climate change and sea level rise is likely to have a huge impact on the world population and the world economy. The possible impacts of sea level rise on coastal zone include:

- Increased inundation (flooding) of coastal land which may cause loss of life and property;
- More frequent storm-surge flooding, which may cause beach destruction and severe shoreline erosion;
- Accelerated coastal erosion which may also cause destruction of coastal properties and possibly loss of life;
- Seawater intrusion into fresh groundwater and thus reducing the supply of fresh water in coastal towns;
- Altered tidal range in estuaries and tidal river systems and;
- Change in sedimentation patterns.

These impacts coupled with increased temperature, rainfall and storm associated with climate change could cause severe impacts to coastal developments, resources and the coastal economies. Such impact on the coastal economies will go a long way to affect the global economy since every country including the landlocked countries in one way or the other depends on the coast. It must be noted here that the extent of the impact of sea level rise on countries depends on many factors which include:

- The nature of coastline (lowlands/uplands, soft geology/hard geology etc);
- The nature and value of developments on vulnerable coast lands;
- The capacity and affordability to build defence and protection schemes;
- Availability and cost effective source of alternative supply of goods and services to the hinterland and landlocked countries.

It must be noted that the impacts of climate change could be especially severe for developing countries due to the following:

- Limited finance to build defences or resettle vulnerable coastal communities;
- Limited technical expertise to monitor, identify problems and design solutions;
- Poor institutional framework to develop and implement adaptive measures;
- Poor implementation and monitoring of planning policy guidelines to reduce development on vulnerable coast.
- Poor building standards, making most building vulnerable to storms;
- Low awareness of climate change issues;
- Overdependence on natural resources;
- Lack of welfare policies to provide support for victims; and
- Lack of political will to invest in adaptation policies.

IPCC WGI summary report in 2007 indicates that the threats of climate change are so clear and the time to start planning is now. Governments must not behave like the proverbial ostrich that buries its head into sand when it faces a problem and thinks it is hiding. Nations cannot hide or runaway from the realities of climate change and sea level rise. It is clear that there is the need for the global community (politicians, policy makers, economists, scientists and citizens) to continue research and explore sustainable ways of adapting to this global climate change and associated sea level rise. It is important that results and potential solutions should be available and applicable to all irrespective of state of development and economy.

2. METHODOLOGY

In order to make holistic analysis of sea level rise adaptation policies, both the process of coastal adaptation (Klein et al, 2000), and coastal response policy options proposed by Biljsma *et al.* (1996) and adopted by the IPCC (2001) were integrated and analysed to find how each can inform the selection of policy option and implementation of sea level rise adaptation policies. An approach involving a Comparative Impact Matrix was then used to appraise the impacts of each policy option on coastal settlements and its resources and then recommend the preferred policy option that should be possibly adopted, given the human development and the physical condition of a given coastline.

3. SEA LEVEL RISE ADAPTATION POLICIES

Adaptation to environmental change is a fundamental human capability and is not a new concept (Easterling et al, 2004). Throughout the ages, human societies have shown a strong capacity for adapting to different climates and environmental changes. The resilience and flexibility exhibited in the patterns of human settlements show an inherent desire and some measure of capacity to adapt.

Adaptation actions and strategies present a complementary approach to mitigation. While mitigation can be viewed as reducing the likelihood of adverse conditions, (e.g. through greenhouse gas emissions policies) adaptation can be viewed as reducing the severity of many impacts in response to a projected change or actual change in the climate or other changes in the environment. In fact, adaptation aims to enhance or encourage positive effects whilst minimising negative ones. Adaptation may be either planned or spontaneous. McCulloch, et al (2002) categorised climate change adaptation strategies as follows:

- Prevent the loss – adopt measures that reduce vulnerability to climate change;
- Tolerate the loss – do nothing to reduce the vulnerability, and absorb the cost of the losses as they occur;
- Spread or share the loss – do not reduce vulnerability, but spread the burden of the losses over different systems or populations (this is how insurance works);
- Change the affected activity – stop doing things that cannot cope with changes in climate, and substitute other activities; and
- Change the location of the activity – move the activity or system to a more favourable location.

However, Easterling, et al, (2004) viewed adaptation as a risk-management strategy: that is neither free of cost nor foolproof, and the worthiness of any specific actions must therefore carefully weigh the expected value of the avoided damages against the real costs of implementing the adaptation strategy. Thus, there is a need for comparative assessment of adaptation policies and strategies so that those likely to be most effective in particular circumstances can be identified.

Biljsma *et al.* (1996) identified three possible coastal response options to sea-level rise, which were adopted by IPCC (2001) comprising: Protection; Accommodation; and Retreat.

Contrary to this view, Klein and Nicholls (1999) argue, that the adaptation policies proposed by Biljsma *et al.* (1996) have not necessarily been effective in assessing the wide range of technical, institutional, economic, and cultural elements in different localities. Indeed, suggested that the methodology could be limited by a protection-oriented response rather than consideration of the full range of adaptation options. Klein *et al.* (2000) argued that successful coastal adaptation embraces more than just selecting one of the technical options to respond to sea-level rise; it is a more complex and iterative process, with a series of policy cycles. They identified four steps which can be distinguished in the process of coastal adaptation as:

- Information collection and awareness creation
- Planning and design
- Implementation
- Monitoring and evaluation.

If the four steps of coastal adaptation process above are adhered to before the selection of coastal adaptation policy option and after implementation of the selected policy option, positive results can be achieved. This is because; the process of information collection and awareness creation, planning and design should significantly improve knowledge enabling a much better informed selection of coastal adaptation policy that would be suited to both natural and human conditions and acceptable by the local population. These latter two factors are especially important for developing countries. After implementation of the policy, there is the need for monitoring so as to identify remaining uncertainties and gaps in coverage allowing amendments where necessary. Evaluation is also required to enable policy makers to assess how the policy is achieving its objectives.

This implies that adaptive measures will need to be planned well in advance, but only implemented when appropriate, according to proximity of the risk and the “lead-in” time of the measure under consideration. However, developing countries will have to start their capacity building and institution development now if they are to be able to implement measures successfully when required. There is the need for developing countries to study the natural processes of their coastline, identify flood and erosion risk areas (preferably using a zoning approach), design a basic form of shoreline management framework and monitoring system now to facilitate effective adaptation later.

3.1 Protection

This policy aimed at protecting the land from the sea so that existing land uses can continue, by constructing hard structures (Figure 1) as well as using soft engineering measures (Figure 2). The first shortfall of protection policy is that it is generally costly and has limited or finite long term effectiveness. It tends to overly control or operates against natural processes and can trigger effects detrimental to long-term sustainability. For instance seawalls may be effective as flood protection, but in an open coast with long wave fetch, wave reflection and scour at the base of a seawall can cause loss of beach in front of the seawall (Krauss and McDougall, 2006). Even in a sheltered coastline, local waves in a storm surge may lead to the failure of a protection structure. Groynes are effective where there is significant longshore drift, but they can be subject to bypassing, and do not address crossshore transport losses. Hard structures usually require regular maintenance to achieve full longevity and this is not always available/adhered to in developing countries leading to earlier than anticipated failures.

One negative impact of protective structures is the “knock-on effect”. Seawalls for instance almost always cause terminal scour (out flanking) downdrift (figure 3). Groynes also may succeed in trapping sediment updrift and cause starvation (erosion) of sediment downdrift and possibly leading to the continuous construction of expensive groynes or other form of protective structure along the entire coastline.

“Soft” engineering methods such as beach replenishment or artificial breakwaters are used increasingly amongst developed countries and offer opportunities to avoid some of the problems associated with hard structures (e.g. Hamm et al. 2002). However, these techniques do require better technical knowledge and continued monitoring for effective performance making them potentially less applicable for developing countries.

However, in spite of the short-comings of the protection policy, it may still be the best sea level rise adaptation policy depending on the values of properties along the coastline, the cultural heritage of the local people as well as the contribution of the vulnerable coastal resources to the local and national economy.

Figure 1: Hard Coastal Protection Structures

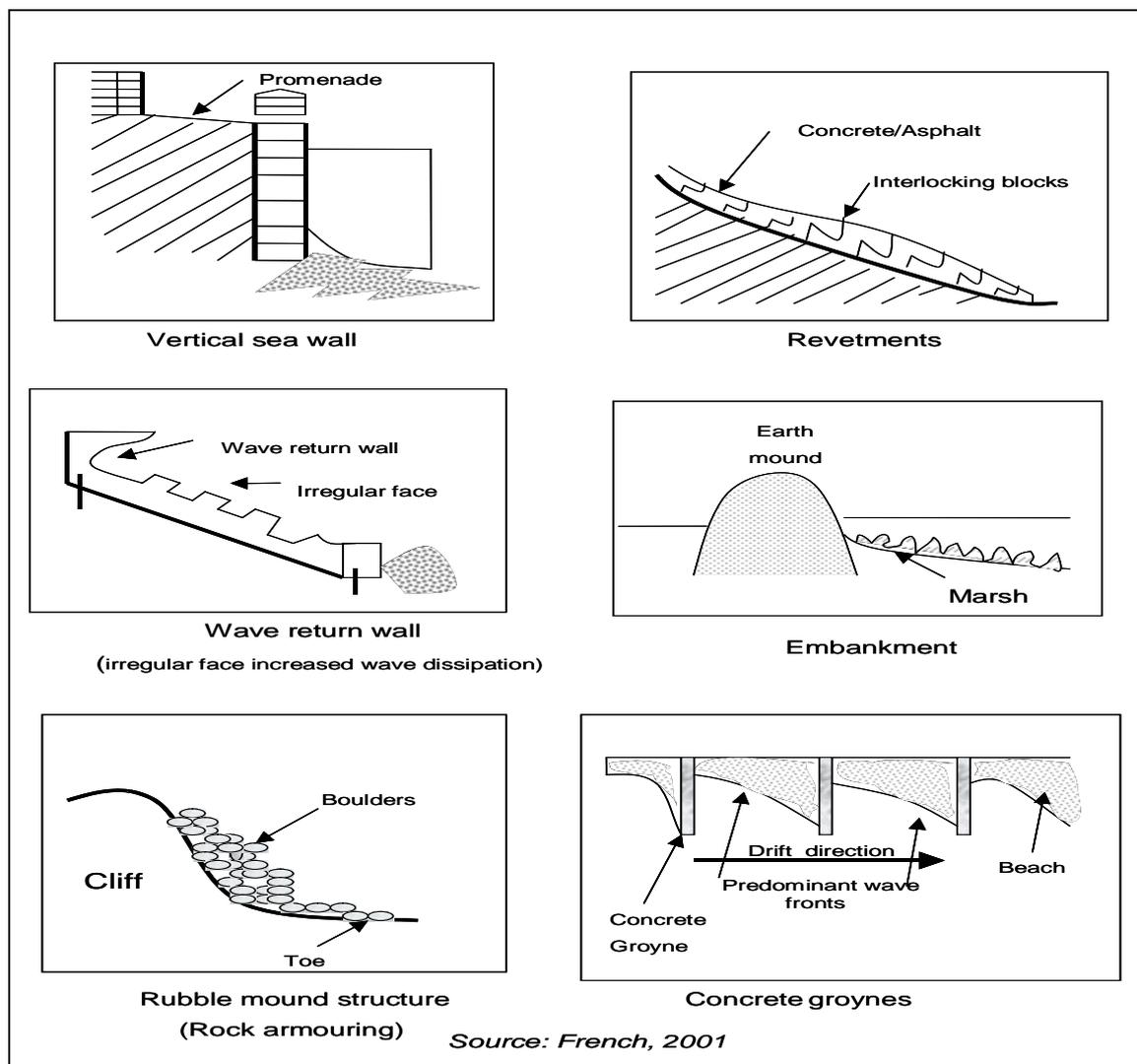
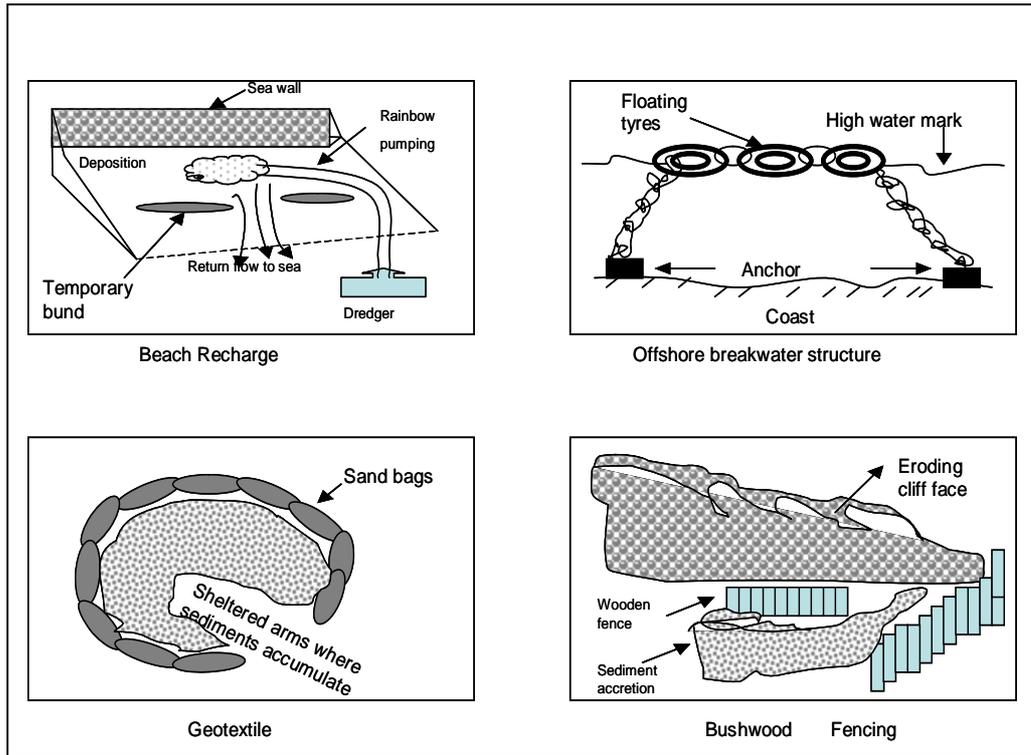
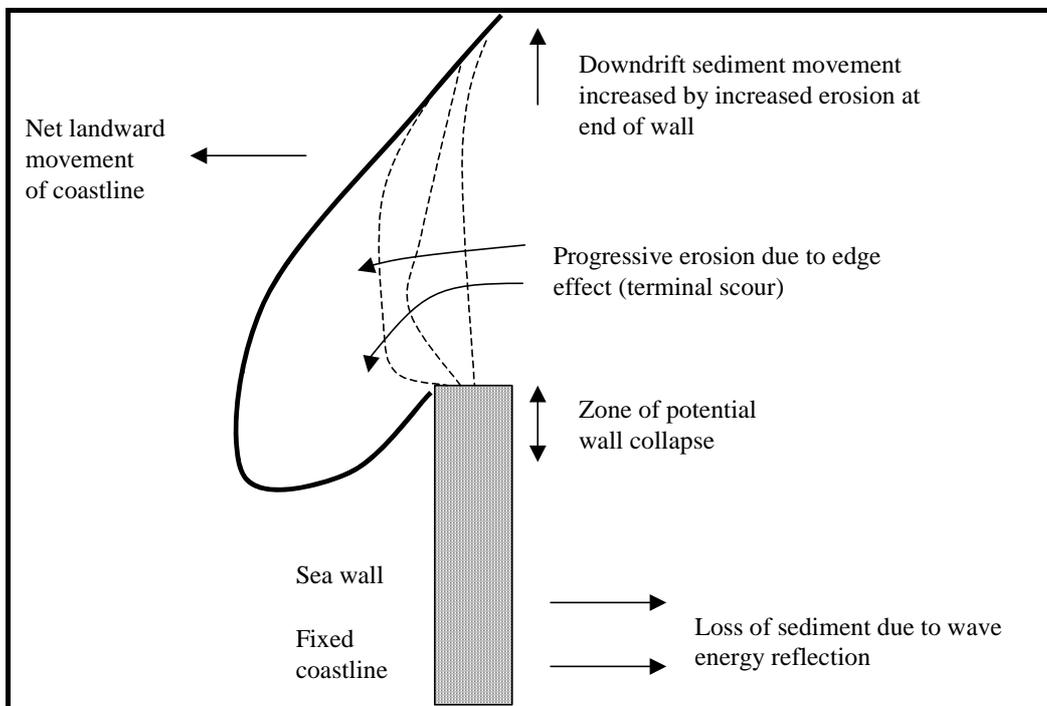


Figure 2: Soft Coastal Protection Structures



Source, French, 2001

Figure 3: Typical End Effects (Terminal Scour) Associated With Sea Wall



3.2 Accommodation

This policy implies that people continue to occupy the land but make some adjustments properties and activities. The policy involves: redesign of structures (e.g. elevating buildings and strengthening foundations) to minimise impact of flooding and; zoning and proper land use policy to encourage only low capital investments on vulnerable lands; soft approaches like dyke opening, wetland renewal, dune rehabilitation and beach re-feeding to enhance natural resilience; drainage modifications for built up areas that might become inundated; growing flood or salt-tolerant crops; and storm warning, preparedness and evacuation schemes.

Accommodation allows wetlands and other natural coastal features to migrate inland through wash-over and tends not to result in the environmental problems that can occur with protection. It reduces risks without the expense of full protection, but it does not completely reduce risk. Indeed, substantial risks can remain if measures are not implemented carefully e.g. storm warnings available, but communications with rural areas poor and without education of local populations appropriate reactions may not be made. Because of the problem of significant residual risks these methods alone may not be suitable for densely populated cities and centres of economic activity. However, the measures can be implemented at community level and may be suited to developing countries supported by appropriate technical guidance.

3.3 Retreat

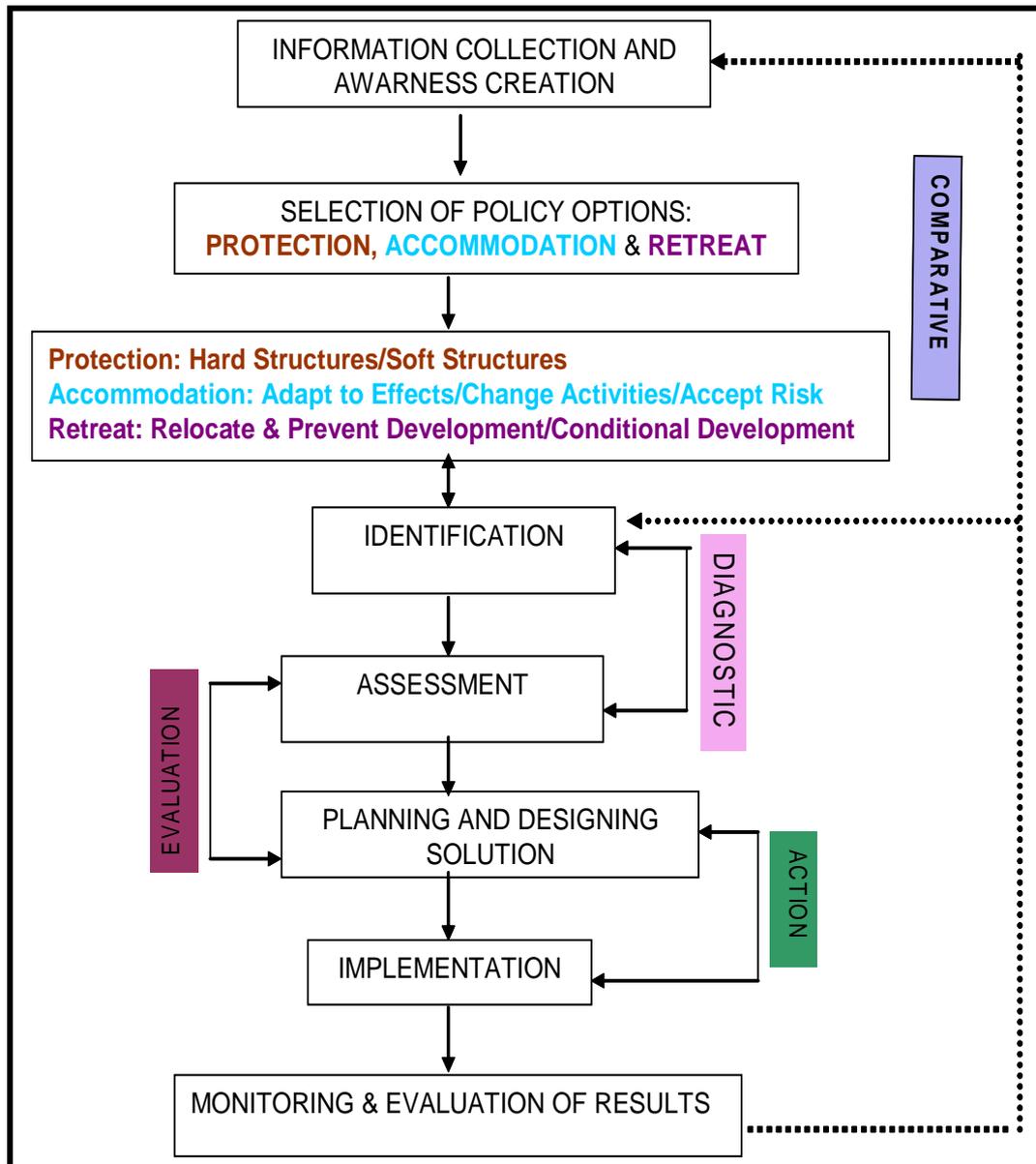
Retreat involves either only a partial, or perhaps no attempt to protect the land from the sea. In an extreme case, the coastal area is abandoned and coastal landforms and ecosystems are allowed to shift landwards. This policy option is recommended for highly vulnerable coastlines, where the market cost and/or technical difficulty of protecting the coast far exceeds the benefits of providing protection. To be effective, vulnerable populations and infrastructure need to be shifted away from hazardous zones. The potential benefits of this policy include savings on cost of defences, habitat and wetland conservation and maintain aesthetic value of the coast. The opportunity cost of obtaining these benefits includes loss of land, properties, heritage and payment of high compensations.

Effective organised retreat, rather than simply doing nothing, does require planning and organisation within a strong governmental framework and does assume that land is available to support displaced populations. Implementation requires legislation and regulations that prevent development and possibly settlement on vulnerable coastal lands and properties. It may involve public education, taxation, insurance and zoning policies. In fact, in areas where reliable data on historical rate of shoreline recession are available, a setback distance may be fixed based on predicted rate of recession into the future. The success of this policy depends on the ease with which vulnerable communities can be resettled inland which in developed countries appears conditional on the willingness of government and local authorities to pay compensation. In developing countries this may not be possible due to inadequate funding to provide housing and the payment of compensation.

4. INTEGRATED PROCESS FOR SELECTING SEA LEVEL RISE ADAPTATION POLICY OPTION

Management of any environmental problem requires a concerted effort of all stakeholders. There is therefore the need for integrated and participatory approaches in the selection and implementation of adaptation policy options. The physical processes of the coast, its natural resources and the socio-cultural philosophy of the local people need to be understood in order to select appropriate and sustainable policies. Figure 4 outlines the various processes that should be followed in stages to achieve sustainable adaptation to sea level rise.

Figure 4: Integrated Processes for Selection Adaptation Policy Option



This framework could be adopted and implemented in developing countries. This will help to create awareness and also increased participation in the decision making process. Not only

would the information collection aspect help the developing countries to identify the true extent of vulnerable, it would also require input from local staff and could help to build capacity in such areas. The monitoring aspect in the framework will also help to reduce the site specific “protect and forget” philosophy which is characterised by donor funded coastal defences in developing countries. However, there are gaps that need to be filled for effective implementation of the framework. First, due to limited technology and poor planning policies in developing countries, there is a gap in the planning and designing solutions on the framework. There is the need for training of skilled personnel in coastal science and coastal zone management as part of capacity building. In fact, a search through degree programmes in Sub-Saharan Africa Universities indicates that very few offers degree courses in coastal management. Secondly, the limited finance in developing countries also creates a gap in the policy implementation, especially where protection is considered as the best policy option.

5. COMPARATIVE MERITS OF ADAPTATION POLICY OPTIONS

The aim of this assessment is to identify both the nature and human condition that make one policy option either better or has comparative advantage than the others. Table 1 and table 2 show comparative impact matrix for Natural conditions and human condition respectively. To be able to choose a reliable policy option there is the need for data gathering. Natural coastal data that need to be gathered include: geology (hard/soft), relief (low/high/cliff), drainage (estuary/delta/lagoon/marsh) and the physical processes (waves, tide, wind and drift). Data on human activities along the shoreline also should be collected and related to the natural conditions of the coast.

The results will be a combination of human developments and natural coastal conditions. Example, harbour city located on a hard coastline and say an urban settlement on a low coastline or in a delta. The human and natural combination one gets after the information gathering would determine whether comparably, protection, accommodation or retreat is the best option for a particular section of a coastline.

The general principle that can be deduced from table 1 and 2 is that where valuable developments and economic activities have been already located on vulnerable coastal lands, protection should be the best policy option unless the cost of protection exceeds the value of the developments or the economic activities. Furthermore, where the cost of protection exceeds the value of development and economic resources on vulnerable coastal lands, accommodation should be the best policy option and encourage only low investment on such lands. Finally, where vulnerable coastal lands are not developed or where the cost of accommodation far exceeds the value of development and economic activities on the land, then retreat should be the best policy option.

Table 1: Comparative Impact Matrix for Natural conditions

Impact /effects	Protection	Accommodation	Retreat
Hard coastal geology	This may not be beneficial since the natural conditions can withstand the impacts of sea level rise. Perhaps minor schemes like cliff toe stabilisation may be necessary.	Natural conditions provide the necessary resilient for accommodation and there will not be the need to retreat. There may be the need for beach nourishment and rehabilitation of barriers against flooding.	There is no need for retreat since the hard geology can withstand erosion and thus offer natural protection.
Soft Coastal geology	There is the need for protection since the natural resilient may not be enough to withstand the impacts of sea level rise. Where there is much rainfall and clayey geology, cliff slumping may make protection difficult and expensive.	It may be very difficult to accommodate erosion and slumping of soft cliffs	The natural resilient is not strong enough to withstand the impact so retreat will leads to greater loss of land, properties and coastal infrastructure. Here retreat may not be the best option.
Low coastline	Protection against inundation and erosion will be required. Without protection against flooding, there will be increased intrusion of saltwater into aquifers, loss of beaches and wetlands.	It may be very difficult to accommodate inundation, erosion and reduction of freshwater supply.	This will allow wetlands and beaches to migrate inland and survive in the long-term but this implies loss of arable farmlands, low food production and high cost of resettlement and payment of compensations.
High (cliff) coastline	May require little protection in the form of cliff stabilisation and erosion but not protection against flooding.	High cliffs provide a natural protection against flooding and thus making accommodation possible.	Retreat may not be economical since the natural condition makes accommodation easy.

Table 2: Impact Matrix for Human conditions

Impact /effects	Protection	Accommodation	Retreat
Developed coastlines	Must be protected if the cost of protection is less than the value of land and properties that would be lost as result of the impact.	Should be embraced if the soft defences recommended by accommodation can offer the necessary protection for life and properties	Should be considered only where the cost of protection far exceeds the value of vulnerable land and properties.
Undeveloped coastline	Allowing the natural processes to operate along an undeveloped coastline may be economical than protection. Protection may be needed where allowing natural processes my leads to severe contamination.	Accommodation may be ideal where the land is used for agricultural production and ecotourism.	This may be considered the best option for undeveloped coastlines, except where land is really scarce (Small Islands) or the undeveloped land along the coast is earmarked for agricultural production.
Where local economy and culture depend on coastal and marine resources	Protection should be the best option if it may not lead to the destruction of the particular coastal resource which support the economy (eg. beach)	This should be the best option since it will use soft approaches to maintain the natural resilient in order to keep the particular coastal or marine resource.	Retreat should not be an option, except where the local economy depends on ecotourism.
Where local economy/culture does not depend on coastal and marine resources.	This should not be considered, except where vulnerable land and properties are of high value than the cost of protection (eg. Small Islands)	It should be possible to accommodate the impacts since residual impacts may not affect local economy (no or less impact on local economy)	Should be possible to retreat. Because the local economy may not be affected.

6. IMPACTS OF ADAPTATION POLICIES ON COASTAL SETTLEMENTS IN DEVELOPING COUNTRIES.

The processes of adaptation to sea level rise in both human and natural systems are very complex and dynamic, often involving numerous assessments depending on existing conditions. Table 1 and 2 provides comparative merits of coastal responds adaptation policy on both Natural and human scenarios of different coastlines. It can be identified that the choice of policy option may be very difficult if one begins to overlay the natural coastal conditions with the human conditions. For instance, what policy option would be best suited

for developed coastline on a soft coastal geology? The success of any option that will be selected will depend on the ability to address the financial considerations, the local capacity to deal with sea level rise, good planning and reliable data on the coastline.

In developed countries such as UK, USA, and the Netherlands, many coastlines are heavily urbanised and the majority of them are well protected with hard and/or “soft” engineering measures. They also have monitoring systems in place to check the resilience of their schemes and the capability to act quickly to maintain and fine tune their performance. Developed countries also have the planning, financial and technical capacity to upgrade existing defences and even build new defences to withstand the impacts of sea level rise and would be able to implement effectively almost any of the coastal response adaptation policies. They have the luxury of being able to select the most sustainable or environmentally friendly options, can implement accommodation measures to address residual risks and have the infrastructure and welfare systems enabling communities to recover from “unanticipated” events that do cause problems.

Developing countries in Sub-Saharan Africa, on the other hand do not have these capacities, but they also presently have much less development along their coastlines. For instance, Ghana has only 11% of her 540km coastline developed. There are also many fewer examples of coastal engineering in these countries, except at harbours and a few erosion “hot spots”. It means that there are opportunities to avoid the potentially costly and unsustainable “development – risk – protection” cycle by attempting to apply retreat and accommodation policies to manage the extent to which their populations and economic activities overlap into the most hazardous areas. However, almost all the countries are currently experiencing rapid coastal urbanisation and this threatens to increase the future risks and the consequent demands for protection options

This type of approach is not applicable for all developing nations, for example Nicholls and Mimura, (1998) identified that several developing countries in Asia have populated deltas which are vulnerable to sea level rise as well as increased coastal urbanisation. Often the population pressure is such that all fertile land has to be farmed with safety from episodic coastal hazards being perceived as being less important than the provision of food and the opportunity to improve living standards e.g. Bangladesh. Other vulnerable situations such as coral islands may also require novel approaches for they are so small that “retreat” would usually involve migration to a neighbouring higher or larger island or nation.

Analysis of Tables 1 and 2 indicates that where the coastline is developed such that value of the properties along the coast would be considerably higher than the cost of building defences, then protection should be the best option irrespective of the nature of the coastline. However, developing countries may lack the capacity and resources to implement protection policies without assistance. Even then it can be argued that major expansion of defences which themselves can encourage further development may not be a long term solution. Instead it could be better to confine protection to a necessary minimum and attempt to educate and direct development away from hazardous locations and to employ accommodation measures to mitigate risks along populated, but more rural coasts.

7. CONCLUSION

Recent IPCC reports provide increasing confidence that coastlines throughout the world are likely to be subject to increasing flood and erosion pressures due to climate change and its effects upon storms and sea-levels.

Based on the experiences of developing countries, a range of adaptive management policies can be identified that could potentially offset some of the worst problems. However, for such policies to be effective they need to be matched carefully to the local requirements of coastlines and their characteristics. They need to be planned in advance and implemented within an organised framework that includes elements of monitoring, maintenance, local community involvement and capacity building.

A particular problem affecting developing countries is that they do not have the necessary technical knowledge and organisational frameworks to effectively implement some of the more sustainable measures at present. Instead there is a risk that assistance could be provided for provision of engineering solutions that could benefit major urban areas for limited periods whilst doing nothing to discourage present trends for expansion of new development in hazardous areas. Investments in retreat and accommodation policies are therefore needed alongside any further protection in these areas.

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BIOGRAPHICAL NOTES

Isaac Boateng is a founding member and chief executive officer of CoastNet-Ghana, a Non-governmental Organisation involve in Coastal Zone Management in Ghana. He is also a Part-time Lecturer at the University of Portsmouth where he is currently undertaken a PhD research studies at the Geography Department. Isaac holds MSc degree in Coastal and Marine Resource Management from the University of Portsmouth, MA. Level research study in Scandinavian Welfare Model from Roskilde University, Denmark and also B.Ed degree in Social Studies from the University of Cape Coast, Ghana. He has also taught at the Liberal Studies Department of Kumasi Polytechnic in Ghana.

Malcolm Bray is a senior lecturer in Coastal Geomorphology at the University of Portsmouth, UK. He completed his PhD at the London School of Economics which involved sediment budget analysis and assessment of shoreline management methods. He has some 16 years of experience in applying science to the management of shorelines and has completed numerous consultancy projects for local governments and national government agencies in the UK. He has supervised a variety of PhD projects including a study of the Indonesian shoreline.

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