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West Africa Coastal Areas Management Program

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REPORT

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Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis

D11: Final project report

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List of Acronyms and Abbreviations

CBA / *ACB*	Cost Benefit Analysis / *Analyse Coût-Bénéfice*
CCA / *ACC*	Climate Change Adaptation / *Adaptation au Changement Climatique*
CI / *IC*	Coastal Index / *Indicateur Côtier*
CLC	Corine Land Cover / *Données de couverture et d'occupation des sols Corine*
COCED	Cost Of Coastal zone Environmental Degradation / *Coûts de la Dégradation de l'Environnement Côtier*
CRAF	Coastal Risk Assessment Framework / *Plan d'Evaluation des Risques Côtiers*
DRR / RRC	Disaster Risk Reduction / *Réduction des Risques de Catastrophe*
EVI */ IVE*	Economic Vulnerabity Index / *Index de Vulnérabilité Economique*
EWS	Early Warning System / *Système d'Alerte Précoce*
GDP / *PIB*	Gross Domestic Product / *Produit Intérieur Brut*
IRR / *TRI*	Internal Rate of Return / *Taux de Rendement Interne*
IUCN / *UICN*	the International Union for Conservation of Nature / *Union Internationale pour la Conservation de la Nature*
NDF / *FND*	the Nordic Development Fund / *Fonds Nordique de Développement*
NPV / *VAN*	Net Present Value / *Valeur Actuelle Nette*
SVI / *IVS*	Social Vulnerability Indicator / *Indicateur de Vulnérabilité Sociale*
TA / *AT*	Technical Assistance / *Assistance Technique*
ToR / *TdR*	Terms of Reference / *Termes de Reference*
WACA	West Africa Coastal Areas management program / *Programme de Gestion des Zones Côtières d'Afrique de l'Ouest*
WAEMU / UEMOA	West African Economic and Monetary Union / *Union Economique et Monétaire Ouest-Africaine*

1. INTRODUCTION

1.1 THE ASSIGNMENT

The West African coastal area hosts large infrastructure, major industries, tourism, agriculture and fishing activities as well as human settlements and its forerunners (e.g. communication routes) that drive economic growth and provide the livelihoods for many. It is one of the most rapidly urbanising areas in the world and, as in many West African countries, the economic activities which form the backbone of national economies are located within the coastal zone. However, demographic pressures and increasing exploitation of coastal resources have led to rapid coastal environmental degradation. Coastal ecosystems in West Africa now face a range of challenges, including coastal erosion, overexploitation of natural resources (such as fisheries and sand/gravel mining), marine and coastal pollution, rapid urbanization and unsustainable land use, and overall poor environmental governance (The World Bank, 2016).

To address these challenges, the World Bank is developing a *Programmatic Technical Assistance* (TA) for a *West Africa Coastal Areas Management Program* (WACA). The project '*WACA Erosion and Adaptation'* is part of the WACA Programmatic TA and aims to promote sound coastal management practices for a selected group of countries. In the countries covered by the present assignment, Benin, Côte d'Ivoire, Ghana and Togo, the project is financed by the Nordic Development Fund (NDF), which has entrusted the World Bank for its implementation.

As part of the project '*WACA Erosion and Adaptation'*, the main objective of the consultancy services for the *'Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis*' is to provide a framework allowing to:

- study and quantify the coastal erosion and flood risk based on the available data,
- identify and rank hotspots along the coast in terms of hazards and vulnerability,
- quantify the cost of coastal environmental degradation,
- compare possible DRR and CCA measures in economic terms in a Cost Benefit (CBA) analysis.

This framework will be applied in order to select hotspots and develop plans for 4 pilot locations in Ghana, Côte d'Ivoire, Togo and Benin.

This study comprises the following deliverables:

- D0: Inception Report (IMDC, 2016);
- D1[a,b,c,d]: Reports on the qualitative review of natural hazards and risk mapping, for each country (IMDC, 2017a, 2017b, 2017c, 2017d);
- D2: Report on the definition of the pilot sites for each of the four countries and the detailed methodology (IMDC, 2017e);
- D3[a,b,c,d]: Reports for the quantitative risk assessment of coastal erosion and flooding for each pilot site (IMDC, 2017f, 2017g, 2017h, 2017i);

- D4[a,b,c,d]: Reports for the COCED analysis for each of the countries (IMDC, 2017j, 2017k, 2017l, 2017m);
- D5: An Executive Comparative Report on the coastal zones management and the COCED results (IMDC, 2017n);
- D6[a,b,c,d]: Reports on the identification and justification of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) measures for each pilot site (IMDC, 2017o, 2017p, 2017q, 2017r);
- D7[a,b,c,d]: Reports on the Cost Benefit Analysis of the selected DRR and CCA options (IMDC, 2017s, 2017t, 2017u, 2017v);
- D8: An Executive Comparative Report on the selected DRR and CCA options (IMDC, 2017w);
- D9[a,b,c,d]: PowerPoint presentations for the meeting with each communities council;
- D10: Policy note COCED, policy measures and recommendations (IMDC, 2017x);
- **D11: Final project report [present deliverable].**

1.2 SCOPE OF THE REPORT

This report is the final summary report of the study *'Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis*', which is part of the '*WACA Erosion and Adaptation'* project within the *'West Africa Coastal Areas Management Program'.*

Instead of providing a complete description of all work done within this study (already available in previous deliverables), it will highlight the main outcomes of the subtasks, and will provide guidelines and recommendations for the future application of the developed methodology. As such, it can serve as manual for future users of the COCED methodology for the selection of DRR and CCA options for coastal hazards. Wherever useful, reference will be made to the detailed descriptions in other deliverables of the study.

1.3 STRUCTURE OF THE REPORT

The report starts with a short description of the aims of the present work in chapter 1. The main steps of the study are summarised in chapter 2, and reference is made to other deliverables for more detail. Recommendations are formulated in chapter 3, and references are listed in chapter 4.

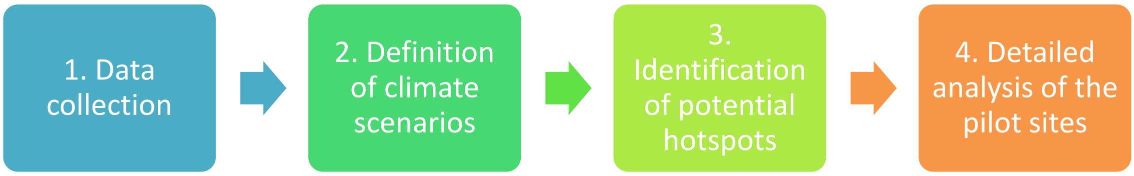
2. STEPS OF THE PRESENT STUDY

This section will summarize the various steps followed in this study and will serve as a “table of content” to indicate references to previous deliverables

The successive steps described hereunder are:

- Characterization of coastal erosion and flooding
- COCED analysis
- Comparison of DRR and CCA measures
- Communication

2.1 CHARACTERIZATION OF COASTAL EROSION AND FLOODING HAZARDS



2.1.1 Data collection

Deliverable D1 "Qualitative review of the natural hazards and risk mapping" for each individual country (IMDC, 2017a, 2017b, 2017c, 2017d) includes a summary of the data collection (i.e. the available & missing data) and a first qualitative analysis of the natural hazards on national scale.

The report **gathers and summarises the necessary information** needed for the analysis and quantification of the coastal flooding and erosion hazards. A focus is put on the specific data needed for the selection of the pilot sites in each of the countries, based on an impact based approach, and the quantitative risk assessment of coastal erosion and flooding for each pilot site.

To **support the selection of the pilot sites** in each of the countries (see Deliverable D2), data on exposure and hazards at country level are not only presented and discussed, but also processed into coastal Indicators, allowing for ranking of the different sites according to selected criteria (economic, social and natural vulnerability; coastal erosion and flood hazard, today and in the future).

The **available and missing data** for the hazard analysis at country level and / or pilot site level are listed in this report, and a priority for further data collection is assigned (e.g. absolutely needed, preferably available, nice to have). This overview further details the data needed for the quantitative risk assessment of coastal erosion and flooding.

In general, there are quite some data available at the national level, and for some sites along the coast. However, these are mainly qualitative and descriptive data. Much less quantitative data have been found. Furthermore, some data sources are identified (e.g. existing or ongoing studies), but it has not always been possible to obtain the reports, the GIS data layers, or the numeric databases. For the pilot sites, collected data have been complemented by in-situ observation during site visits. Acquisition of new data (e.g. topgoprahic or bathymetric measurements) was not part of the scope of the present study.

2.1.2 Definition of climate scenarios

Deliverable D3 "Reports for the quantitative risk assessment of coastal erosion and flooding for each pilot site" (IMDC, 2017f, 2017g, 2017h, 2017i) defines the different climate scenarios taken into account for the study of the different hazards and their evolution under climate change. Scenarios RCP 4.5 and 8.5 forecasts of the fifth assessment report of the International Panel on Climate Change (IPCC, 2014) have been selected for this study. They represent an average scenario (RCP 4.5) and a more extreme one (RCP 8.5). Based on local information and state-of-the-art studies and publications, these scenarios have been detailed and adapted for each of the countries.

The boundary conditions for the hazard assessment have been defined, for the period 2015 – 2100, and include:

- (mean) sea level, and relative sea level rise due to climate change
- annual wave climate, and future changes due to effects of climate changes
- extreme conditions (waves and storm surges) with and without climate change, for events with return periods of 10, 50 and 100 years.

2.1.3 Identification of potential hotspots

In **Deliverable D2 "Report on the definition of the pilot sites for each of the four countries and the detailed methodology" ,** the ranking of the potential hot spot sectors along the coasts of Benin, Ivory Coast, Ghana and Togo is presented according to the **CRAF methodology** (i.e. the Coastal Risk Assessment Framework) on regional level. CRAF uses a spatial analysis to assess the coastal hazards, the climate variability and their effect on the coastal areas and consists of a 2-phases approach:

Phase 1: the coastal-index method to identify potential hotspots – regional level (deliverable D2)

Phase 2: detailed analysis of the pilot sites: creation of detailed hazard and vulnerability maps – pilot site level (see deliverable D3)

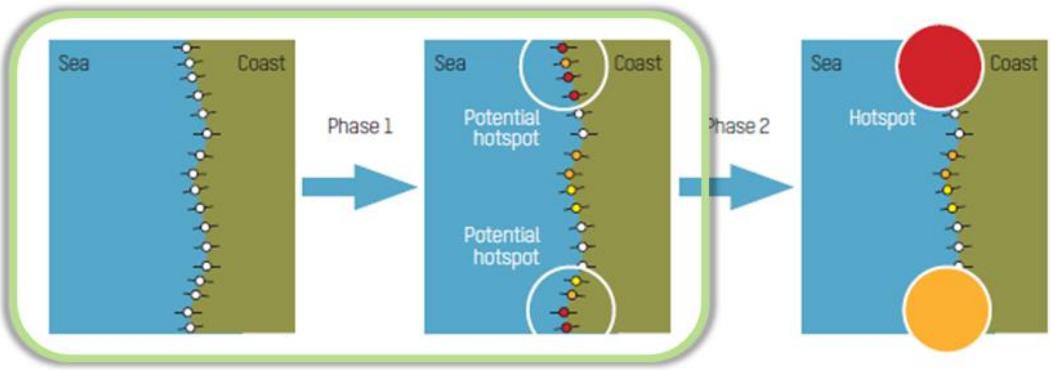


Figure 2-1: The 2-phases approach of the CRAF methodology – Phase 1: identification of potential hotspots

The CRAF methodology has been applied per sector (cfr. IUCM / WAEMU studies of 2011 & 2015) and the Coastal Index has been determined for: coastal erosion individually, coastal flooding individually and for coastal erosion and flooding combined, and in all cases for present and future conditions. By considering both present and future conditions, the effect of climate change on the hazard indicator, and therefore on the coastal index, is investigated.

The Coastal Index is obtained by combining the Erosion and/or Flood Hazard indicator with the Exposure Indicator. The exposure indicator measures the relative exposure of different receptor types: the Social Vulnerability Indicator (SVI), the Economic Systems Indicator (ESI) and the Natural Systems Indicator (NSI), as shown in the 2 figures below.

Figure 2-2: The Coastal Index

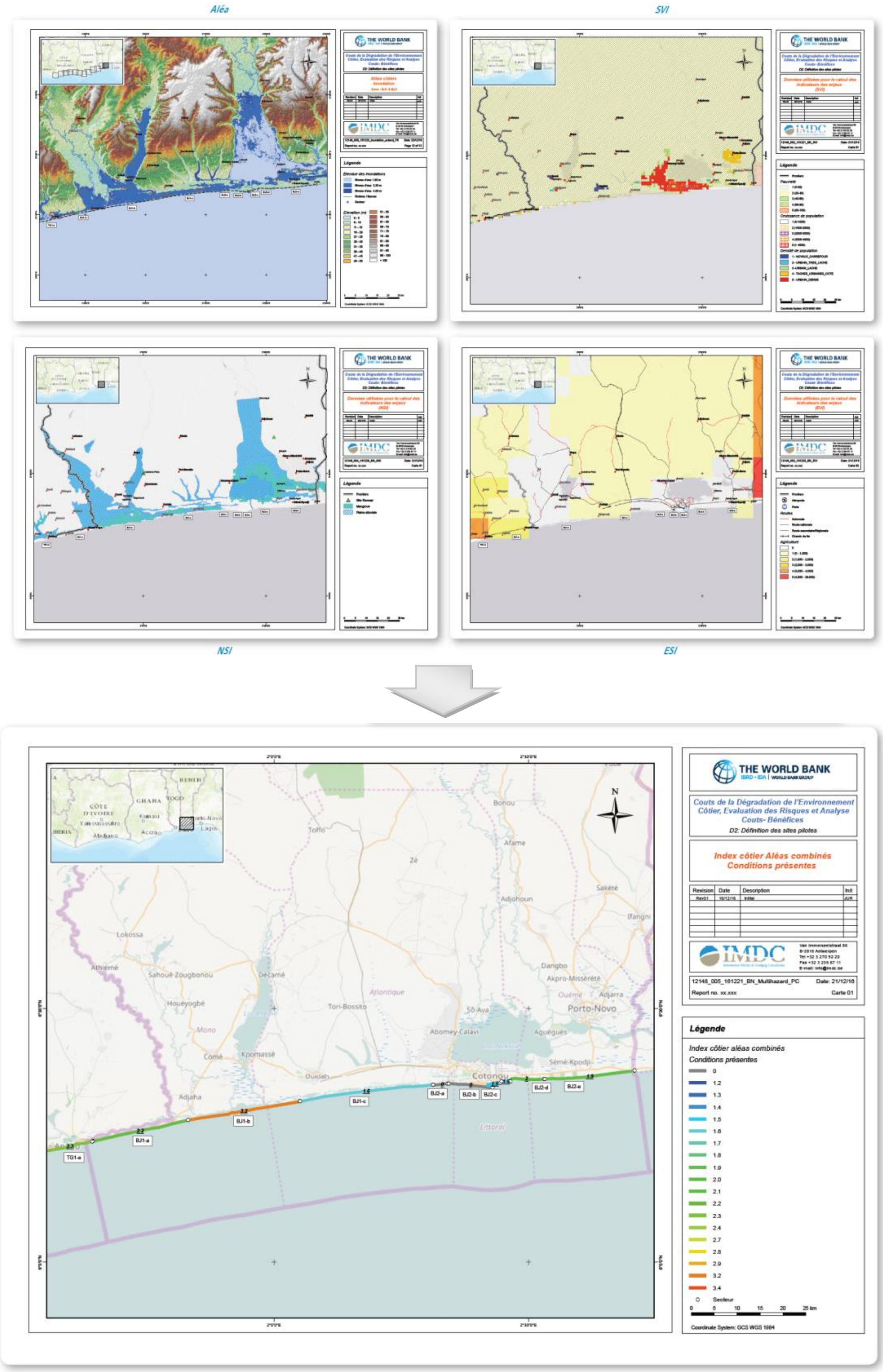


Figure 2-3: Hazard Indicator (top left), combined with the Exposure Indicator (based on the SVI – top right, the ESI – middle right, and the NSI – middle left), into the Coastal Index (bottom). Example maps for Benin, for present conditions.

Based on the ranking of the hot spot sectors along the coasts according to the Coastal Index for coastal erosion and flooding in future conditions, a **proposition of pilot zones** for the multi hazard risk assessment is made. These proposed pilot sites were discussed with the Client and the four governments, after which a final choice has been made. External factors have also influenced this choice, such as for example: administrative limits, data availability, political interest, urgency, etc.

This resulted in an interesting selection of 4 different pilot sites, with different types and levels of coastal risks and vulnerability, allowing a thorough testing of the newly developed methodology of this study:

- Ghana: sector from New Ningo to Lekpoguno
- Côte d'Ivoire: Abidjan, sector Port Bouët
- Benin: sector border Togo – Grand Popo
- Togo: sector Togoville – Agbodrafo – Aného

2.1.4 Detailed analysis of the pilot sites

Deliverable D3 "Reports for the quantitative risk assessment of coastal erosion and flooding for each pilot site" (IMDC, 2017f, 2017g, 2017h, 2017i) presents the characterisation of the coastal hazards and a quantitative risk assessment for the selected pilot sites (one in each country).

For each pilot site a general description is given and the main hazards and exposure types are identified. Following this, the methodology and results of the detailed hazard modelling is presented. The proposed approach, which is appropriate for the level of detail of the information available, can be further detailed and improved when more information becomes available.

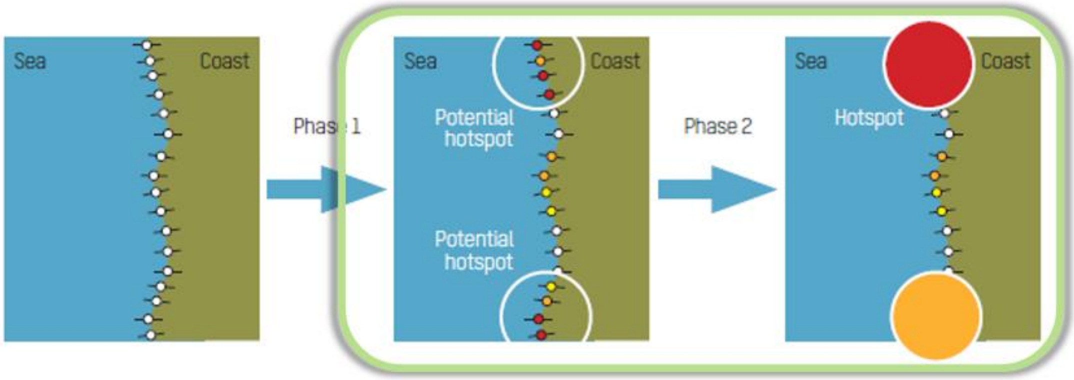


Figure 2-4: The 2-phases approach of the CRAF methodology – Phase 2: detailed analysis of the pilot sites.

In the present case, the following (numerical) models are used to address the different hazards:

- Erosion: short-term erosion (e.g. during storms) is predicted with the 1D cross-shore XBeach model, while long-term coastline evolution is studied with the Shorelines model and/or historical coastline evolution trends. The combined results of both models give the surface of land lost due to coastal erosion in the future.
- Coastal flooding: is estimated using a TELEMAC-2D model taking a tidal cycle in combination with a storm surge into account. The volume overtopping the dune crest is estimated using a theoretical formula and then propagated inland through a hydrodynamic model. The model results include flood extent, depths and velocities under present and future (storm) conditions.

Due to the lack of detailed nearshore bathymetry and beach topography, the differences in erosion rates obtained for scenarios under different return period storms or under different climate change scenarios are within the margin of uncertainty of these results. Therefore only the order of magnitude of the results is taken forward to the next steps of the study.

The limited availability and low resolution of topography and bathymetry (nearshore, and inside inlets, lagoons and estuaries) affects the accuracy of the predictions of the flood model and does not allow to identify significant difference between the two selected climate scenarios (RCP 4.5 and 8.5).

These results are used to assess the associated likely impacts on population and community infrastructure and serve as a base for damage calculations, which are presented in Deliverable 4 (IMDC, 2017j, 2017k, 2017l, 2017m).

2.2 COCED ANALYSIS

Each deliverable D4 "COCED analysis for each of the countries" (IMDC, 2017j, 2017k, 2017l, 2017m) starts with a short description of the present situation with respect to human occupation, economic activities, the characteristics of the natural environment and the risk of degradation.

2.2.1 Data collection

Deliverable D1 "Qualitative review of the natural hazards and risk mapping" for each individual country (IMDC, 2017a, 2017b, 2017c, 2017d) includes a summary of the data collection (i.e. the available & missing data) for the socio- economic aspects.

The report **gathers and summarises the necessary information** needed for the subsequent phases of the study. A focus is put on the specific data needed for the COCED analysis at country level and pilot site level, and the Cost Benefit Analysis of the selected DRR and CCA options for each pilot site.

To **support the selection of the pilot sites** in each of the countries (see Deliverable D2), data on exposure at country level are presented and discussed, including the economic, social and natural vulnerability.

The **available and missing data** at country level and / or pilot site level are listed in this report, and a priority for further data collection is assigned (e.g. absolutely needed, preferably available, nice to have). This overview further details the data needed for the COCED analysis and for the CBA of DRR and CCA options.

In general, there are quite some data available at the national level. However, these are mainly qualitative and descriptive data. Much less quantitative data have been found. Furthermore, some data sources are identified (e.g. existing or ongoing studies), but it has not always been possible to obtain the reports, the GIS data layers, or the numeric databases. For the pilot sites, data mainly come from the in-situ observation during site visits.

2.2.2 Qualitative description

The qualitative analysis has identified and described multiple mechanisms and treats that lead to coastal degradation, including pressures from different land uses, and lack of adequate land use management, pollution, (over) exploitation of natural resources, coastal erosion, climate change and sea level rise. This is included in **deliverable D4** (IMDC, 2017j, 2017k, 2017l, 2017m).

2.2.3 The COCED methodology

In addition to the qualitative description and analysis of threats to sustainability of the coastal zone, a method is developed to assess, quantify and value in monetary terms the erosion and coastal flooding risks.

This methodology integrates methods and data from different scientific disciplines and approaches. It builds on damage functions that have been developed in other parts of the world for detailed assessment of flood risks, and adapts them to coastal erosion. It also makes use of a combination of economic data on GDP for different sectors and of detailed available maps to identify economic assets at risks and estimate their importance on a per hectare basis. **Deliverable D4** includes the methodology, together with the country specific values (IMDC, 2017j, 2017k, 2017l, 2017m).

The available information and data allow to implement this methodology for the analysis of material damages to buildings and urban infrastructure and – to a lesser extent – economic activities (industry, services, harbor, and agriculture) and transportation.

Much less information is available for impacts of flooding on human health and on natural zones. A methodology was developed to test to which extent these impacts are likely to be important, using simplified and expert based damage functions in combination with methods and data from health economics and environmental economics. It was not possible to develop a method nor gather data to monetize impacts on cultural assets (e.g. historic buildings).

The method results in an estimation of areas subject to erosion and flood risks as well as of the number of people exposed and expected material damages. It allows to assess the time path of the expected impacts, and to highlight the impact of sea level rise and of both demographic and economic growths. The method foresees the integration of future development of land use, but no data or maps were available for such implementation in the present study.

Additionally, the method can be implemented at different levels of detail and geographical scales, and is a complement to more qualitative and local assessments. It allows to bridge the gap between the more general, top-down modelling approaches that estimate risks at a the level of a larger region or continent and the bottom-up local analysis starting from local circumstances, land uses and description of impacts.

To improve the accuracy of the results, it is recommended to make further rough assessments at pilot site level to identify the type of land uses affected, the type of impacts that are likely to be predominant and support the evaluation of the costs of adaptation measures with more precision. A first priority is a better integration of top-down data related to land use with bottom-up local information, with a specific focus on expected future developments.

2.2.4 COCED of Benin, Côte d'Ivoire, Ghana, Togo and respective pilot sites

A quantitative analysis has been performed both at national level and at pilot site level using the COCED methodology described above. The evolution of both erosion and coastal flooding has been determined in terms of surface but also in terms of type of land affected (rural, urban, economic, natural) and number of people affected. Whereas at regional level a GIS approach has been used to estimate the extent and intensity of the hazards, a more detailed approach, based on the use of hydrodynamic and hydro-morphological models, was used at pilot site level.

Damages have been calculated with damage functions which have been defined per land-use type for material damages mainly, since there are no satisfying flood-damage functions available for impacts on human health. A first estimate of such impacts has however been provided using rough and simplified function for fatalities.

The analysis has been done for the period ranging from 2015 to 2100, and effects of climate change (e.g. sea level rise, changes in metocean conditions) have been taken into account. As a general remark, the risks increases over time, and will be affected negatively by demographic and economic growth.

The combined erosion and flooding risks have been expressed in relation to the estimated GDP of the coastal zone and of the country (at regional level) or to the estimated GDP of the pilot site.

In **deliverable D5 “An Executive Comparative Report on the coastal zones management and the COCED results”** (IMDC, 2017n) a summary of the results and comparison is given for Benin, Côte d’Ivoire, Ghana and Togo at regional level and at pilot site level. The main conclusions are repeated below.

The natural environment that forms the physical and resource base of the coastal zones is in general highly vulnerable and subject to several simultaneous pressures. Those pressures risk to degrade the coastal environment, which will undeniably have consequences for economic development and human wellbeing in the area. The present study focussed on the impacts of coastal flooding and erosion that are a threat in the current situation, which are likely to intensify as a result of climate change and sea level rise.

The areas at risk for flooding and erosion in the short, medium and long term (2015, 2050, 2100) have been identified, the related damages and risks have been quantified accounting for the current land uses (rural, urban, economic) and future demographic and economic growth. The assessments confirms the threat of erosion and flooding for sustainable development at the coastal zones in all four countries, and 4 pilot sites.

The modelling of erosion and flooding shows that substantial part of the coastal zones is at risk for erosion or flooding. For 2015, it ranges from 6% of the area for Côte d’Ivoire tot 22% for Benin. For all pilot sites, the size of the area affected will substantially increase up to 2100 (+ 50 % to +300%), with a maximum of 50% for Benin. All 4 pilot studies are at risk for frequent (ten yearly) coastal flooding. In addition, assessment of the land uses in the affected areas shows that – on average – the affected areas are as valuable as the average for the coastal zone or pilot sites in terms of number of inhabitants per ha and GDP/ha. Consequently, the risks can amount to several % of local GDP.

The analysis also shows that risks are country and location specific, and that it is possible to account for these specificities. Some of these differences are driven by physical factors, which explain vulnerability for erosion and flooding, and how these treats will develop over time. Second, land uses affected differ between countries. Total damages and risks are mainly driven by the share of urban and economic land uses in the affected areas. It is further logical that risks expressed in $/ha are higher for the richer countries (in terms of GDP/capita).

The method offers an accounting framework that integrates different types of information, and that combines generic steps (e.g. damage functions) with country specific data and information. The analysis shows that it is possible to assess the damages and risks from coastal erosion and flooding on men and the economy, and – although more uncertain – on natural areas.

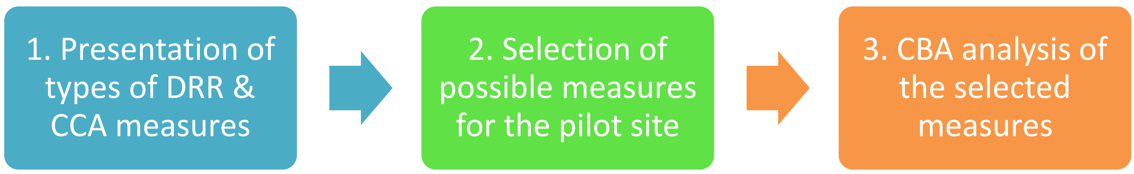
For **a further development of this framework**, the following elements are important:

- Mapping of current land uses: The analysis in the current reports builds on a detailed (1ha grid) but desk top analysis of land uses, combining generic economic indicators with generally available, detailed maps of population density. For three out of four pilot studies a first reality check of available land-use maps has been made, but the analysis would improve by a further, more detailed checking, focusing on the areas affected, especially related to e.g. economic land uses and transportation infrastructure.
- Mapping of future land uses. An important element of risk assessment is to account for future demographic and economic growth, and how this is likely to affect future land uses.

In this report, this has only been done in a very generic, simplified manner. The quality of the analysis would improve if maps for future land uses, which are being developed, would be integrated in this method.

- Damage functions and assets at risk for economic land uses and transportation.
- Damage functions for impacts on human health, including risk for fatalities from coastal flooding.
- Damage function for erosion. A first estimate of the cost of measure for relocation has been made. This could be further developed building on region specific information or case studies related to relocation.
- Impacts on natural areas: the ecosystem services delivered by natural areas have been integrated based on generic data, but do not cover in the specificities of interaction between nature, man and the economy for these coastal zones. The concept of the ecosystem services offers a framework to document and assess this interaction, as well as the consequences from erosion and flooding.
- The impact of land-use policies and governance on risks for erosion and flooding.

2.3 COMPARISON OF DRR AND CCA MEASURES



2.3.1 Types of measures

In **deliverable D6** "**Reports on the identification and justification of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) measures for each pilot site**" (IMDC, 2017o, 2017p, 2017q, 2017r) possible adaptation options to reduce, prevent and mitigate risks and environmental degradation are identified and discussed. These options include protection measures (e.g. construction of dykes, beach nourishment, etc.), planned retreat and accommodation (e.g. flood proofing of buildings).

A selection of different measures is made taking into account the pilot site characteristics and (potentially) existing or planned measures (e.g. multi-sector plans). They are later studied and compared in a cost-benefit analysis (see Deliverable D7). Flexible strategies, in which the preferred measures vary over time, are also considered. They consist of adaptation pathways combining one type of short term measures (10 years) followed by different types of measures for the medium (20 to 50 years) or long term (over 50 years) (see example on following figure). This allows countries and policy makers to adapt gradually, and integrate more detailed information, new knowledge and future evolutions while still being able to plan in advance.

2.3.2 Application to the pilot sites

A selection of very different DRR and CCA strategies was made in order ease the distinction and selection of the most suitable approach for the different pilot sites. Typically the following strategies have been investigated:

- 1. Protection: new dikes are built are beach nourishments are performed in order to avoid all risks (thus leaving very few residual risks). This typically involves high investment costs.
- 2.a Planned retreat: which consist of moving people and economic activities from zones subject to erosion or flooding, accounting for costs for rebuilding infrastructure and productivity losses due to adaptation. With this strategy, the hazards remains unchanged but much less population and infrastructure are affected
- 2.b Accommodation: includes adaptation measures in flood prone areas (e.g. dwelling and industrial buildings are adapted to be made flood proof). These costs are lower compared to relocation costs in scenario 2a. On the other hand, higher residual risks of flooding remain (e.g. indirect damages).
- 3. Combination of protection in the short term and planned retreat / accommodation in the longer term (after 2050). This is a strategy which changes throughout time to adapt to an evolving situation.

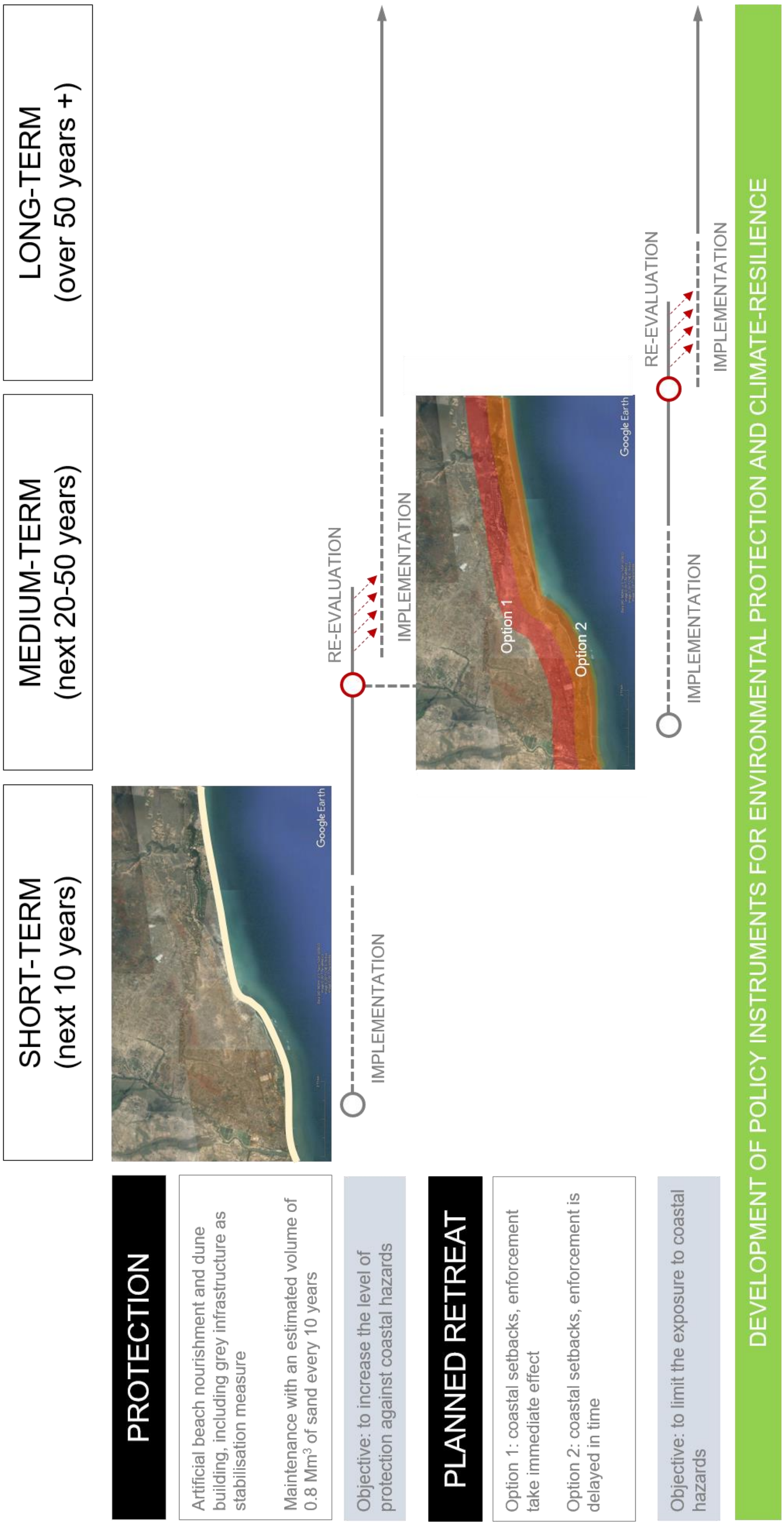


Figure 2-5: Illustrative example of a flexible adaptation pathway (example taken from the Ghana report).

2.3.3 Cost-Benefit Analysis (CBA)

The comparison of the different DRR and CCA measures for each pilot site is presented in **Deliverable D7 "Cost Benefit Analysis of the selected DRR and CCA options"** (IMDC, 2017s, 2017t, 2017u, 2017v).

In the cost-benefit analysis, the costs and benefits of DRR and CCA measures at the pilot sites are calculated and compared. Costs include investment costs and maintenance costs and are calculated over different time horizons (2015, 2020, 2030, 2050; 2075 and 2100), using low and high cost estimates. They also take the impact of demographic and economic growth into account.

The CBA is based on actualized costs and benefits. The discount rate used in this study is 6% but results for other discount rates (2%, 4%, and 8%) are also given.

Benefits of the DRR and CCA measures correspond to the value of the avoided damage due to erosion and coastal flooding, as calculated in the COCED analysis (see §2.2). Additionally, these benefits are assessed over different time horizons and use the same demographic and economic growths rates as well as same discount rates.

The criteria for the cost benefit analysis is the net present value (NPV) or net benefit for the scenario under different time horizons, discount rates and low and high estimates of costs. A positive NPV indicates that the benefits are larger than the costs and that the project generates net welfare.

Typically, coastal protection projects require important investments over the short run, which need to be earned back by yearly benefits (avoided costs) over a longer term. It is therefore logical to obtain negative NPVs in the short run. The assumptions and time horizon for which the NPV becomes positive were assessed.

CBA for the 4 pilot sites

The CBA was performed for the DRR and ACC strategies mentioned above (1. protection, 2a. retreat, 2b. accommodation and 3. combination) at the level of the pilot sites.

The main findings and conclusions of the CBA for the DRR and CCA measures for the pilot sites in the four different countries are included in **deliverable D8**, which is the **"Executive Comparative Report on the selected DRR and CCA options**" report (IMDC, 2017w).

This preliminary costs benefit assessment based on rough estimates of both costs and benefits allows to draw some general conclusions on cost/benefit ratios for the different measures based on the results obtained for the 4 pilot sites.

Scenario 1, protection, ensures the lowest residual risk (zero risk) but the investment costs are that high that they are unlikely to be paid back by avoided risks, at discount rates of 4% and 6%.

Scenario 2, planned retreat and adaption, allows to obtain most of the benefits (50% to 98%) at a fraction of the costs of scenario 1 (2% to 12%), and the investment in relocation can be earned back by avoided damages. A combination of planned retreat for areas at risk for erosion and adaptation of buildings (including industrial installations) in flood prone areas offers the best cost/benefit ratio for all countries, and the early investment will be paid back by reduced risks in a few decades, both at low and high cost estimates.

The cost benefit analysis of scenario 3 (combination of protection in the short run with retreat and adaptation in the long run) is dominated by the high investment costs for protection in 2015 and the net present values remains negative for all pilot sites. Only for Côte d'Ivoire, this may be an option to be studied further.

As this analysis is a quick scan based on rough indications of costs and benefits, the results only indicate which type of measures are most promising for further analysis. As the risks for coastal erosion and flooding in the reference scenario differ between the countries, a further analysis should account of these local differences. The type of land use at risk is an important factor, both related to current land uses and potential future land uses.

It must be noted that the reliability of the selection of measures depends on the accuracy of the cost and benefit estimates and that for policy-supporting application of the method, it is advisable, given the important issues at stake and the scale of the interventions, that more detailed data and parameters are used.

It is also not possible to monetize all costs and effects so this implies that the cost benefit analysis is only a partial result or one input for decision making. Other criteria should also be taken into such as: financial, technical, and political feasibility, social acceptability, and environmental sustainability. A multi-criteria analysis (MCA) can be a useful tool to combine and take into account all these different effects.

2.4 COMMUNICATION

The present study had a strong technical focus i.e. development and testing of methodologies. Stakeholder involvement and communication represented only a small portion of the assignment but much care was dedicated to it given the nature of the topic, which potentially has strong social and environmental impacts.

As part of the present assignment, communication to the country representatives and the relevant stakeholders has been organised and supported with a number of reports, presentations, workshops, brochures and a policy note:

- The study reports, as listed in section §1.1
- Powerpoint presentations: e.g. at the WACA kick-off meeting (19/10/2016), kick-off meetings per country at the start of the study (07/02/2017), and during the regional meeting (26/03/2017) (as part of deliverable D9)
- Workshops organized to present and discuss the selection of the pilot sites, and to discuss the final results of the study and their possible future usage (first workshops end of March 2017 and final workshops in September and October 2017) (as part of deliverable D9)
- Brochures, summarising the ranking of hotspots for coastal risks and the selection of the pilot sites (as part of deliverable D9)
- A policy note, describing the context and challenges of the present study as well as its achievements and recommendations (IMDC, 2017x)

An example of the brochures created in the frame of this study is shown below.

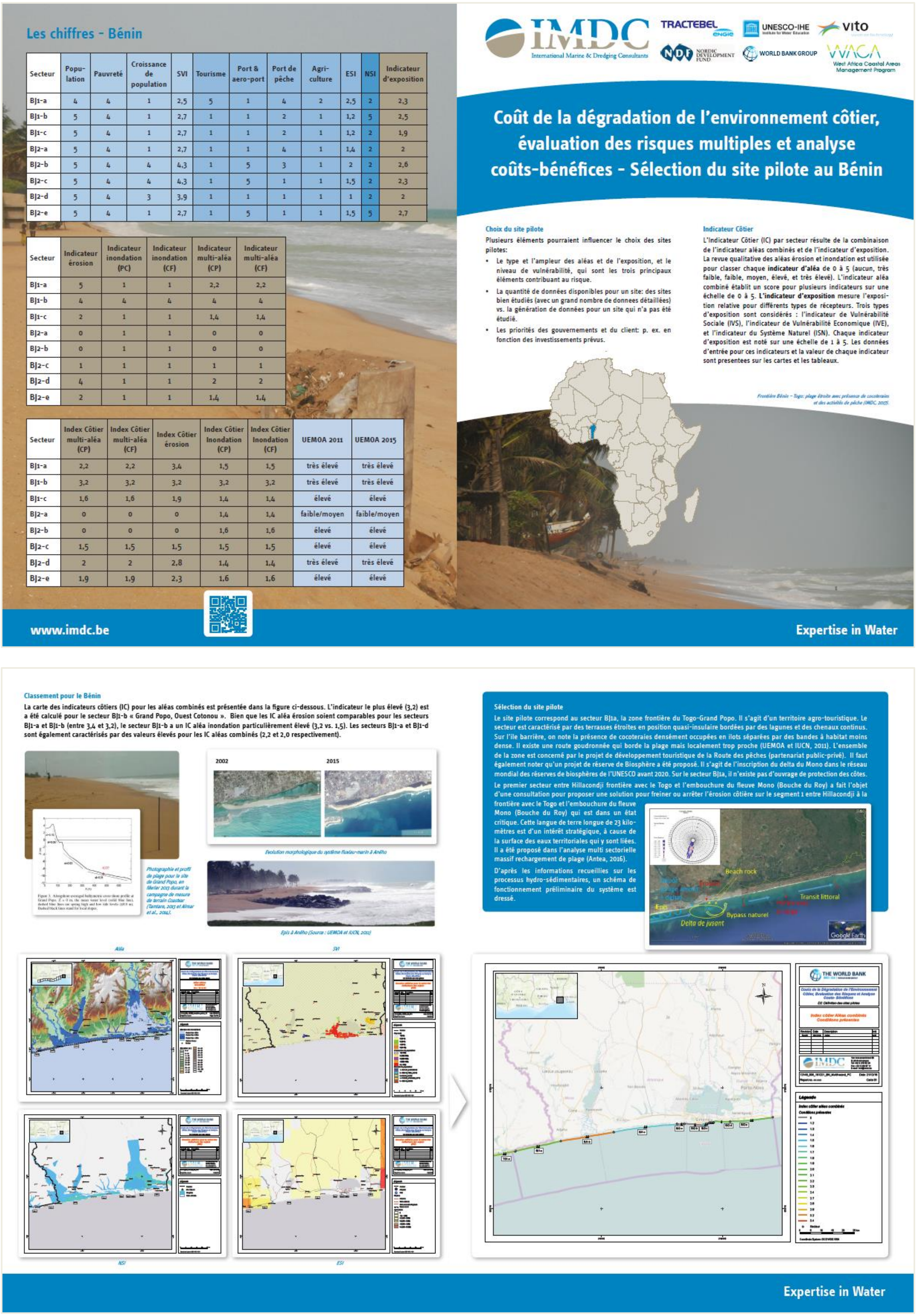


Figure 2-6: Example of an A4 folded brochures created for Benin in the frame of the present study.

3. RECOMMENDATIONS

3.1 PROMOTE RISK ASSESSMENT TOOL DEVELOPMENT & APPLICATION

Present coastal erosion and flood hazards in combination with the expected effects of climate change require not only a solid coastal zone management strategy but also investments in DRR and CCA measures.

Within the present study, a framework was developed in order to not only study and quantify the coastal erosion and flood risk based on the available data, but also to quantify the cost of coastal environmental degradation, and identify and compare possible DRR and CCA measures in economic terms.

The results obtained by this type of analysis helps to further develop strategic investment plans, by indicating the sites where investments should come first, and by highlighting the RRC and CCA measures that should be preferred. The framework has been applied within the present study in Benin, Côte d'Ivoire, Ghana, Togo, but can be replicated and used in other West African countries (to support WACA investments, for instance) or elsewhere.

The proposed methodology, inspired by the CRAF (i.e. the Coastal Risk Assessment Framework) (Ferreira et al., 2017; Viavattene et al., 2017), is robust and flexible:

- it can be applied on different spatial scales: regional level (countries) or pilot site level (several (tens) of km),
- it can make use of very detailed data (e.g. hazard assessments from detailed numerical models), or generally available datasets (raster based data, resolution of 0(10-100km)),
- it can be applied with different sorts of tools: from basic applications (GIS based approaches) to very detailed models (e.g. hazard assessments with detailed numerical models)
- it can serve at different stages of a study or project cycle: pre-feasibility, feasibility, predesign, detailed design, since it can cope with different data types and different levels of detail.

The methodology should also be reused at different times to make sure that measures remain adapted to the risks as the latter may evolve with time for various reasons (e.g. climate change, economic or demographic growths, change in land use, etc.).

As described in the introduction, the problems linked to coastal erosion and flooding in the study area are huge. The economic, environmental and social costs of the remediation options will likely be of the same nature, thus requiring very well informed decision making. The present methodology represents a very efficient tool to serve this purpose.

Recommendation on risk assessment tool development & application:

> *"Promote the application of **coastal risk assessment tools** to optimise resources to be spent on **coastal risk management**."*

Who should act? World Bank, national and regional administrations, coastal managers, academic community, consultants.

3.2 IMPROVE DATA QUALITY AND ACCESSIBILITY

In the present study, all applications of tools have shown a need for spatially-accurate and up-to-date topographic, bathymetric, physical, and impact data (e.g. on vulnerability or socio-economic impacts of disasters) using uniform standards, in order to produce reliable results.

The findings of our study confirm once more what has already been stated before on the data availability for these type of studies by e.g. (Brown et al., 2011): "The lack of data on Africa's coast is especially striking and this is a major barrier to better analysis. Missing data includes information on present rates of sea-level change and coastal geomorphology through to good data on socio-economic trends. Good coastal environmental management depends on this type of information, and it should be a priority to improve collection. This suggests a need for national and regional efforts to collect data, as well as international efforts using remote sensing techniques".

It is important to note here that there is a need to systematically evaluate, record, share, and publicly account for disaster losses and understand the economic, social, health, education, environmental and cultural heritage impacts, as appropriate, in the context of event-specific hazard-exposure and vulnerability information. One first important step towards more reliable results would be to collect or make existing data available such as: detailed topographic and bathymetric data, and (long-term) metocean measurements.

Examples of data to be collected:

- *Detailed topography and bathymetry data: these data are crucial to adequately determine the erosion and flood hazards.*
    - *At the time of this study, the only data available were large scale bathymetries (e.g. Gebco, C-map, etc.), and coarse topographies.*
    - *Missing data include beach profiles, nearshore and surf zone bathymetry, and detailed topographic data*
- *Metocean conditions measurements: these data are crucial to get a better insight in the local conditions and the effects of climate change.*
    - *Time series of measurements (water levels, waves, wind, etc.) are missing along the coast of West-Africa, both long-term and short term.*
    - *Long-term times series are needed to correctly determine design conditions for different return periods, and to assess the changes induced by a.o. climate change (e.g. sea level rise)*
    - *Short term time series can serve for calibration and / or validation of the different models for the hazard assessment*

- *Socio-economic data*
  - *Mapping of current land uses: The analysis would improve by a further, more detailed checking of the land uses, focusing on the areas affected, especially related to e.g. economic land uses and transportation infrastructure.*
  - *Mapping of future land uses. An important element of risk assessment is to account for future demographic and economic growth, and how this is likely to affect future land uses.*
  - *Damage functions and assets at risk for economic land uses and transportation.*
  - *Damage functions for impacts on human health, including risk for fatalities from coastal flooding.*
  - *Damage function for erosion. A first estimate of the cost of measure for relocation has been made. This could be further developed building on region specific information or case studies related to relocation.*
  - *Impacts on natural areas: the ecosystem services delivered by natural areas have been integrated based on generic data, but do not cover in the specificities of interaction between nature, man and the economy for these coastal zones. The concept of the ecosystem services offers a framework to document and assess this interaction, as well as the consequences from erosion and flooding.*
  - *The impact of land-use policies and governance on risks for erosion and flooding.*

Recommendations on data

> *“Encourage countries and administrations to* ***collect, analyse and share baseline data*** *in general, in order to allow future more detailed studies on coastal hazards and DRR and CCA measures”*
>
> *“Establish protocols and systems to compile* ***standardised datasets*** *that allow for better understanding and prediction of impacts.”*
>
> *“Build the* ***knowledge base on coastal flood and erosion impacts*** *in West-Africa through historical research and standardised protocols for post-event recording with awareness-raising on the need for such information.”*

Who should act? Countries at regional level to provide framework; data collection by local administrations.

3.3 FROM SINGLE HAZARD TO MULTI-HAZARD IMPACT ASSESSMENTS

Within the present project, direct and indirect impacts of two different hazards, coastal erosion and coastal flooding, have been analyzed independently and jointly. Understanding where and how these multiple hazards will likely affect social and economic systems and infrastructure in coastal areas enables a more intelligent and cost-effective selection of DRR and CCA measures. An impact-based approach is therefore crucial to risk reduction decision-making. It can be adopted at different spatial levels (regional at country level vs. local at pilot site level), and with varying level of detail (qualitative vs. quantitative), as has been shown by the application on the four countries part of this study. Adding different hazards, such as river flooding, into this analysis is possible, and would give an even broader and more complete insight into the land and people at risk.

Examples: in all case study sites, flooding (with different extent and intensity) due to river overtopping or heavy rainfall has been reported. Stakeholders often requested to also take those type of hazards into account, which was however beyond the scope of the present study.

It must be noted here that the measures aimed at reducing the risk of coastal flooding along lagoons or rivers (protection, retreat, etc.) presented in this study may well have a positive impact on river flooding. Taking this hazard into account will automatically increase the benefits of the measures, at no additional cost.

Recommendations on impact – based approach

> *"Promote the **development and use of impact-based assessments to define and select DRR and CCA measures,** and promote the integrated assessment of **multiple hazards** at once"*

Who should act? World Bank, national and regional administrations, coastal managers.

3.4 STRONGER STAKEHOLDER INVOLVEMENT

Stakeholders, not only experts but also ordinary citizens play an important role as providers and recipients of information on coastal risk and approaches to define and select DRR and CCA measures. Local residents are understood as gatekeepers of important historical and cultural knowledge, who often hold the key to understanding behaviours and attitudes in relation to coastal risk and DRR approaches and measures. Site visits allowed to get a grasp of this local knowledge, to better understand the local environment at risk. Effective disaster risk reduction requires an 'all-of-society' engagement and partnership.

An active involvement of different stakeholders was encouraged and facilitated by performing a multi-criteria analysis (MCA) of the different proposed DRR and CCA measures during the final workshop for the presentation and discussion of the results of the study. First the MCA allowed to take into account environmental, social and political aspects in selecting the preferred DRR and CCA measures, next to the technical and economic information obtained from the present study. Second, the MCA promote interaction and discussion in between the different stakeholders during the workshop, which might results in new and better contacts that will also last afterwards.

Example:

- *The discussions that took place in the national workshop showed that participants did not have extensive experience in discussing coastal management issues together. The creation of ad hoc platforms to share views on these questions and find solutions in common could be encouraged.*

- *Another lesson from the consultation of stakeholders in the national workshops was that participants mostly think that protection is the best (or even only) option. The economic analysis has however shown that it is, in general, the least viable option economically-speaking. These divergence give a hint to the difficulties that will be encountered along the way to reconcile the various interests in order to make acceptable and economically viable decisions.*
- *Certain stakeholders have also insisted on the fact that national political and institutional particularities should also be taken into account, through consultation of stakeholders, as people and institutions in the region function in different manners (e.g. Ghana vs. French speaking countries).*

Recommendation on stakeholder involvement

> *"Cultivate **inclusive stakeholder processes** to support 'all-of-society' approaches and ensure that local knowledge is recognised and valued as a complement to scientific knowledge to **develop an integrated understanding of coastal** risk and to devise locally appropriate DRR approaches and measures."*

Who should act? Policy makers at national and local level; academic community; consultants and research funding bodies.

3.5 PROMOTE NATIONAL AND REGIONAL DRR AND CCA MANAGEMENT

Through in-depth analysis of the four different countries and the selected pilot sites, the project has revealed some interesting challenges for DRR management in West-Africa. Despite the differences in between the countries, some common challenges have become evident.

These relate primarily to the need for clarity in governance structures and procedures as well as the importance of citizen engagement, both in terms of providing local knowledge and in terms of awareness-raising for effective coastal DRR and CCA responses.

Also, the coastal erosion hazard in West-Africa is a regional phenomenon, which can only be tackled by regional, cross-boundary operation and management. DRR measures with a positive impact in one country could heavily deteriorate the situation in the neighbouring country.

Examples:

- *Integrated coastal zone management involves the cooperation between different sectors, and different responsible authorities and administrations (nature & environment, infrastructure, economy, etc.). A clear view on the different responsibilities is needed, to allow initiative is taken and projects can be organised.*
- *The pilot sites in Togo and Bénin are in fact part of the same larger scale system and river delta. A first step in understanding the complete system and defining a combined management approach for both countries has been taken in the present study, by studying the coastal erosion and coastal flood hazards in one single large model.*

Also further detailed studies should be done at cross-border level, and should be supported by both countries.

- *One of the main morphological process in the study area is the overall eastward drift of the sediments (aka "the West African sand river"). As a consequence of this drift, measures which are implemented in a specific location may impact sites situated further east. This highlights the importance of a concerted approach to coastal zone management, especially in the case of trans-boundary impacts as would be the case of the development of groynes in east Togo for instance.*

Recommendation on coastal risk governance

*"Find ways in which authorities and/or competences can be organised and exchanged to ensure **a regional approach to coastal management** and the implementation of DRR and CCA measures.*

Who should act? World Bank, national, regional and municipal administrations.

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