Integrating Sea-Level Rise Adaptation into Planning Policies in the Coastal Zone

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SUMMARY

This paper reviews different climate induced sea-level rise adaptation policy options and assesses how these policy options can be integrated into planning policies in the coastal zone to increase adaptive capacity. In order to identify a holistic and efficient way of integrating sea-level rise adaptation into planning policies, relevant and related literature on both sea-level rise adaptation policies and planning policy in the coastal zone were reviewed and gaps in the adaptation planning policies identified. A framework for the integration of climate induced sea-level rise adaptation into planning policies in the coastal zones was developed based on qualitative appraisal of coastal adaptation policy options for different coastal conditions, potential risk to natural and human resources and the possible impacts of each policy option on coastal settlements and resources in the face of climate change and associated sea-level rise. The paper concludes that due to recent climate related devastations in the coastal zones, such as 2007 flooding in the UK, Ghana and Bangladesh and 2006's hurricane Katrina in USA, a range of adaptive management and planning policies that could potentially offset some of the worst climate related problems need to be identified and implemented. However, for such policies to be effective, they need to be matched carefully to local economic and environmental conditions as well as the coastal characteristics. They also need to be planned in advance and implemented within an organised framework that includes elements of monitoring, maintenance, local community involvement and capacity building.

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1. INTRODUCTION

There is increased scientific understanding and a very high confidence of the dangers and impacts of climate change on natural ecosystem, managed and human systems and the capacity of these systems to adapt to their vulnerability. The biggest danger, many experts warn, is that climate change will cause sea levels to rise increasingly rapidly. The Inter-governmental Panel on Climate Change (IPCC) Fourth Assessment Report, published in 2007, has the following projections: temperature is likely to rise between 1.1^{o}C and 6.4^{o}C by 2099 and sea level likely to rise between 0.18m – 0.59m by 2099. Arctic summer sea ice may disappear by the second half of the century; increase in heatwaves is very likely and increase in tropical storm intensity likely, the latter being likely to cause severe problems for tropical developing countries. Walsh et al (2004) indicated that although scientific evidence for future sea-level rise seems convincing, the available estimates of future sea-level rise are not sufficient for planning purposes because of high uncertainties. However, the IPCC, (2007) report concluded that there is 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.

Nicholls, et al (2007) acknowledged that since the IPCC Third Assessment Report (TAR), our understanding of the implications of the climate change for coastal systems and low-lying areas has increased substantially and the level of uncertainty has reduced considerably. Six highly confident coastal planning policy-related facts that emerged from the IPCC 2007 report are:

- Coasts are experiencing the adverse consequences of hazards related to climate and sea-level rise.
- Coasts will be exposed to increasing risks, including coastal erosion, over coming decades due to climate and sea-level rise.
- The impact of climate change on coasts is exacerbated by increasing human-induced pressures.
- Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries, due to constraints on adaptive capacity.
- Adaptation costs for vulnerable coasts are much less than the cost of inaction.
- The unavoidability of sea-level rise, even in the long-term, frequently conflicts with present-day human development pattern and trends.

Rising sea-levels is particular problems in the world because a majority of the world's population lives in coastal areas and hence many of the world's built assets are located in the coastal zone. Sixty percent of the world's 39 metropolises with a population of over 5 million are located within 100km of the coast, including 12 of the world's 16 cities with populations

greater than 10 million (IPCC, 2007). The growing trends of human development along coasts exacerbate their vulnerability due to increased risk to life and property. Dang, (2003) identified that in China, 100 million people have moved from inland areas to the coast in the last twenty years. Nicholls and Mimura (1998) have estimated that 600 million people will occupy coastal floodplain land below the flood level by 2100. Quite apart from this, a 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 induced 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 the 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 destruction of life, property and beaches and severe shoreline erosion e.g Hurricane Katrina;
- Accelerated coastal erosion, which may also cause destruction of coastal properties and possibly loss of life;
- Seawater intrusion into fresh and groundwater sources thus reducing the supply of fresh water in coastal towns;
- Altered tidal range in estuaries and tidal river systems which may destroy estuarine ecosystems; 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 coastal economies will go a long way to affect the global economy, since every country, including landlocked countries, depend on the coast in some form. It must be noted, that the extent of the impact of sea-level rise on countries depends on many factors including:

- the nature of the coastline and the level of exposure (delta, marsh, estuary lowlands/uplands, soft geology/hard geology etc);
- the nature and value of developments on vulnerable coastal lands;
- the capacity and affordability to build defence and protection schemes;
- the natural adaptive capacity of the coast;
- adaptation planning and mitigation and
- availability of cost effective sources of alternative supply of goods and services to the hinterland, landlocked countries in times of climate hazards.

It is important to mention that sea level changes are caused by many factors. Bird, (2000) outlined the causes of sea level change under four broad themes. They are: (1) eustatic movement of the sea level, (2) steric changes, (3) sedimentation and (4) tectonic movements. The first two factors involve increase or decrease of the volume of water in the ocean basins as a result of a rise and fall in the water supply from the earth interior or an increase in atmospheric temperature resulting in warming and expansion of the ocean's water and vice versa. The last two factors, on the other hand, cause sea level change through reduction of the

ocean basin and upward or downward movement of the earth crust. The two important points worth noting are:

- Sea level change caused by the last two factors are relatively local but sea level change caused by the first two are world-wide because the oceans are inter-connected (Bird, 200).
- It is probably much easier to plan for the adaptation to sea level change caused by temperature changes (because it evolves over time) than planning for the adaptation to sea level change caused by tectonic movements, since their occurrence is more sudden.

These two points have informed the recent international research into climate change and associated sea level rise as well as the world-wide education on issues of climate change and the international advocacy for mitigation and adaptation of the impacts of climate change.

The IPCC, (2007) identified that one way of increasing adaptive capacity is by introducing the consideration of climate change development planning, by including adaptation measures in land-use planning and infrastructure design and measures to reduce vulnerability in existing disaster zones. The threats of climate change are so clear and the time to start planning is now. Perhaps, the way to achieve sustainable settlement and development in the coastal zone is the integration of sea-level rise adaptation into planning policies in the coast zones *now* so that we can reduce, if not prevent, the potential deleterious impacts of sea-level rise on settlements and development in the coastal zone.

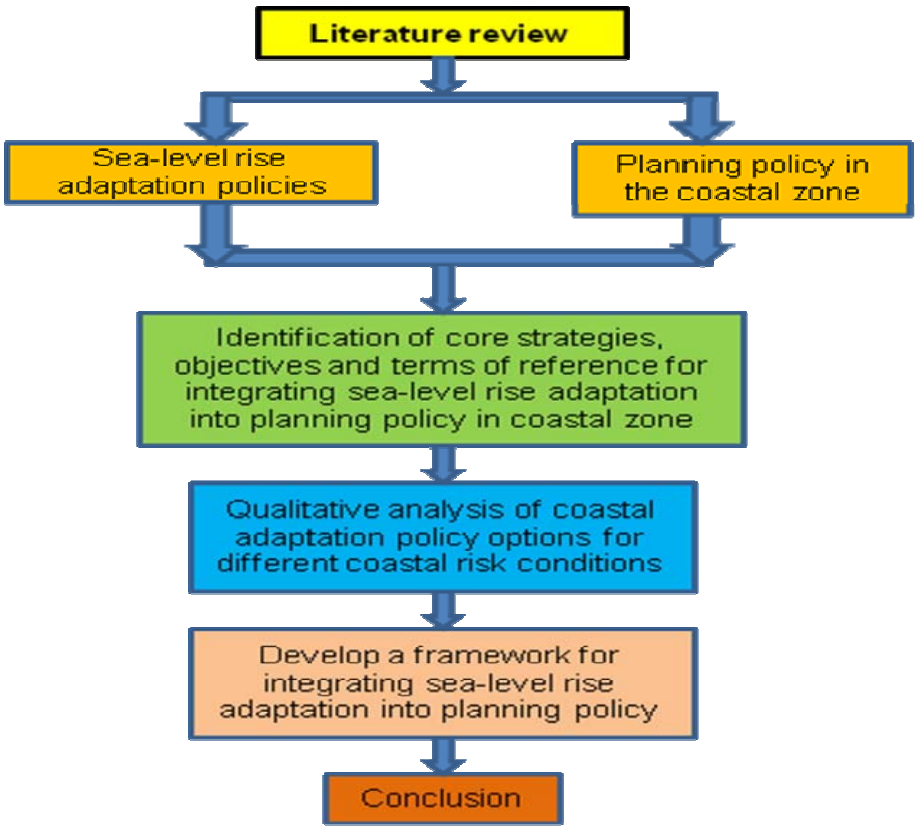
In fact, the need to prepare adaptive responses to reduce impacts of climate induced sea-level rise on coastal zones cannot be overlooked, irrespective of the possibility of mitigating some of the more extreme effects through emissions controls. Adaptive capacity varies from one coastal community to another due to differences in: coastal topography; physical exposure; human settlement patterns; climate; scientific technology and economic development. Despite these variations, the policy making process and the planning systems required for sustainable adaptive action is very complex due to several limitations imposed by the significant uncertainties in the projection of sea-level rise, financial considerations and numerous physical, social, economic, legal and political factors which, make many countries more vulnerable because they have inadequate adaptive capacity in financial, planning, social, economic, legal and in some case political considerations.

2. METHODOLOGY

In order to identify a holistic and efficient way of integrating sea-level rise adaptation into planning policies, a literature review was conducted on both sea-level rise adaptation policies and planning policies in the coastal zone. Based on the literature review, the core strategies of sea-level rise adaptation, objectives and terms of reference for integrating sea-level rise adaptation into planning policy in the coastal zone were identified. Then qualitative appraisal of coastal adaptation policy options for different coastal conditions was undertaken based on an appraisal of potential risk to natural and human resources and the possible impacts of each

policy option on a coastal settlements and their resources should sea level rise. Preferred policy options that should be adopted, given the human development and the physical condition of a given coastline, were recommend. This was used as a basis for the development of a framework for integrating sea-level rise adaptation into planning policy in the coastal zone. Figure 1 below provides an illustration of the methodology.

Figure 1: Outline of Methodology



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 climatic conditions 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. However, our understanding of human adaptive capacity is less developed than our understanding of responses by natural systems, which limits the degree to which we can quantify societal vulnerability in the world's coastal regions (Nicholls et al, 2007).

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.

3.1 Climate change adaptation strategies

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 for implementation. Easterling, et al (2004) observation implies that any adaptation policy option that is selected for a given coastal settlement must be based on cost benefit analysis.

3.2 Coastal Response Options to Sea-Level Rise

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.

The Protection policy aimed at protecting the land from the sea so that existing land uses can continue, by constructing hard structures as well as using soft engineering measures. The first shortfall of protection policy is that it is generally costly and has limited or finite long term effectiveness. It may me toppled by storm surge and other extreme weather conditions associated with climate change (e.g. Hurricane Katrina in New Orleans, 2006). It tends to overly control or operate 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 crosshore transport losses. Hard structures usually require regular maintenance

to achieve full longevity and this is not always adhered to 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. Groynes also may succeed in trapping sediment updrift and cause starvation (erosion) of sediment downdrift and possibly lead to the continuous construction of expensive groynes or other forms of protective structure along the entire coastline.

"Soft" engineering methods such a 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.
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.

The Accommodation policy implies that people continue to occupy the land but make some adjustments to properties and activities. The policy involves: redesigning 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 are 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.

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.

3.3 The Process of Coastal Adaptation

Klein and Nicholls (1999) argue, that the adaptation polices 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, they observed 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. The four steps are:

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

According to Klein et al (2000) if the four steps of coastal adaptation process above are adhered to before and after the selection of the coastal adaptation policy option and implementation of the selected policy option, positive results can be achieved. The reason is that following the first two steps should significantly improve knowledge, and participation, which will in turn; enable a much better informed selection of coastal adaptation policy that would be suited to both natural and human conditions and also acceptable to the local population. These last three steps are equally important since the selected adaptation policy option needs to be implemented and also monitored after implementation of the policy, so as to identify any uncertainties, gaps in coverage and allowing amendments where necessary (see figure 2). 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. IPCC, (2007) observed that there is inadequate data and literature on climate change and sea-level rise in developing countries. This situation may affect adaptation planning and adaptive capacity in the development countries. Perhaps, it is worth noting that developing countries will have to start their capacity building and institution development now if they are to be able to implement adaptive 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), and design a basic form of shoreline management framework and monitoring system now to facilitate effective adaptation later.

3.4 Strategic Coastal Defence Policy Options

Another sea level rise adaptation policy that has gained much attention in the UK and perhaps other coastal countries is the Shoreline Management Plan (SMP). It is a plan that identifies one coastal defence strategy for a specific length of coastline (a "management Unit") and for a defined period of time, typically up to 50 years. The first plans were prepared to cover the coast of England and Wales in 1993. The guidance for SMP has been extensively reviewed since 1993. The latest SMP guidance was published by Department for Environment Food and Rural Affairs (DEFRA) in 2006. DEFRA, (2006) SMP guidance outlined four strategic coastal defence/adaptation policy options to deal with effects of sea-level rise. They are:

- **Hold the line**: protect the economic assets of the frontage and backing flood risk areas.
- **Advance the line**: reclaim land lost to the sea where no environmental impacts would result from seaward movement of defences.
- **Managed Realignment**: where there is a potential long-term technical and environmental benefit.
- **No active intervention:** vast flood risk areas where there is limited potential benefit from controlled inundation.

It must be noted here that the key to successful application of DEFRA strategic coastal defence options is based on sound understanding of coastal processes and the involvement of stakeholders to ascertain potential hazards, vulnerability, resilience and risk to the environmental and economic resources of a given coastal system. The duration for the application of a strategic coastal defence option to an area could be a short-term (20years), a medium-term (30years) and a long term (50years) period. DEFRA believe that to minimise future risk is to encourage fully engagement of local people and planning authorities to ensure that the adaptation plan is link to and inform Regional Spatial Planning Strategies and Local Development Frameworks. This will help to ensure that inappropriate development does not take place in areas that are at risk of flooding or erosion either now or in the future.

4. PLANNING POLICY IN THE COASTAL ZONE

Town planning by its nature is essentially concerned with shaping the future (Ward, 2004). This does not mean that town planners should ignore the past. The past always have some influence on the present and the future. This indicates that planning policies are extensively influenced by the past, present and the future expectations. Keeble, (1969) defined, Town planning as the art and the science of ordering land-uses and siting the buildings and communication routes so as to secure the maximum level of economy, convenience and beauty. This traditional definition also emphasis the need to ensure that siting of buildings, infrastructure, social and economic developments do not only provide present and future convenience but also justify maximum economic benefit at present and in the future. This also implies that cost-benefit analysis of developments is a very important factor that should be considered before given planning permission for some key developments.

The key concepts of the two definitions above show that planning policy in the coastal zone should be based on anticipated future occurrences and problems (climate change, sea-level rise and its anticipated impacts on the coastal zone), exploring their probable impact (Risk assessment), and appraisal of policy options and strategies to solve the problems (assessing alternative adaptation and mitigation options) and the selection of the best sustainable options for implementation. The question often asked by many people is, what does spatial planning have to do with climate change? Many people often forget that spatial planners set the vision for development and decide the way we use and develop the environment. The choice about the use and development of land, coasts and sea could significantly affect the rate of greenhouse gas emissions, the speed and severity of climate change as well as the impact of sea-level rise on coastal settlement.

The adoption of Integrated Coastal Zone Management (ICZM) by many coastal nations has led to the increased level of participation in the decision-making process and the strengthening of institution in the coastal zone. ICZM has helped in the building of capacity, creating awareness of the dynamics and the complexity of the coastal systems and how it should be managed and above all it has developed a sense of ownership of the coastal zone and its institutions among the stakeholders.

One important tool of the concept of sustainable development that has contributed significantly to the developments in the coastal zones is Environmental Impact Assessment (EIA). It tries to ensure that developments do not cause extreme harm to the earth and that any significant harmful effects of a development are mitigated or properly managed. EIA is a process with several important purposes. It is an aid to decision making (Glasson, 1999). Perhaps, it is right to state that many developers nowadays see EIA as a key hurdle to jump before they can get permission to proceed with their development activities.

EIA is a tool that is used to assess physical impacts of development (e.g. building, road and industry) on the natural environment. However, considering the likely effects of climate change and sea-level rise identified by IPCC, 2007, in particular, the impacts on the coastal zones, perhaps it is time introduce Climate Change Impacts Assessment (CCIA) (e.g. impacts

of temperature extremes, high or low rainfall, sea-level rise, storm surge, flooding, and erosion) prior to a physical development of an area. Sustainable development is likely to be achieved in the coastal communities if development decisions are made based on both EIA and CCIA.

In most countries, EIA has been integrated into national and local planning policies. Since CCIA could be defined as complementary to EIA, it is probably better if CCIA is also integrated into planning policy so that both could be done by developers concurrently. However, the best way of achieving CCIA in the coastal zone is to integrate climate change and sea-level rise adaptation into the Planning Policies of coastal developments. Another question that comes out at this point is what amount of sea-level rise should therefore be assumed for planning purposes? Walsh et al, (2004) suggested that the best approach might be through risk assessment, based upon the estimated probability of various estimates of sea-level rise. They further explained that for all types of sea-level rise risk assessment, the scenario-building exercise should incorporate all ranges of uncertainty that can be quantified, whether by expert analysis, dynamic modelling or statistical method or a combination of both. This idea of risk assessment from Walsh, et al (2004) is either similar or seems to support the proposition of CCIA in coastal planning policy.

5. INTEGRATING CLIMATE CHANGE AND SEA-LEVEL RISE ADAPTATION INTO PLANNING POLICY IN THE COASTAL ZONE

The coast is an area where land and sea interact (Boateng, 2006). The coastal zone refers to the zone (coast and its adjoining hinterland and offshore) where the coastal environment exerts an influence. The landward limit of the coastal zone, though defined differently by coastal nations, can be said to be marked by the 30m contour above sea level. The coastal zone and its ecosystem is believed to be among the most productive areas that provide food, livelihood and home to millions of species in the world. Coastal zones have a very complex and dynamic environmental system and are perhaps the most vulnerable area in the face of climate change and associated sea-level rise. Hence there is the need to integrate sea-level rise adaptation into planning policy in the coastal zone so as to ensure sustainable development and maximise economic benefit from the coastal zone.

Management of any environmental problem requires the concerted effort of all stakeholders. There is therefore the need to adopt a participatory approach in the integration of the sea-level rise adaptation into the planning policy process. Quite apart from this, the physical processes of the coast, the natural resources and the socio-cultural philosophy of the local people need to be understood in order to select appropriate and sustainable adaptation polices. Table 1 outlines the core strategies and terms of reference for sea-level rise adaptation and Figure 2 (page 16) provides a framework for the various processes that should be followed, in stages, to achieve sustainable integration of sea-level rise adaptation into planning policy. It is important to note that planning policy can operate at different “levels”: regional, national and local “levels”. The framework below can be used to integrate sea-level rise adaptation into planning policies at all scales (perhaps with little modifications), if the planning policy agenda/objective is to achieve sustainable adaptation to climate induced sea-level rise.

Table 1: Summary of the Review of Sea-level rise Adaptation Policies

CORE SEA-LEVEL RISE ADAPTATION STRATEGIES	TERMS OF REFERENCES	SOURCES
Sea-Level Rise Adaptation Objectives	Prevent the loss Tolerate the loss Spread or share the loss Change the affected activity Change the location of the activity	McCulloch, et al (2002)
Sea-Level Rise Adaptation planning process	Information collection and awareness creation Planning and design Implementation Monitoring and Evaluation.	Klein *et al.* (2000)
Sea-Level Rise Adaptation policy options	Protection Accommodation Retreat (or) Hold the line Advance the line Managed Realignment No active intervention	Biljsma *et al.* (1996) adopted by IPCC (2001) DEFRA (2006)
Basis for selection sea-level rise (SLR) adaptation policy option for implementation	Risk/ hazard assessment Cost benefit analysis Local sea-level rise projections Appraisal of the SLR adaptation policy options base on adaptation objectives, natural vulnerability of the coast and human development.	Walsh et al (2004)

5.1 Appraisal of Coastal 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 a comparative advantage to the others. Tables 2A, 2B and 2C show the appraisals for human conditions, natural conditions, and strategic coastal defence options 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), local predicted sea-level rise scenario and the physical processes (waves, tide, wind and drift). Data on human activities along the coastline also should be collected and related to the natural conditions of the coast.

The outcome will be a combination of human developments and natural coastal conditions; for example, a harbour city located on a hard coastline or an urban settlement on a low

coastline say in a delta. The information gathered on the intensity of human development, the natural coastal morphology and the physical processes operating along the coast would determine whether protection, accommodation or retreat is the best option for a particular section of a coastline.

The general principle that can be deduced from tables 2A, 2B and 2C are the obvious outcomes which indicate that where valuable developments and economic activities have been already located on vulnerable coastal lands, protection (hold/advance the line) should be the best policy option unless cost benefit analysis shows that the cost of protection will exceed 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 (management realignment) 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 (no active intervention) should be the best policy option.

Table 2A: Appraisal of SLR* Adaptation Policy Options for Human Development 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 more economical than protection. Protection may be needed where allowing natural processes 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 will not lead to the destruction of the particular coastal resource supporting the economy (eg. beach)	This should be the best option as it will use soft approaches to maintain the natural resilience 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 higher value than the cost of protection (eg. small islands)	It should be possible to accommodate the impacts since residual impacts may not affect the local economy (none or less impact on local economy)	Should be possible to retreat, because the local economy may not be affected.

Table 2B: Appraisal of SLR* Adaptation policy options for Natural Coastal Conditions

- Sea level rise

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 resilience 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 often withstand erosion and thus offer natural protection.
Soft Coastal geology	There is the need for protection since the natural resilience may not be enough to withstand the impacts of sea level rise. Where there is much rainfall and clay geology, cliff slumping may make protection difficult and expensive.	It may be very difficult to accommodate erosion and slumping of soft cliffs	The natural resilience is not strong enough to withstand the impact so retreat will lead 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, thus making accommodation possible.	Retreat may not be economical since the natural condition makes accommodation easy.

Table 2C: Hypothetical Appraisal of DEFRA's Strategic Coastal Defence Option

Option	Appropriate for	Adopt Where	Notes
Hold the line	Existing development	Industrial or urban development present.	May also be appropriate for satellites or ribbon development, depending on value protected and cost of protection
	Infrastructure	Present and cannot be moved.	Coastal infrastructure is often sited to take advantage of the combined land and sea resource. Any impacts, particularly on the adjacent coast must be accounted for.
	Future planning allocation	Infrastructure or development planned which can justify the need for and coast of production.	Current planning guidance presumes against development in areas subject to coastal flooding or erosion.
	Conservation sites	Need for protection and positive benefit to the site, or a site exists as a consequence of the present "shoreline"	This needs careful consideration of how the site would evolve if it were reconnected or exposed to an open and active shoreline.
Advance the line.	Future planning allocation.	Development must use coastal frontage or requires direct access to sea.	Likely to have significant impact on remainder of management unit and adjacent units
	Advancing shoreline.	Coast is advancing and value of reclaimed land is greater than any protection costs and there is no attendant negative impact on adjacent coast.	Great care is needed to ensure that this is a long-term trend and that enclosing a sediment sink is not to the net detriment of the system.
Managed Realignment	Narrow coastal margin	Coast is defended and is retreating or steepening and there is room to allow set back of defences or remove landward constraint.	As coastal margins gets narrower (steepening beaches, loss of salt marsh etc) exposure increases and leads to more massive and expensive defences, and that justify the need to consider realigning of the shoreline.
No active intervention	Conservation sites	Protection is detrimental to conservation interests and could be improved by allowing natural processes to operate.	May need to be managed as a single, stepped or progressive change depending on the conservation interests
	Retreating shoreline	Foreshore is eroding and value of land lost is less than the cost of protection	For this to be a worthwhile option there should also be a nature conservation benefit or at least no loss.
	Mobile natural features	A feature moves with time, often in a cyclic pattern.	Providing room to move is particularly appropriate in the vicinity of spits, tidal inlets, estuary margins etc.

5.2 Framework for Integration

The framework (Figure 2) could be adopted and implemented in most coastal countries for the integration of climate change adaptation into national and local planning policies. The point of insertion or application of this framework in countries that have planning policy guidance is where the Planning Authority needs to decide whether a given development or a project needs to carry out an EIA. Another parallel decision that must be made at this level is whether the development or the project should equally conduct CCIA (Climate Change Impact

Assessment) or not. While EIAs consider the management and mitigation of environmental concerns of a project, the CCIA will consider project vulnerability in a climatic environment and how it can be adapted to the environment given climate change scenarios. Based on professional judgement, a Planning Authority could recommend either assessments (EIA and CCIA) or both to be conducted on a proposed development. On the other hand, where there is no formalised planning policies (e.g. in some developing countries) the framework can be applied to all proposed developments in the coastal zone. However, in both situations the framework can be adapted to develop a planning policy for climate change adaptation for a coastal zone.

Figure 2: Framework for Integrating Sea-level rise Adaptation into planning policy

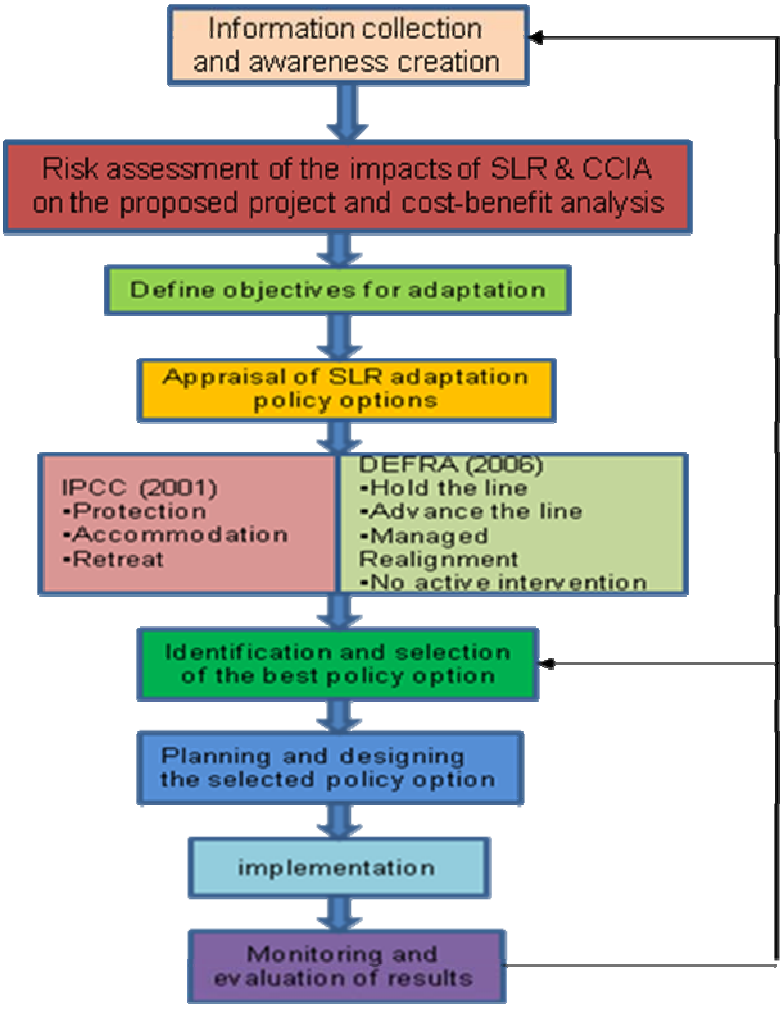
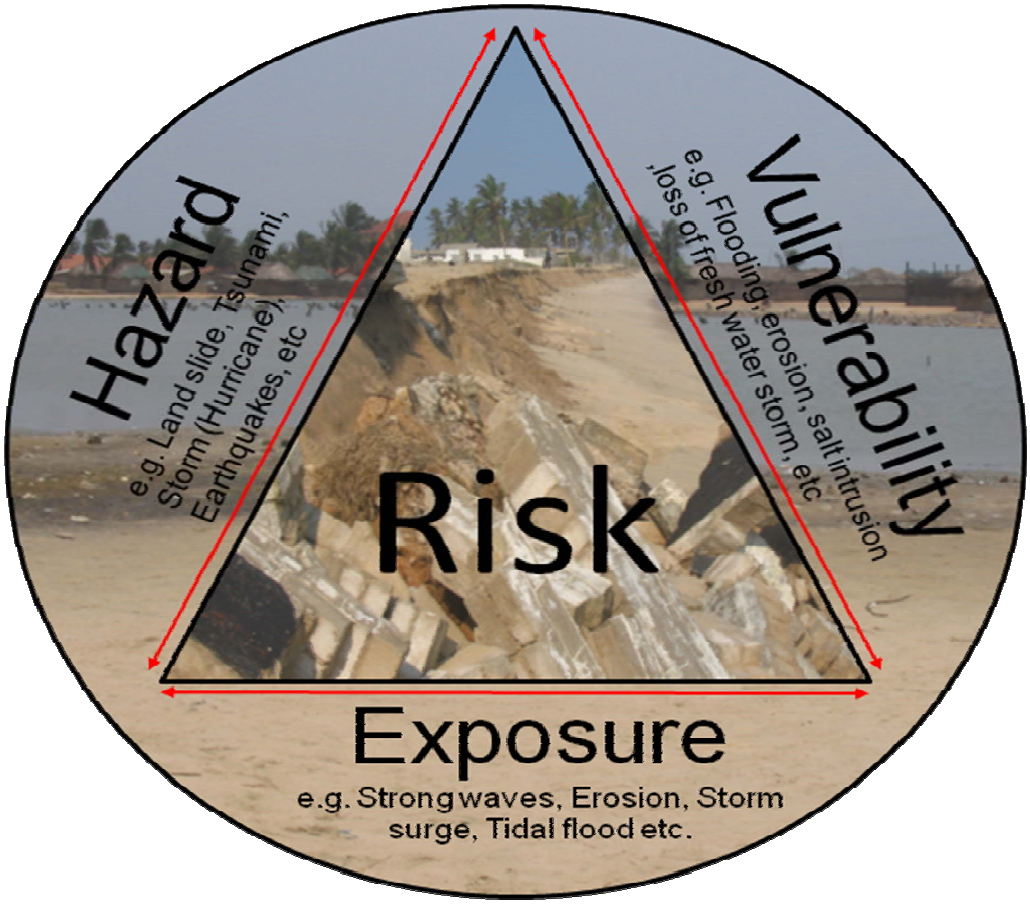


Figure 2 above suggests that climate change adaptation planning starts with information collection and creation of awareness on the issues of climate change. The important information collected (section 5.1) should be used to conduct risk assessment of the possible impact of climate change on the proposed development or on the plan area. The risk assessment should be base on the following:

– The proposed development or the plan area vulnerability to the present and future climate change;
– The proposed development or the plan area exposure to the present and the likely future impacts of climate change; and
– The potential hazard likely to cause damage to the proposed development or the plan area resulting from climate change.

The risk triangle (figure 3) summarises the three dimensions that climate change risk assessment needs to consider. In Figure 3, the circle represents the entire coastal zone and the triangle inside the circle represents the dimensions of risk in the coastal zone that need to be assessed.

Figure 3: Climate Change Risk Assessment Triangle



Source: after Crichton (2001)

When the present risk and the potential risk of future climate change have been ascertained then a cost-benefit analysis can be done based on the development of the proposed project in the plan area without adaptation policy and with adaptation policy. The results of the cost-

benefit analysis should be used to define adaptation objectives (Table 1) for the proposed development or the plan area. The defined objective(s) will then feed into the appraisal of climate change adaptation policy options (Tables 2A, 2B and 2C). The appraisal will help the assessor to identify and select the best adaptation policy option for implementation.

After implementation there should be monitoring and evaluation of results. If the evaluation indicates that the policy is not achieving the intended objective(s) then it might be a wrong identification and selection of the policy option and therefore the policy review must start from there. Again, it might also be the fact that insufficient information was collected at the beginning, which implies that the whole process needs to be reviewed.

The framework does not only create awareness of climate change but also help increased participation in the decision making process. Not only would the information collection aspect help some developing countries to identify the true extent of vulnerability but 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 (e.g. Keta Sea defence in Ghana). However, there are gaps that need to be filled for effective implementation of the framework. First, due to limited technology and weak planning policies in some coastal countries, there is a knowledge gap in the planning and design 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 offer 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.

6. IMPACTS OF ADAPTATION POLICIES ON COASTAL SETTLEMENTS.

The processes of adaptation to Climate change and sea level rise in both human and natural systems are very complex and dynamic, often involving numerous assessments depending on existing conditions. Table 2A, 2B and 2C 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 different natural coastal characteristics with the human development. For instance, what policy option would be best suited for a developed coastline with a soft coastal geology? The success of any option to 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 the 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 have the planning, financial and technical capacity to upgrade existing

defences and even build new defences to withstand the impacts of climate change and 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 and 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 less development along their coastlines. For instance, Ghana has only 11% of her 550km 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

It could be argued that the author's approach may not be applicable for all developing countries. For example Nicholls and Mimura, (1998) identified that several developing countries in Asia have populated deltas that 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, and safety from episodic coastal hazards is perceived as 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. Whatever the case may be, the approach offers a holistic assessment of vulnerability and rigorous appraisal of climate induced sea level rise adaptation policy options for planning in the coastal zone. For instance, developing countries could use the framework to identify the best adaptation planning policy option for their coast before seeking donor support for implementation.

7. CONCLUSION

The analysis above indicates that where a coastline is developed such that the 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. Even then it can be argued that major expansion of defences themselves can encourage further development and 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. Retreat and manage realignment should be considered where protection and accommodation are likely to fail or cause severe damage to other parts of the coastline. The no active intervention option on the other hand, should be considered where the application of any other option might cause destruction of a conservation site and also where

the conservation value exceeds the value of land loss. However, developing countries may lack the capacity and resources to implement some of these policy options without assistance.

This implies that the approach could not be generally applied to all coastal settings without some modifications. The framework may require some modification in order to meet the differences in economic strength, institutions, technology, values, development patterns, coastal geomorphology and coastal tenure relations.

The IPCC (2007) report provides 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. The recent devastations caused by climate related hazards to most coastal communities (e.g. 2007 flooding in UK, Ghana and Bangladesh as well as 2006 Hurricane Katrina in USA), are clear signs of the IPCC findings. They indicate the strong need for adaptation planning and advance preparation for disaster risk management such as early warnings systems, victims' evacuations and accommodation, health care and insurance. Therefore, there is an urgent need for every coastal community to explore and identify climate change adaptation plan that could potentially offset some of the worst climate change problems, since the impacts of climate change and associated sea level rise is global and probably more predictable and adaptable than other causes of sea-level rise. However, for such adaptation policies to be effective they need to be matched carefully to the local coastal conditions, characteristics and the economic activity at the backshore. They also need to be planned in advance and implemented within an organised framework that includes elements of monitoring, maintenance, local community involvement and capacity building.

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BIOGRAPHICAL NOTES

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