Western Indian Ocean Coastal Challenge:

Towards a Credible Economic Valuation Strategy to Determine the Consequences of Climate Change in the Western Indian Ocean

7 December 2014

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1 Introduction

The Western Indian Ocean (WIO) economies, especially the island states, are vulnerable, economically and otherwise, to climate change impacts, such as possible sea-level rise, the change in the intensity and frequency of extreme events, changes to the marine ecology, and various other consequences of climate change. In response to this, a coordinating platform was developed, the Western Indian Ocean Coastal Challenge (WIOCC).

In support of the WIOCC, WWF-Madagascar has engaged Futureworks to assist in the development of a strategy to develop a credible economic valuation process to assist in the determination of the consequences of climate change. The strategy outputs are to be used for lobbying for local adaptation, international mitigation and for soliciting international resources to promote local resilience.

The WWF terms of reference state: "*An important tool for identifying and quantifying the incremental costs of climate change on the region's marine and coastal ecosystems and resources, is the economic valuation of climate change impacts, such that the WIOCC will be able to demonstrate through sound evidence and science-based approaches the real costs of climate change on our marine systems and to various sectors, particularly in relation to food security and economic development. A number of studies have already been undertaken in this regard, providing a basis, but information remains scattered and there is need for further consolidation in order to provide a basis for defining the best strategic direction for the WIOCC in moving forward.*"

Based on the above motivation, this analysis has two objectives:

1. A literature review of relevant studies undertaken in the WIO and internationally, that would inform :
   - The current understanding of economic impacts of climate change in the WIO,
   - The gaps in understanding WIO coastal climate change economic impacts, and
   - The best practice to quantify the economic implications of climate change at regional level (i.e. across a number of states).

2. To recommend an economic valuation strategy for the WIOCC to adopt, that will develop a suite of credible economic measures of the impacts of climate change, and will include:
   - The selection of a suite of key economic metrics to analyse,
   - A process of developing credible metrics,
   - A proposed sequencing of actions, and
   - A high-level indication of budget requirements to implement the strategy.

This report addresses both the first and second objectives.

2 Research Method

The analysis has taken a strategic perspective given the rapid timeframe and limited resource available. Consequently, there has been a focus on the economic impacts of climate change in coastal areas, especially quantitative economic data. The analysis has not engaged with the broader impacts of climate change – as a large literature exists on this. Furthermore, there has been a focus on the economic changes, using the principles of additionality – identifying those impacts which can be ascribed to climate change.

The purpose of the literature review was to undertake an objective analysis of the relevant available research on the economic implications of climate change in the coastal areas of the WIO. A systematic approach was adopted to identify in a structured way, the appropriate and related research.

The literature search was conducted at various scales, starting with regional (i.e. Western Indian Ocean), then international, and lastly for each of the target countries located within the WIO. This includes:

- Comoros
- Kenya
- Madagascar
- Mauritius
- Mozambique
- Reunion
- Seychelles
- Somalia
- South Africa[1]
- Tanzania

Note that the literature search focused specifically on the coastal zone and research on inland areas was generally excluded from the review.

The literature review focused on the following three sources of information:

- Web-based research e.g. technical reports, government publications, articles, and popular works;
- Published journal articles using the Scopus database;
- Western Indian Ocean Coastal Challenge (WIOCC) reports.

The web-based literature search was conducted using the Google search engine and keyword approach. Terms such as 'economic', 'costs', 'Indian Ocean', 'coast' and 'climate change' were used to identify appropriate and relevant research. As part of the web-based literature search, the bibliographic references of studies that specifically related to the research topic were also used. With the web-based literature search, there was a bias towards review of government publications, such as climate change response strategies, and technical reports produced by organisations such as the World Bank, UNEP and EU. In general, popular works based on anecdotal information or opinion was excluded from the review. In addition to the review of economic impacts of climate change, we also identified the stated aspirations (or visions) of the WIO countries with respect to understanding the economic impacts of climate change on the coast, and these are outlined in Table 1.

The web-based literature search on the economic implications of climate change in the WIO is thought to have been relatively comprehensive given that with each subsequent keyword search, the same research studies kept coming up. Where there is possibly a gap, is a literature search of specific climate change impacts e.g. sea-level rise, extreme weather events etc. for each of the eight target countries. This is however beyond the scope of this literature review as majority of these studies would not be focussed on the economic implications of climate change. Furthermore, the majority of research on the impacts of climate change on for example agriculture and rainfall variability tends to focus on inland areas.

The search for peer-reviewed journal articles was conducted using the platform for academic literature called Scopus. Searches in Scopus was limited to the countries mentioned, climate change, and either economic cost and/or economic valuation. The Google Scholar search engine was also used to conduct more general searches.

Furthermore, WWF sent the team a number of reports which were also assessed.

Some 26 journal papers and research reports were identified as having relevance to the review (see **Annexure 1**). We understand that we have only been able to access reports and journal articles readily available, and there may be relevant papers which we have not been able to access. However, the trends emerging in the review are not likely to be substantially altered by several more relevant papers, and we believe the spread of research analysed to date provides a good indicator of current trends.

At the onset of the literature review, a table / framework was developed to assist with the summarising and analysis of literature collected (**Annexure 2**). The framework provided a means to review the papers and to collate key information pertinent to economic change. This included for example the unit of measure, pricing year, currency, costs, stocks or flows, valuation method, the country and the impact causal agent(s). The literature sources were listed on the vertical axis, and the key facts on the horizontal axis.

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[1] South Africa was only considered from a methodological or best practice point of view, to ensure that a focus was maintained on the WIOCC countries.

From the information contained in **Annexure 2**, summary tables were developed (see for example Table 2 and Table 4). The purpose of Table 2 is to identify gaps in the literature review by plotting the impacts of climate change (vertical axis) against the key economic sectors likely to be impacted upon by climate change (horizontal axis). This table also highlights the bias in research focus on particular impacts, such as sea-level rise and extreme weather events, and in particular sectors, such as livelihoods, infrastructure and fisheries. The purpose of Table 4 is very similar to Table 2 in that it also identifies gaps in the literature, but with a focus on quantitative economic costs and numbers of people affected by climate change. The economic values were also adjusted to the same reference year (i.e. 2013) using USA and EU inflation figures. Again, Table 4 highlights the bias in economic valuations towards particular impacts such as sea-level rise.

During the review we also made note of useful papers which outlined good baseline data and good methods that could add value to further work. Note, that the review did not seek baseline data, but merely noted those references which would be useful in further work. The baseline and methods references are therefore not comprehensive.

In addition to the literature review several discussions were held with role players in the WIOCC. See section 3.5 for details.

3 Results

3.1 Introduction

As discussed above a survey of existing literature with respect to the plausible impacts of climate change on the Western Indian Ocean countries has been conducted. A list of 26 studies has been considered (**Annexure 1**), and a summary of which can be found in **Annexure 2**.

To analyse the scope and countries covered in the literature two methods where used. First, discussed in Section 3.2, the studies have been three-dimensionally classified in terms, of i) climate change bio-physical parameters, ii) the affected sector of the economy studied, and iii) the country focused on. This section broadly identifies the scope of research undertaken in the WIO to date.

This is followed by another three-dimensional classification (Section 3.3), in terms of i) climate change bio-physical parameters, ii) the affected sector of the economy, and iii) the values of the economic impact. This section focuses on the quantified economic values of climate-induced change.

These will subsequently be considered.

3.2 Country visions for understanding the economic impacts of coastal climate change

A review of the WIO countries policies on climate change action plans was undertaken to identify their respective aspirations or visions for understanding the economic impacts of climate change on the coast. Table 1 outlines the vision of countries in the WIO.

Table 1 : Country visions for understanding economic impacts of coastal climate change

Country	Reference	Economic vision
Kenya	Republic of Kenya (2013), National Climate Change Action Plan 2013-2017	The National Climate Change Action Plan (NCCAP) sets out a low carbon climate resilient development pathway to help Kenya meet Vision 2030's goals. A key concern is achieving long-term sustainable economic growth up to and beyond Vision 2030 in the face of climate change.
Madagascar		*National Adaptation Programme of Action is in French.
Comoros		------
Mauritius	Mauritius (2013), National Climate Change Adaptation Policy Framework	Policy goals: • Avoid, minimise or adapt to the negative impacts of climate change on key assets of Mauritius, namely agriculture, water, fisheries, and ecosystems.

Country	Reference	Economic vision
		• Avoid or reduce damage to human settlements and infrastructure caused by climate change. Key policy principles: • Recognising that economic resilience is key to coping with climate change, do all possible to promote the development of strong and diversified economy. Strategies: F4.2. Undertake an economic evaluation of marine and coastal ecosystems.
Mozambique	Mozambique (2008), National Adaptation Programme of Action	The occurrence of extreme climate events in Mozambique constitutes a great barrier to swift sustainable economic development due to human and material damages. Third activity: Reduction of climate change impacts in coastal zones • General objectives: Contribute to the sustainable development of the coastal area through the reduction of social and economic climate change impacts via coastal integrated management systems based on the community needs, and increased education of state officials and community institutions on coastal zone vulnerabilities. • Specific objectives: 1. Identify, characterize and map the eroded land and coastal vegetation; 2. Identify rehabilitation techniques for dunes and mangroves to mitigate the effects of erosion; 3. Identify participative actions for erosion mitigation; 4. Develop strategic actions to sensitise and disseminate good practices in coastal communities.
Reunion	Message from the Conference "The European Union and its Overseas Entities: Strategies to counter Climate Change and Biodiversity Loss", Reunion Island, 7-11 July 2008	Recommendations: A. How should we adapt to climate change, increase the resilience of ecosystems and reduce the vulnerability of human cultures and activities? Adaption planning and related policy recommendations: • Take into account the impact on biodiversity and ecosystem services of all mitigation and adaptation planning and interventions, using cost/benefit analyses, longer-term environmental impact assessments (20-50 years), and holistic approaches that integrate and balance environmental, social and economic/development aspects. • Promote voluntary coastal-zone management programmes for adaptation to climate change as a tool to build ecosystem resilience, protect ecosystem services and secure local livelihoods.
Seychelles	Seychelles (2009), Seychelles National Climate Change Strategy	Climate Change will directly impact key economic sectors such as tourism and fisheries. Seychelles is economically, culturally and environmentally vulnerable to the potential effects of climate change and associated extreme weather events. Vision is to minimise the impacts of climate change through concerted and proactive action at all levels of society.
Somalia	Somalia (2013) National Climate Change Action Plan	Vision: Make the Somali people more resilient to climate change, recognizing their high vulnerability in an economy that is dominated by subsistence agriculture and livestock rearing and undermined by the heterogeneity of clan-based conflicts Adaptation measures for Somalia: • Coastal and marine resources
South Africa	South Africa (2009), National Climate Change Response White Paper	Objectives: • Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity. Principles:

Country	Reference	Economic vision
		• Intra- and Inter-generational sustainability – managing our ecological, social and economic resources and capital responsibly for current and future generations • Economic, social and ecological pillars of sustainable development – recognising that a robust and sustainable economy and a healthy society depends on the services that well-functioning ecosystems provide, and that enhancing the sustainability of the economic, social and ecological services is an integral component of an effective and efficient climate change response
Tanzania	United Republic of Tanzania (2007), National Adaptation Programme of Action (NAPA)	As Tanzania's economic base is dependent on the use of natural resources, the economy is highly vulnerable to the adverse impacts of climate change and extreme weather events. Sustainable development can be achieved when both short and long terms strategic actions are put in place to address climate change impacts on agriculture and other key economic sectors. Due to the importance of the sea and coastline, the welfare of the population living by the coast and the socio-economic value to the country, the coastline has to be protected against and effect of climate change.

The country visions highlight that countries anticipate that climate change will impact on coastal resources and that it represents a clear threat to their national economies. –There is a common concern on fisheries, tourism, ecosystems and vulnerable sectors of society, and a widely held perspective that sustainable economic growth is necessary to promote resilience. There are also several references to the need for a suite of tools that will assist in understanding the economic implications of climate change, such as cost benefit analyses and ecosystem services supply, demand and risk assessment. -These aspirations will be used to direct a valuation process.

3.3 The Scope of Research Undertaken to Date in the WIO

Climate change's plausible impact on society is multi-faceted. In this review eight such impact pathways have been considered, namely:

1. Sea level change,
2. Sea surface temperature change,
3. Salt water ingress / intrusion,
4. Thermocline circulation changes,
5. Ocean acidification,
6. Extreme weather effects,
7. Ocean productivity changes, and
8. Change in alien invasive species.

These eight pathways can be distinguished, but they are not independent from each other and the one pathway of change does not imply no response of the other. The pathways can, and do, operate simultaneously, but in varying degrees of severity and over different temporal and geographic spaces. They do have, however, separate implications for resource use, livelihoods and economic development. The impact on the economy of, for example, a change in sea level is different from that of a change in sea productivity. The magnitude of the economic impact of the change in climatic conditions is also derived from a range of variables. This will be considered later. In addition to the eight pathways, two secondary effects have been considered, namely human migration and change in access to marine resources. A good baseline data category was also identified, largely a means for noting useful baseline studies for future research.

Seven categories or sectors of economic impact on which climate change can have an impact have been distinguished, followed by two additional general classifications, these nine classifications are:

1. The state of natural capital,
2. Tourism,
3. Agriculture,
4. Fisheries,

5. Infrastructure,
6. Livelihoods,
7. Macro-economy,
8. Studies highlighting best practises, and
9. Studies highlighting research gaps

The summary of the review, based on the studies listed in **Annexure 2**, is provided in **Tables 1** and **2** and **Figure 1** and **Figure** 2.

Table 2: Cross-sectional review of literature with regard to climate change's impact pathways on various economic sectors / categories

Plausible climate change impact	Economic sectors / categories of plausible impact								
	State of natural capital	Tourism	Agricul-ture	Fisheries	Infrastructure	Livelihoods	Macro-economy	Best practice methodology	Gaps
Sea level changes	5, 6, 11	6	1, 5, 6, 23	5, 23	4, 6, 14, 18	2, 4, 6, 18, 22, 23, 26	1, 2, 3, 6	1, 2, 6, 7, 10, 11, 12, 18, 23, 25	7, 22, 25
Sea surface temperature changes	8, 9			8, 9, 15, 26	14	8, 15, 22		8	22
Salt water ingress / intrusion	6, 22, 26								
Thermocline circulation changes									
Ocean acidification									
Extreme weather effects	21		17, 26		13, 18	16, 17, 18, 21, 26		13, 16, 17, 18, 21, 25	22, 25
Ocean productivity changes									
Change in alien invasive species				20				20	
Responses by immediate community									
Human migration			23	15, 16, 23		23		23	
Access to resources		19, 20		9, 20	20	9		20	
Other									
Baseline data		3, 19	3	19		4, 19	19, 22	24	24

Note: The numbers in the cells refer to the publication number in **Annexures 1 and 2**.

The literature largely focusses on economic impacts resulting from sea level change, changes in sea surface temperature and extreme weather effects. See **Table 2**. Studies covering the economic impact of salt water ingress or intrusion, thermocline circulation changes, ocean acidification, ocean productivity changes and changes in invasive species are few and far between. The impacts of these additional climate change pathways on the economy are not made explicit, and therefore current decision making regarding climate change is likely to be only partially informed.

Table 3: Summary: Cross-sectional review of literature with regard to climate change's impact pathways on various economic sectors

Climate change pathway – HIGH occurrence in literature	Economic sector - HIGH occurrence in literature
• Sea level change • Sea surface temperature changes • Extreme weather effects	• State of natural capital • Agriculture • Fisheries • Infrastructure • Livelihoods
Climate change pathway - LOW occurrence in literature	**Economic sector - LOW occurrence in literature**
• Salt water ingress / intrusion • Thermocline circulation changes • Ocean acidification • Ocean productivity changes • Change in alien invasive species	• Tourism • Macro-economy

In terms of the scope of economic analysis on coastal climate change impacts, only a partial perspective has been developed for the WIO. There has not been a systematic assessment of the climate change impacts and the possible economic consequences there-of. There are major elements of climate change pathways and economic sectors which have not been addressed (the lower rows of Table 3). Tourism impacts and impacts on the economy as a whole resulting from climate change have received little research attention. This is particularly of concerning given the role of imports and exports, and tourism in the WIO economies, especially the island states. For example, there are no indications of the percentage contribution of tourism to the country economies in the WIO states. Even for those sectors which have received relatively more attention, there is insufficient evidence to develop a regional perspective of the economic implications of climate change on the coast, and therefore little material to develop a convincing motivation of the need to take local adaption actions and international mitigation actions.

One critical issue highlighted is the possible 'double impact' of climate change for coastal communities, where inland agricultural productivity declines may lead to increased coastal in-migration (as already the case in Mozambique and Tanzania) and this could then be coupled with marine productivity declines associated with climate change, thereby generating a growing demand on a declining supply. Several of the papers also point to the critical need to generate robust marine ecosystems as these have shown a greater ability to rebound after extreme weather events like sea surface temperature rises and associated coral bleaching. This work also highlights the double benefit of investing in marine resources management, as elevated management will generate greater yields, but also generate a robust system that able to bounce back from climate change perturbations.

One critical issue highlighted is the possible 'double impact' of climate change for coastal communities, where inland agricultural productivity declines may lead to increased coastal in-migration and this could then be coupled with marine productivity declines associated with climate change, thereby generating a growing demand on a declining supply.

Not only is there a strong bias in terms of the topics covered, there is also a bias in terms of the countries covered. As can be seen in **Figures 1 and 2**, Tanzania and Mozambique are the two countries best represented in the studies, both in terms of the number of the studies, indicated by the high of the bars, and the number of the climate change parameters and economic sectors covered. The Seychelles are also reasonably well represented. The Comoros and Somalia, however, are poorly represented both in terms of topics and the number of studies.

In **Figure 1** considering climate change parameters, sea-level change, the light blue bar, is by far the most-researched topic. Change in sea surface temperature (orange bar) and extreme weather effects are also fairly well represented. In **Figure 2** considering economic sectors, livelihoods, the orange bar, is the most researched topic, followed by a mix of fisheries, infrastructure and natural capital.

The quantum or values of the plausible economic impacts of climate change, as per the studies reviewed, will now be considered.

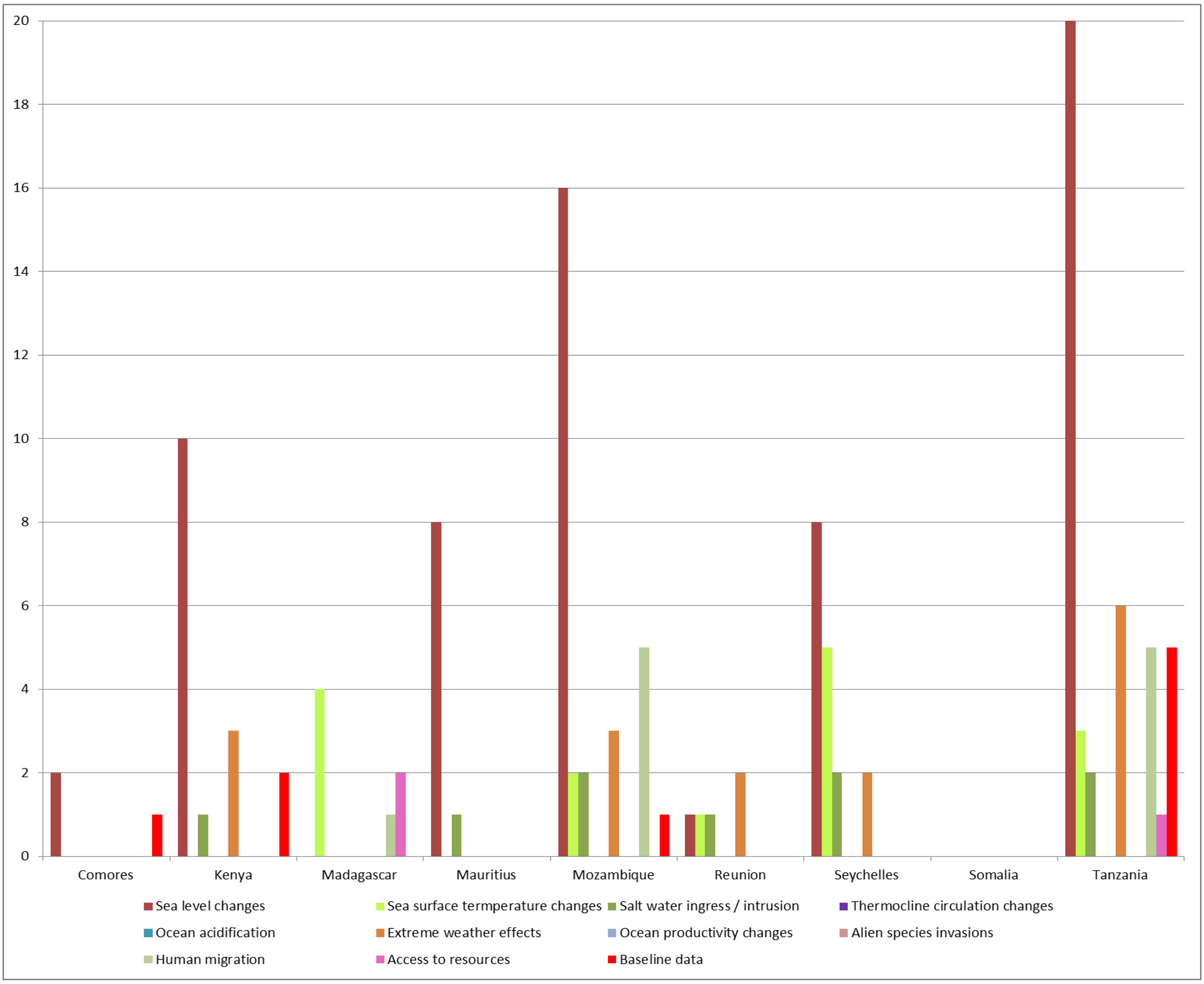


Figure 1: Country representation in studies with respect to the climate change drivers impacting the economy

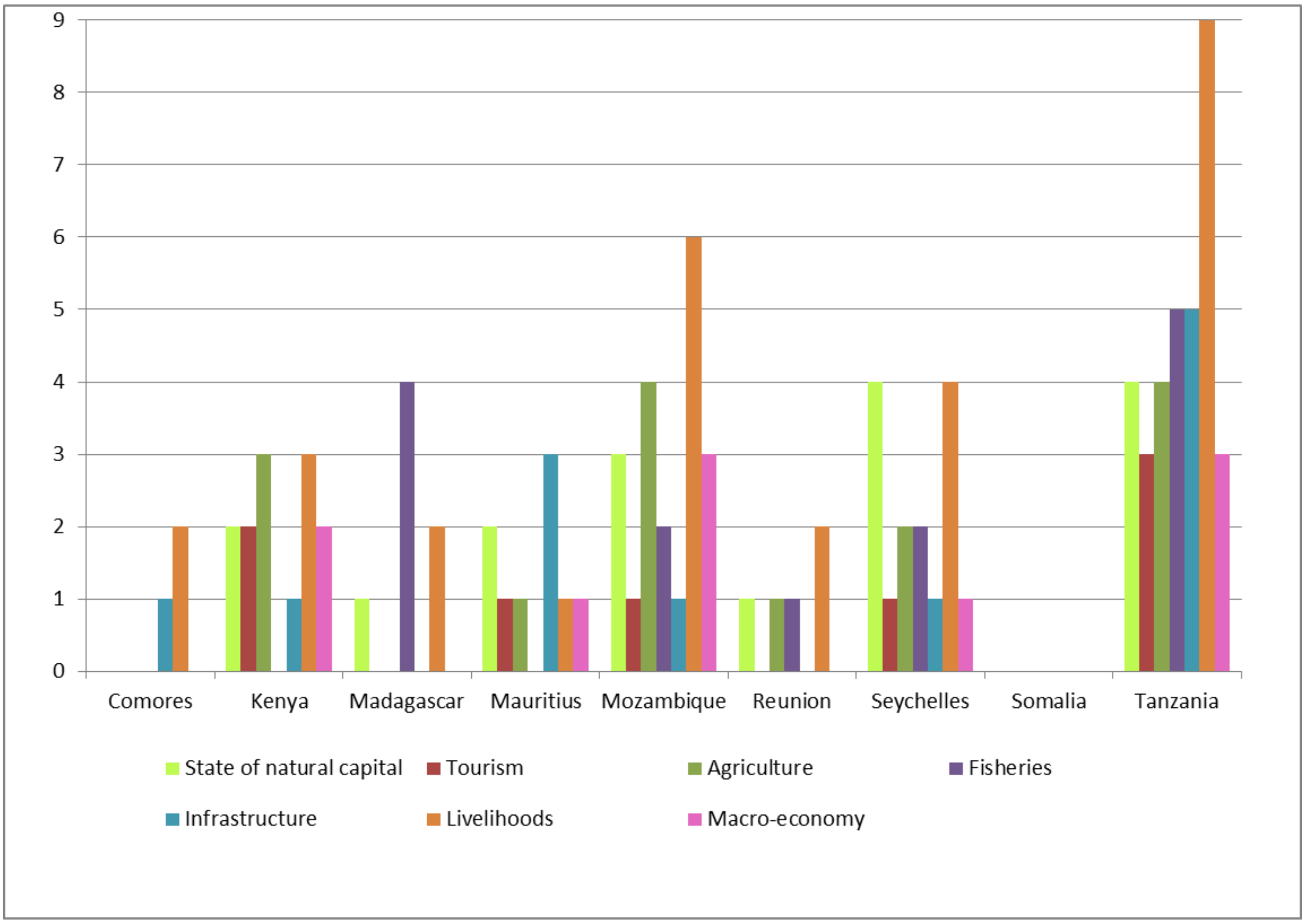


Figure 2: Country representation in studies with respect to the economic sectors impacted by climate change

3.4 Valuation of Potential Impacts of Climate Change

Studies attempting to value and/or estimate the potential impact of climate change on the economy in coastal areas focused only on the following economic sectors:

- State of natural capital (largely measured in terms of changes in area),
- Change in the macro-economy,
- Changes in the number of people exposed,
- Infrastructure, and
- Changes in fisheries.

The climate change pathways that were considered in these valuation studies are:

1. General climate change:
    a) Two studies have been conducted,
    b) which estimated that:
        - there could be a $6 billion cumulative loss to the Mozambican economy, and
        - a 2,6% decline in GDP growth in Kenya.
2. Sea level rise:
    a) A large number of studies and assessments have been conducted,
    b) which estimated that, among others:
        - Mozambique will suffer from an annual loss in wetlands to the value of $1,4 billion with an estimated 384,000 people affected by sea level rise and a further 2,3 million people affected by storms,
        - infrastructure to the value of $11,5 billion will be at risk,
        - Mtwara, Tanzania, will lose an estimated 211,000ha of land area,
        - an estimated 351,000 people in Dar es Salaam, Tanzania, will be affected with infrastructure to the value of $5,7 billion at risk,

- Kenya will lose an estimated 48,000ha of wetlands.

3. Sea surface temperature rise:
   a) Two studies in Reunion and the Western Indian Ocean region were conducted,
   b) which estimated that:
      - in Reunion a 43% decrease in the recovery rate of corals are expected,
      - in the Western Indian Ocean region, it is anticipated that the impact of sea surface temperature rise could exceed $4,3 billion in annual losses.
4. Extreme weather events:
   a) Only one study considering the impact of extreme events - the displacement of people and damage to infrastructure of a cyclone in Seychelles.

A summary of the results are provided in Table 4.

Table 4: Summary of the estimates of the plausible economic impact of climate change on various economic sectors

		STATE OF NATURAL CAPITAL			MACRO-ECONOMIC			PEOPLE EXPOSED / AFFECTED			INFRASTRUCTURE			FISHERIES		
PRIMARY DRIVER	**Region**	**Description of impact**	**Median value**	**Ref. code**	**Description of impact**	**Median value**	**Ref. code**	**Description of impact**	**Median value**	**Ref. code**	**Description of impact**	**Median value**	**Ref. code**	**Description of impact**	**Median value**	**Ref. code**
General climate change	Mozambique				Cumulative cost to Mozambican economy between 2003 and 2050	$6 141mil	1									
	Kenya				Loss of GDP each year by 2030 (%)	2.6%	2									
Sea level changes	Kenya				Economic costs per year by 2030 and 2050	$173 mil	2	Number of people affected per annum (n)	48 000	2						
	Tanzania	Total loss of mangroves, swamps, marshes & tidal pans with 1m sea-level rise	46 600	5												
	Tanzania	Land area inundated with 0.5 - 1m sea-level rise (ha)	37 050	5												
	Maputo, Mozambique							Exposed population with sea-level rise & more intense storms by 2070	384 000	6	Exposed assets with sea-level rise & more intense storms by 2070	$11 579 mil	6			
	Dar es Salaam, Tanzania							Exposed population with sea-level rise & more intense storms by 2070	351 000	6	Exposed assets with sea-level rise & more intense storms by 2070	$5 735 mil	6			
	Mombasa, Kenya	Land area submerged with 0.3m sea-level rise (ha)	4 600	6												

Tana Delta, Kenya	Land area submerged by 2050 with 0.3m sea-level rise (ha)	48 100	6		Number of people affected with 0.3m sea-level rise	400					
Mauritius	Beaches inundated with 1m sea-level rise (km)	26	6								
Tanga, Tanzania	Mangroves at risk with 0.5m sea-level rise (ha)	1 025	6								
Tanga, Tanzania	Land area at risk with 0.5m sea-level rise (ha)	3 520	6								
Bagamoyo, Tanzania	Seasonal swamps at risk with 0.5m sea-level rise (ha)	1 800	6								
Bagamoyo, Tanzania	Land area at risk with 0.5m sea-level rise (ha)	3 300	6								
Mtwara, Tanzania	Mangroves at risk with 0.5m sea-level rise (ha)	2 780	6								
Mtwara, Tanzania	Land area at risk with 1m sea-level rise (ha)	211 700	6								
Dar es Salaam, Tanzania	Land area at risk with 1m sea-level rise (ha)	24 700	6					Land area at risk with 1m sea-level rise	$103 mil	6	
Tanzania					Number of people affected by 0.1m and 0.43m sea-level rise by 2030 and 2100	913 500	6	Total cost of residual damage with 0.1m sea-level rise by 2030	$151 mil	6	

	Kenya					Number of people affected by 0.1m and 0.43m sea-level rise by 2030 and 2100	145 250	6				
	Mozambique	Annual loss of wetland value with 0.1m and 0.43m sea-level rise by 2030 and 2100	$1 326 mil	6		Number of people affected by 0.1m and 0.43m sea-level rise by 2030 and 2100	2 271 000	6	Total cost of residual damage with 0.1m and 0.43m sea-level rise by 2030 and 2100	$205 mil	6	
	Mauritius	Annual loss of wetland value with 0.1m and 0.43m sea-level rise by 2030 and 2100	$993 mil	6								
	Sub-Saharan Africa	Total area of wetlands lost with 1m sea-level rise	335 906	11								
		Total value of wetlands lost with 1m sea-level rise	$86 mil	11								
	Dar es Salaam, Tanzania								Value of coastal infrastructure at risk with 0.5m and 1m sea-level rise	$136 mil	13	
	Dar es Salaam, Tanzania					People affected by 1:100 year flood event with 1m sea-level rise by 2005 and 2070	120 000	18	Infrastructure affected by 1:100 year flood event with 1m sea-level rise by 2005 and 2070	$986 mil	18	
Sea surface temperature rise	Reunion	Decrease in recovery rate of coral	43%	26								

	Indian Ocean region		Economic costs due to abnormally high sea temperatures in 1998 (predicted to occur annually by 2050)	$4 317 mil	26							
Extreme weather events	Seychelles					Number of people displaced by Hyacinthe Cyclone	7 500	26	Damage to infrastructure with Cyclone Dina	$89 mil	26	

In summary, the literature review shows that there is limited systematic quantification of economic losses arising from climate change impacts, and consequently the WIOCC community is not well placed to effectively communicate the implications of climate change to its own policy makers and to the international community. The following points are worth noting:

- We found limited statements of the size and condition of the coastal natural capital which promote climate change resilience – in any country or the region (although there is probably a lot of this information available as biodiversity statistics). It is only mangroves and coral reefs which get mention. There are some examples of area reductions in natural capital in some countries.

- None of the WIO research papers clearly identified the suite of ecosystem services which coastal natural capital supplies to society. Fisheries are the only ecosystem service which gets good attention. Liquete *et al*. (reference 24) outlines some key principles which could be applied to WIO analyses.

- While there has been some focus on the relationship between marine ecology, fisheries and climate change, there been little focus outlining and quantifying the relationships between natural capital and tourism. Furthermore, the relationship between climate change, built infrastructure and tourism is also not explored in any detail.

- While there are papers that address livelihoods and show the vulnerability of people accessing marine resources, there is little qualitative evidence indicating how many people are vulnerable and to what extent their livelihoods are vulnerable. The exception is Mozambique, which provides a good example of the numbers of people who could be impacted. Consequently, the severity of possible impacts on livelihoods for most states and then the WIO region, are not made clear.

- The current roles of livelihoods and the tourism sector in the economy (such as income generation, job creation, poverty reduction, exports) are not addressed and neither are the changes or costs of climate change to these metrics explored.

- The study by Brown et al. (ref. 6) is the level of research that is required for the WIO in terms of the economic implications of climate change and costs of adaptation. However, this study only focuses on sea-level rise. Similar scale studies are required for the other impacts such as rising sea temperatures, salt-water intrusion etc.

- The quantitative data collated in Table 4 cannot be aggregated, and consequently a big picture or summation of key monetary and livelihood metrics cannot be presented at this point. This implies that a common framework is required to direct studies to collect data in a standardised way that can be aggregated effectively to inform regional decision making.

3.5 Project Collaborators' Perspectives on Key Economic Research Questions

Discussions were held with several project collaborators to garner their perspectives on key economic questions and issues they believed needed to be addressed in a valuation strategy. This was undertaken to supplement the literature review to ensure that collaborators' perspectives of key issues and questions were reflected in the review and would direct a proposed strategy in the next phase of the work. The following people shared their perspectives with the team and we are grateful for their insights:

- David Obura - CORDIO East Africa
- Christophe Legrand – Indian Ocean Commission
- José Rakotomanjaka – Quality and Environment Integrated Management
- Harifidy Olivier Ralison – WWF Madagascar
- Valerie Burgener – WWF International
- Andrew Mather – Ethekwini City Engineer (Durban)
- Debra Roberts – Ethekwini Environmental Planning and Climate Protection Department (Durban)
- Graham Ashford – University of the Sunshine Coast (Australia)

The perspectives of the collaborators are outlined in the mindmap in **Figure 3**.

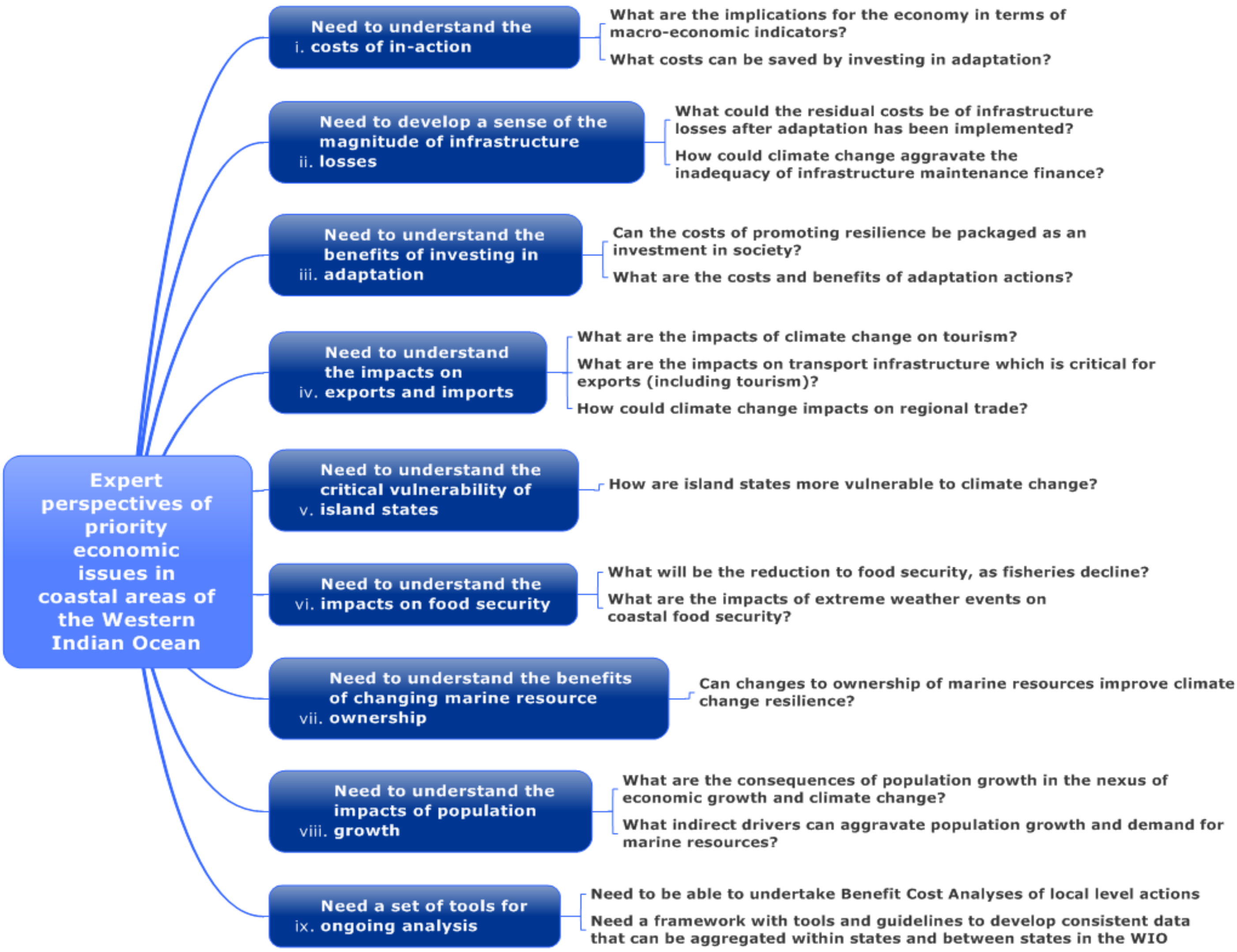


Figure 3: A mindmap of collaborators' perspectives of key economic questions and issues

These insights correlated relatively well with the literature. Two key points emerged that the literature did not highlight, and these were:

- The need to focus on the benefits and costs of adaptation, and
- The need for a set of tools to support on-going economic analysis of climate change.

These insights were also used to inform the conceptual model of the social-ecological system.

3.6 Conceptual Model of Climate Change / Economy Social-Ecological System

In reviewing the published papers and reports for the WIO region, a conceptual model of the climate change / economy social ecological system was developed by the authors to help understand and illustrate the critical linkages emerging between components of the social-ecological system - see **Figure 4**. This model can be seen as a qualitative summary of the research literature published. The literature suggests that 3 key impacts emerge from increasing carbon and elevated atmospheric temperatures in the WIO, and these are:

- Declines in ocean productivity,
- Increases in sea levels and storm surges, and
- Declining inland agricultural productivity.

The decline in ocean productivity, associated with changes in the size and condition of natural capital, results in reductions in ecosystem service levels, which in turn lead to lower resource consumption or service benefits per household.

The increases in sea level and storm surges could flood low-lying agricultural areas and built infrastructure. This would be exacerbated by declines in buffering ecosystem services, and together lead to further declines in built capital or infrastructure conditions, leading to less accessibility for people, governments and business. This would lead to less consumption of social, tourism and business services, with impacts for trade, exports and welfare. With reduced access to and availability of natural assets and ecosystem services for consumption, livelihoods will be threatened. Furthermore, less access to ecosystem services will also result in less tourism and trade, with consequences for economic resilience and livelihood resilience.

The declining inland agricultural productivity , either immediately adjacent to the coast or far inland, will promote in-migration to the coast, accelerating an already growing resident population, and elevating demand for open access marine resources – some of the last 'free resources' of value to access. The possible growth in oil, gas and mineral extraction on the coast could further promote population increases, elevating demands for coastal resources. Increasing demand can further reduce natural and built services per capita, and over use of natural assets will depress natural capital and the associated flows of services.

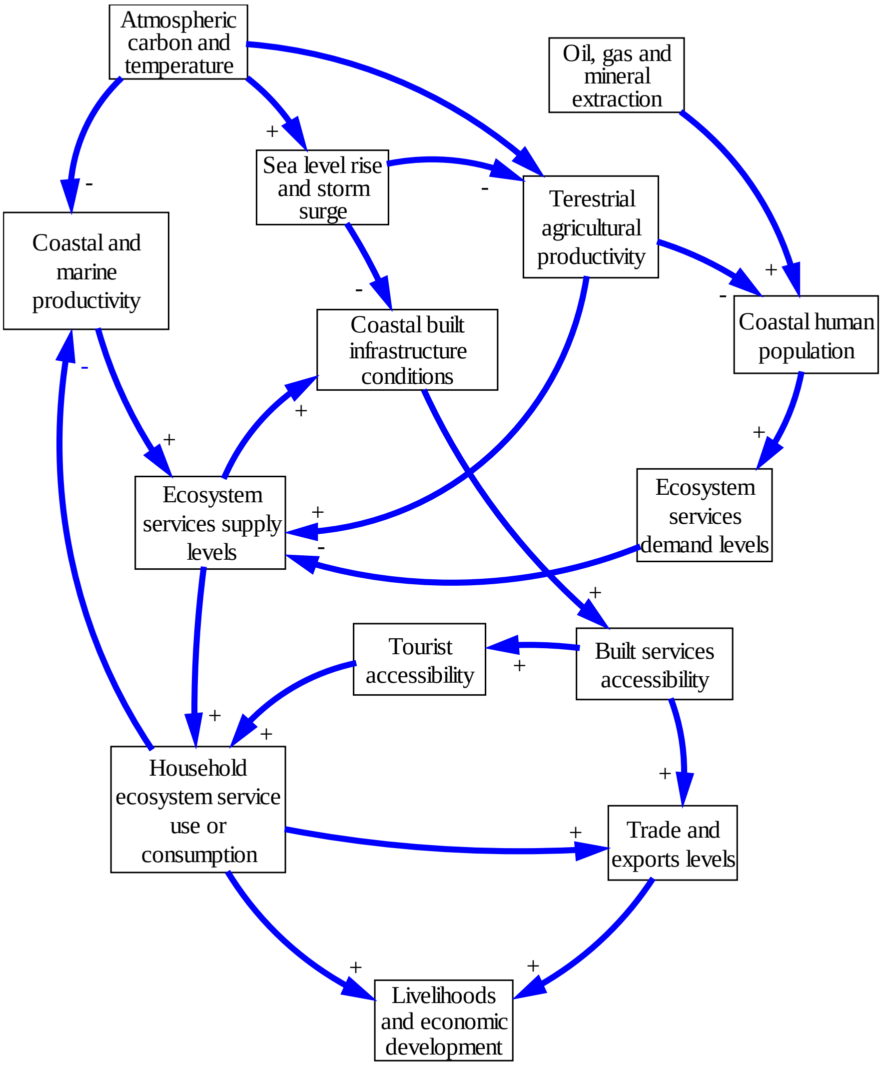


Figure 4: Conceptual model of the climate change / economy social-ecological system

This model serves to highlight the system linkages between the social, ecological and meteorological systems in the Western Indian Ocean, where climate changes can influence the entire system. It also highlights the role of natural, built and human capital, and their interdependencies. The implications of this complexity for an economic impact valuation strategy or process, are:

- Modelling is required due to the number of variables and lack of data,
- Relationships between the components need to be understood, or at least explored to predict their range and magnitude of influence,
- The possible futures associated with climate change and population growth should be engaged using scenarios,
- Single number monetary values will be inadequate to explain impacts, and a combination of values measuring and/or predicting natural capital, human wellbeing and monetary costs will be necessary.

4 Implications for the way forward

From the above discussion it has emerged that:

1. There is a lack in a region-wide and systematic coverage of the issues concerned leading to many research gaps and topics that have not been covered at all. The current understanding of the plausible economic impact of climate change on the countries of the Western Indian Ocean is therefore, at best, highly patchy and partial. To illustrate:
   a) Studies that have been conducted investigating the economic impact of climate change in and among the countries of the Western Indian Ocean have focused mainly on the impacts of sea-level rise, and to a lesser effect the impact of extreme events and the impact of a change in sea surface temperature.

  b) The economic impacts considered are focused on the state of natural capital, agriculture, fisheries, infrastructure, and livelihoods, with the emphasis on the number of people displaced and the area potentially lost due to sea-level rise and affected by extreme events.
  c) The country focus is highly biased towards Tanzania and Mozambique with the others receiving much less attention.
2. There seems to be no regional-wide integration of the research results leading to a difficulty in developing a regional-wide picture of the potential economic impact of climate change. The information currently available cannot be aggregated due the range of methods and parameters used.
3. There seems to be little to no focus on the plausible knock-on effects of climate change, and other drivers of change on terrestrial resources and populations on coastal and marine resources. This is necessary as coastal and marine resources are deemed “resources of last resort” to vulnerable communities.
4. There seems to be little to no focus on the cost of adaptation and mitigation, especially the development of buffers and/or various forms of capital that would contribute to the building of a resilient society under climate change.
5. There are examples that can be used to highlight the implications of climate change, but the diversity of societies, research approaches and economic characteristics will require a more systematic country and regional analysis before an adequate baseline picture emerges, that can used to reflect on future changes.
6. Even though there is a relatively high occurrence of some economic sectors in the review, there is not a systematic assessment of all states in the region, limiting the basis to argue for support at a regional level.
7. There is no systematic comparison of the costs of climate change impacts with and without adaptation.
8. Much of the climate change science reflects a range of possible future scenarios, however this review indicates that few economic analyses engage with a range of scenarios. The economic analyses of climate change should reflect scenarios to ensure that there are consistent messages, and to promote credibility.
9. Without a clear indication of the positive role natural assets or natural capital plays in climate change adaptation, there is little motivation for investing in their management.
10. There is a clear need to develop an understanding of the possible future costs of climate change impacts as a motivation to invest in adaption and mitigation. However, as these estimates will reflect a future without management interventions and are therefore highly speculative, there also needs to be a focus on adaptation costs – a more realistic perspective of climate change costs. Consequently, there needs to be sufficient quantitative information highlighting the threats of climate change, coupled with an analysis of climate change adaption costs and benefits.

Recommendations that follow from this synthesis are:
1. Embarking on an economic valuation strategy, that might entail:
  a) The development of a range of scenarios based on participatory modelling techniques to determine a rationale for investment in mitigation and adaptation.
  b) A structured and integrated region-wide research process performing a detailed analysis of the costs and benefits of adaptation and mitigation.
  c) Development of a set of tools and guidelines to support the generation of local, national and regional data that can be effectively aggregated to inform policy and adaptation practice.

5 Motivation for an economic valuation strategy

Whist the review indicated that the information available is not sufficient to develop a big picture or systematic picture of the economic impacts of climate change, there are several good cases studies which highlight the magnitude of the possible impacts of climate change. For example, climate change may result in:

- Kenya could experience a 2.5% reduction in their GDP, and a loss of 48 000ha of high value wetlands.
- Mauritius could lose USD993 million per year in wetland values.
- Mozambique could see USD11.5 billion worth of infrastructure at risk, with 384 000 people affected by sea level rise, and 2.3 million people affected by storms.
- Tanzania could see USD5.7 billion worth of infrastructure at risk, with 913 500 people impacted by sea level rise.

Furthermore, the suite of existing studies available enables a social-ecological systems understanding to be developed (see Figure 4), that serves to highlight the systemic risks of climate change. For example:

- Climate change’s double impact on the coast – not only will the WIO marine habitats be reduced in functionality by climate change impacts, but the marginalisation of inland agricultural areas will lead to coastal migration, with elevated coastal populations, placing greater demands on a diminishing marine resource base, with elevated harvesting pressure and elevated pollution discharge, further compounding the problems of stressed marine habitats. In other words, climate change will concurrently generate increasing demands on and diminishing supply of marine ecosystem services.

- Degraded coral reefs, and other marine habitats, do not bounce back to former conditions after bleaching (or exposure to high sea temperature events) thereby leading to habitat reduction, and declining productivity of associated fisheries, and shifts in harvesting to alternative marine resources.
- Large numbers of households are highly dependent on marine resources (Table 5). The ocean offers households access to high value protein sources and trade goods, with few alternatives available. This value has also led to large scale migration to the coast, such as in Mozambique during the civil war, and appears to be an enduring trend along the African coast. Projecting the current population growth estimates (Table 5), and assuming similar patterns of marine resource use, there could be a growth in resource demand of between 164% to 188% (almost a doubling) in 20 years. This illustrates that even without climate change, there could be a large increase in marine resource users. Also note the Human Development Index (HDI) in Table 5, as this highlights that the relatively lower HDI of people in Mozambique, Comoros, Madagascar, Tanzania and Kenya respectively, are vulnerable.

Table 5 : Country statistics to highlight current and future livelihood vulnerability to coastal climate change perturbations

Country	Population (millions)	% dependent on coast	Population dependent on coast (millions)	Population growth	Future year scenario*	Possible future population (millions)*	% change in resource demand*	GDP per capita	Human development index
Comoros	0.8	41%	0.328	2.5%	20	0.5	164%	1183	0.433
Kenya	41.6	9%	3.744	2.7%	20	6.4	170%	1573	0.509
Madagascar	21.3			2.8%	20			1004	0.48
Mauritius	1.3			1.4%	20			12838	0.728
Mozambique	23.9	66%	15.774	3.2%	20	29.6	188%	885	0.322
Seychelles	0.1	100%	0.1		20			19587	0.773
Tanzania	46.2	25%	11.55	3.1%	20	21.3	184%	1362	0.466

Source: Rakatobe et al. 2012

*Note: shaded columns are own calculations based on provided population growth rates

These quantitative and qualitative examples indicate that there is potential for large scale economic impacts or economic disruptions in the WIO region. **The magnitude and scale of these impacts, especially on large numbers of vulnerable people, warrants a focused and systematic analysis of the economic impacts of climate change in coastal areas.**

The economic valuation strategy requires an inclusion of an 'economic valuation process'. Given the need to:

- include a wide range of stakeholders,
- be integrated with on-going regional climate change science,
- rely on stakeholders for key data inputs, and
- respond to emerging issues in a dynamic way,

we believe a *process* is an essential core to a valuation *strategy*.

6 Recommended climate change project assessment tools

There is a range of different project and/or policy assessment tools available, both on a local and/or project level, and a national level. These tools are too often, and wrongly so, weighed against each other as either being "good" or "bad". All assessments tools have their uses and applications. The question therefore is not what is a "good" or "bad" assessment tool but much rather which are appropriate under which circumstances. A selection of project and/or policy assessment tools are listed in Table 6 and described in terms of various characteristics.

Table 6 : A range of different project and / or policy assessment tools - a comparative analysis

	Input-output based models	SAM-based Computable General Equilibrium models	Systems Dynamic models	Cost-Benefit analysis	Linier programming	Participatory modelling
Description	Framework of inter-industry trade relationships for a specific year modelled using fixed (Leontief-type) coefficients	Framework of inter-industry trade relationships for a specific year (static) or years (dynamic) modelled using Leontief and CES-type coefficients within the context of household data	User-defined models developed to solve complex and dynamic problems using data from various sources, dimensions, metrics, etc.	Project analysis tool to compare the benefits and the costs of various projects with each other	Either single or multiple equations in a system used to make projections given a set of assumptions	A process whereby a modeller uses stakeholder perspectives (usually workshop participants) to derive answers to a pre-stated questions
Examples of software requirements	Excel	GAMS, GEMPACK	VENSIM, STELLA, iTHINK, POWERSIM	Excel	Excel, e-views and various others	Excel
Static or dynamic	Static	Either static or dynamic; the dynamic versions are extremely complex	Dynamic	Dynamic features can be built in	Mainly static, dynamic features rarely built in	Mainly static, dynamic features rarely built in
Partial (i.e. sectoral or regional) or general (i.e. economy- and national-wide)	Mostly general although provincial is possible	Mostly general although provincial is possible	Partial – dimensions are user-defined	Partial – dimensions are user-defined	Partial – dimensions are user-defined	Partial – dimensions are user-defined
Data intensity	Moderate	Extreme	Low to extreme: depends on the user, the problem and the objective	Low to extreme: depends on the user, the problem and the objective	Low to extreme: depends on the user, the problem and the objective	Low – using expert wisdom of the workshop participants
Data requirement	Single year, inter-industry trade data for a pre-defined geographic area	Single year inter-industry and household data for a pre-defined geographic area	User-defined, could be multiple or single years, and comprise a range of different types, including people's perceptions and observed data for a pre-defined study or research boundary	Project specific benefit and costs	Usually based on time-series analysis	Defined by the research question
Technical expertise required	Moderate to high	Extreme	Moderate to high	Moderate to high	Moderate to high	Low to moderate
Inclusiveness of environmental and social variables	Nothing to low	Low to moderate	Moderate to high	Moderate to high	Moderate to high	High
Usefulness to policy scenario modelling	Low	High	High	Moderate	Low	Moderate to high

	Input-output based models	SAM-based Computable General Equilibrium models	Systems Dynamic models	Cost-Benefit analysis	Linier programming	Participatory modelling
Strengths	Very good for quick economic assessments of national and/or regional impacts of policies and large-scale projects	Very good for in-depth macro-economic assessments of policies and large-scale policies	Very good in providing scenario assessments and impacts of various policies or projects under varying conditions	Excellent for inter-project analysis	Depending the quality of the data, good for projecting future trajectories	Very inclusive process involving people; can derive answers to challenging questions in a very short time
Weaknesses	No dynamic dimension, Rarely a social dimension, Weak on smaller-scale project evaluations	Extremely data-hungry requiring very high degree of expertise and weak on smaller-scale project evaluations	Requires special attention to provide macro-economic impact assessment High degree of expertise required	Incapable of macro-economic impact assessment	Incapable of macro-economic impact assessment	Scientific rigour low and the macro-economic application zero

Based on the analysis in Table 6, it should be self-evident that it is unrealistic to expect that a single assessment tool must provide all the answers to all the possible questions in a heterogeneous, dynamic and uncertain environment such as estimating the economic impact of climate change. For that it is much more prudent to use a suite of models.

We therefore recommend that the strengths of participatory modelling processes, cost-benefit analyses and systems dynamic modelling be harnessed together to provide a well-rounded strategy. In doing so WIOCC will be able to have local project-level data analysis that are informed by both local project specific data and scientific evidence of the context within which the projects will take place, as well as the plausible macro-economic impacts thereof. This will also enable regular and timeous updates of the economic impacts of climate change as well as the impact of the response interventions. In that way it would be possible to track progress over time. It would also be possible to expand the scope of the assessment tools as data and expertise increases. The strategy should include:

- Participatory scenario development processes:

  that will be used to determine the perceptions and ascertain the scientific evidence from both policymakers and scientist alike with respect to the plausible economic impact of climate change without any response strategy in place and also with a defined response strategy being actively pursued.

- Cost-benefit analyses:

  that will be used to determine the relative impacts (benefits) and cost-effectiveness of the various current and desired response interventions. This will lead to a prioritisation of the response interventions based on cost-effectiveness and their contribution towards climate change adaptation and the resilience of people to climate change.

- Systems dynamic modelling:

  that will be used to develop a range of scenarios with respect to the national and regional impact of climate change with and without the response strategies.

It is recommended that this suite of assessment tools be integrated with a GIS database to also show the plausible impacts on a spatial basis. A further modification that would be highly advantageous would be to develop a user-friendly software interface that would allow people to use the models developed for WIOCC without having to acquire the necessary skills to operate the models in their crude form.

7 Objectives of the economic valuation strategy

7.1 The outcomes of the proposed strategy

The implementation of the recommended strategy would generate the following outcomes:

- an enriched understanding of the regional wide economic implications of climate change and the plausible response options,
- basis for informed decision making,
- ability to adapt country and regional intervention plans due to access to information, and
- country participants would have an elevated capacity to engage with climate change adaptation.

7.2 The outputs of the strategy

The following outputs would be generated:

- Phase 1 – Creating the base line (year 1)
  - A tool kit to promote standardised data collection and analysis, including a:
    - Systems dynamic model
    - Ecosystem services supply risk assessment model
    - Cost benefit model
    - Templates for data collection that would input into the above tools
  - A body of information regarding the current state of knowledge
  - The cost of inaction regarding climate change at the country level and for the region
- Phase 2 – Analysing the economic impacts of climate change adaptation (year 2)
  - A package of national climate change intervention options:
    - A prioritisation of the national options based on a cost benefit analysis
  - A re-run of the three models per participating country, assessing the economic impacts of interventions, that is changes in ecosystem service levels, the cost-effectiveness of interventions, and the macro-economic impacts
  - A synthesis of the regional economic sector themes
  - A reporting system to track progress
  - Template tied to the three models
  - Models for WIOCC use
- Phase 3 – Tracking climate change interventions (year 3 onwards)
  - Monitoring of country level intervention implementation
  - Review and revise approach and plans

8 Recommended Climate Change Economic Valuation Strategy

The proposed economic valuation strategy is outlined in Table 7. A logical framework is used to show the phase, tasks, expected outputs, timeframes, likely effort and extent of stakeholder participation necessary to implement an economic impact valuation strategy.

Table 7 : A logical framework outlining the proposed economic valuation strategy recommended for the WIOCC

Phase	Task	Description	Output	Timeframe	Level of effort by person and days each	Extent of stakeholder participation
Phase 1 Creating the baseline (year 1)	1.1 Develop a toolkit	Develop a data collection template using readily available data to support modelling processes, which includes: • Template for standardised data collection for input into models • Systems dynamic model for estimating changes in macro-economic and related variables due to climate change and the subsequent responses. • A cost benefit analysis model for comparing the costs and the benefits expressed in terms of financial costs and benefits to society of individual country specific responses to climate change. • Ecosystem services supply and demand model to estimate the changes in services in response to climate change and mitigation.	A toolkit to promote standardised data collection and analysis, including data such as: • Demographics • GIS data • Macro-economic data • Climate data	2 months	Prof time: 4 p @15 d Tech time: 1 p @ 5 d	Limited
	1.2 Data collection	Per participating country: • Populate the data template developed in 1.1 with available information • The collation and packaging of data	A comprehensive database by country and WIO region.	3 months	Prof time: 1 p @ 10 d Tech time: 1 p @ 20 d	Participating countries primarily responsible for data collection
	1.3 Baseline scenario development	Estimate the cost of inaction in various climate change scenarios: • Participatory scenario development addressing a range of climate change futures without interventions including climate change variables (such as changes in ecosystems and ecosystem services (areas, productivity, conditions and service levels), sea level rise, demographic changes, etc.) in order to assess the change in risk and vulnerability to the economy and society. • Estimate plausible ranges of the country and regional macro-economic impacts of climate change following 'no-action' using the systems dynamic model.	Report on plausible change in human vulnerabilities by country. Report on national and regional macro-economic implications of no-action.	6 months	Assuming 6 participating countries: Prof time: 3 p @ 40 d Tech time: 2 @ 50 d	Country specific workshops involving intensive participation by subject specialists and policy makers; taking cognisance of on-going climate change science, policy and implementation process in the region.
	1.4 Review of progress and plans	Reflection on the first year's process and review of the way forward.	Phase 1 close-out report.	1 month	Prof time: 2 p @ 4 d	Limited to a review of progress and provision of comments.

Phase	Task	Description	Output	Timeframe	Level of effort by person and days each	Extent of stakeholder participation
Phase 2 Analysing the economic impacts of climate change adaptation (year 2)	2.1 Collate country level information	Develop list of current and desired climate change adaptation interventions by country. Data required would be: • Develop a template for intervention data collection. • Detailed description of the action, including location, capital and operating costs, desired outcomes, people impacted, etc.	A comprehensive database of response interventions by country and WIO region.	3 months	Prof time: 2 p @ 10 d Tech time: 1 p @ 20 d	Participating countries primarily responsible for development of national response interventions.
	2.2 Analyse the costs and benefits of climate change response on a project and national scale	Estimate the cost and benefits of interventions in various climate change scenarios: • Participatory scenario development addressing a range of climate change futures with interventions including climate change variables (such as changes in ecosystems and ecosystem services (areas, productivity, conditions and service levels), sea level rise, demographic changes, etc.), national interventions, in order to assess the change in risk and vulnerability to the economy and society. • A cost benefit analysis of interventions comparing the costs and the benefits expressed in terms of financial costs and benefits to society of individual country specific responses to climate change. • Estimate plausible ranges of the country and regional macro-economic impacts of climate change following interventions using the systems dynamic model.	Report on plausible change in human vulnerabilities by country following the proposed suite of interventions. Report on the costs and benefits of country interventions, including prioritisation on interventions based on cost effectiveness. Report on national and regional macro-economic implications of the interventions.	8 months	Assuming 6 participating countries: Prof time: 4 p @ 50 d Tech time: 2 @ 60 d	Country specific workshops involving intensive participation by subject specialists and policy makers; taking cognisance of on-going climate change science, policy and implementation process in the region.
	2.3 Develop a regional synthesis of regional economic results, and to recommend future action	Develop a regional synthesis and review the way forward.	Phase 2 close-out report.	1 month	Prof time: 2 p @ 8 d	Limited to a review of progress and provision of comments.
Phase 3 Tracking the interventions (year 3 onwards)	3.1 Implementation of interventions					Countries implement their climate change responses
	3.2 Tracking and evaluating the progress	Provide on-going technical expertise to assist the monitoring and evaluation of the progress made with respect to climate change adaption, from an economics				

Phase	Task	Description	Output	Timeframe	Level of effort by person and days each	Extent of stakeholder participation
		perspective, including support for the use of analytical tools.				

9 Summary

The country visions highlight that countries anticipate that climate change will impact on coastal resources and that it represents a clear threat to their national economies. There is a common concern on fisheries, tourism, ecosystems and vulnerable sectors of society, and a widely held perspective that sustainable economic growth is necessary to promote resilience. There are also several references to the need for a suite of tools that will assist in understanding the economic implications of climate change, such as cost benefit analyses and ecosystem services supply, demand and risk assessment.

The literature reviews indicates that there is a lack in a region-wide and systematic coverage of climate change's economic impacts, leading to many research gaps and topics that have not been covered at all. The current understanding of the plausible economic impact of climate change on the countries of the Western Indian Ocean is therefore, at best, highly patchy and partial. To illustrate:

- Studies that have been conducted investigating the economic impact of climate change in and among the countries of the Western Indian Ocean have focused mainly on the impacts of sea-level rise, and to a lesser effect the impact of extreme events and the impact of a change in sea surface temperature.
- The economic impacts considered are focused on the state of natural capital, agriculture, fisheries, infrastructure, and livelihoods, with the emphasis on the number of people displaced and the area potentially lost due to sea-level rise and affected by extreme events.
- The country focus is highly biased towards Tanzania and Mozambique with the others receiving much less attention.

There seems to be no regional-wide integration of the research results leading to a difficulty in developing a regional-wide picture of the potential economic impact of climate change. The information currently available cannot be aggregated due the range of methods and parameters used. There seems to be little to no focus on the plausible knock-on effects of climate change, especially for tourism, and other drivers of change on terrestrial resources and populations on coastal and marine resources. This is necessary as coastal and marine resources are deemed "resources of last resort" to vulnerable communities. There seems to be little to no focus on the cost of adaptation and mitigation, especially the development of buffers and/or various forms of capital that would contribute to the building of a resilient society under climate change.

Whist the review indicated that the information available is not sufficient to develop a big picture or systematic picture of the economic impacts of climate change, there are several good cases studies which highlight the magnitude of the possible impacts of climate change. For example, climate change may result in:

- Kenya could experience a 2.5% reduction in their GDP, and a loss of 48 000ha of high value wetlands.
- Mauritius could lose USD993 million per year in wetland values.
- Mozambique could see USD11.5 billion worth of infrastructure at risk, with 384 000 people affected by sea level rise, and 2.3 million people affected by storms.
- Tanzania could see USD5.7 billion worth of infrastructure at risk, with 913 500 people impacted by sea level rise.

Furthermore, the suite of existing studies available enables a social-ecological systems understanding to be developed, that serves to highlight the systemic risks of climate change. For example:

- Climate change's double impact on the coast – not only will the WIO marine habitats be reduced in functionality by climate change impacts, but the marginalisation of inland agricultural areas will lead to coastal migration, with elevated coastal populations, placing greater demands on a diminishing marine resource base, with elevated harvesting pressure and elevated pollution discharge, further compounding the problems of stressed marine habitats. In other words, climate change will concurrently generate increasing demands on and diminishing supply of marine ecosystem services.

- Degraded coral reefs, and other marine habitats, don't bounce back to former conditions after bleaching (or exposure to high sea temperature events) thereby leading to habitat reduction, and declining productivity of associated fisheries, and shifts in harvesting to alternative marine resources.
- Large numbers of households are highly dependent on marine resources. The ocean offers households access to high value protein sources and trade goods, with few alternatives available. Projecting the current population growth estimates, there could be a growth in resource demand of between 164% to 188% (almost a doubling) in 20 years. This illustrates that even without climate change, there is likely to be a large increase in marine resource users. The relatively lower Human Development Index of people in Mozambique, Comoros, Madagascar, Tanzania and Kenya respectively, indicate they are particularly vulnerable to climate change.

In conclusion there is a clear need to develop an understanding of the possible future costs of climate change impacts as a motivation to invest in adaption and mitigation. However, as these estimates will reflect a future without management interventions and are therefore highly speculative, there also needs to be a focus on adaptation costs – a more realistic perspective of climate change costs. Consequently, there needs to be sufficient quantitative information highlighting the threats of climate change, coupled with an analysis of climate change adaption costs and benefits.

Following a review of the possible economic tools and methods to use, and current data availability, we therefore recommend that the strengths of participatory modelling processes, cost-benefit analyses and systems dynamic modelling be harnessed together to provide a well-rounded strategy for the WIOCC. In doing so WIOCC will be able to have local project-level data analysis that are informed by both local project specific data and scientific evidence of the context within which the projects will take place, as well as the plausible macro-economic impacts thereof. This will also enable regular and timeous updates of the economic impacts of climate change as well as the impact of the response interventions. In that way it would be possible to track progress over time. It would also be possible to expand the scope of the assessment tools as data and expertise increases. The strategy should include:

- **Participatory scenario development processes:**
  that will be used to determine the perceptions and ascertain the scientific evidence from both policymakers and scientists alike with respect to the plausible economic impact of climate change without any response strategy in place and also with a defined response strategy being actively pursued.
- **Cost-benefit analyses:**
  that will be used to determine the relative impacts (benefits) and cost-effectiveness of the various current and desired response interventions. This will lead to a prioritisation of the response interventions based on cost-effectiveness and their contribution towards climate change adaptation and the resilience of people to climate change.
- **Systems dynamic modelling:**
  that will be used to develop a range of scenarios with respect to the national and regional impact of climate change with and without the response strategies, and will estimate macro-economic impacts.
- **Structured data collection:**
  to inform current analyses and to track future interventions.

These processes and analyses should be combined into three phases:

- **Phase 1: Creating the baseline**
  A baseline that would include an understanding of a future scenario without adaptation interventions, highlighting changes to ecosystem services, risks to vulnerable households and implications for national economic indicators. This should be done for each participating country. This process should take one year.
- **Phase 2: Analysing the economic impacts of climate change adaptation**
  An analysis of the economic impacts of climate change adaptation, highlighting the possible options available for adaptation, the costs and benefits of adaptation for clusters of interventions in each participating country, and again the implications for national economic indicators. These country level

analyses should then be collated to generate a regional perspective, for informing national and international decision making. This process would take one year.

- **Phase 3: Tracking the interventions**

  Is a process to track interventions, and provide on-going economic analysis of options.

Importantly, the process involves stakeholders intimately, with a view to developing capacities, methods and tools which the WIOPCC countries could use after the first two years of the strategy.

Annexure 1: List of Relevant References Analysed

1	Arndt C., Strzepeck K., Tarp F., Thurlow J., Fant C., and Wright L. (2010), Adapting to Climate Change: An Integrated Biophysical and Economic Assessment for Mozambique, Working Paper No. 2010/101, UNU-WIDER http://www.wider.unu.edu/stc/repec/pdfs/wp2010/wp2010-101.pdf
2	Stockholm Environment Institute (2009), Economics of Climate Change: Kenya, Project Report, Oxford http://www.sei-international.org/mediamanager/documents/Publications/Climate-mitigation-adaptation/kenya-climatechange.pdf
3	Republic of Kenya (2013), National Climate Change Action Plan 2013 - 2017, Nairobi http://cdkn.org/wp-content/uploads/2013/03/Kenya-National-Climate-Change-Action-Plan.pdf
4	Indian Ocean Commission (2012), Mapping and Inventory of the Access and Use of Climate Change Related Financing in the Eastern Southern African - Indian Ocean region.
5	Tanzania (2003), Initial National Communication under the United Nations Framework Convention on Climate Change
6	Brown S., Kebede A.S., and Nicholls R.J. (2011), Sea-Level Rise and Impacts in Africa, 2000 to 2100, University of Southampton, Southampton
7	European Union (2014), The Economic Impact of Climate Change and Adaptation in the Outermost Regions, European Union, Belgium http://ec.europa.eu/regional_policy/activity/outermost/doc/impact_climate_change_en.pdf
8	Robinson et al. (2009), Impacts of Climate Variability on the Tuna Economy of Seychelles, Working Paper EA 4272, Université de Nantes, France https://hal.archives-ouvertes.fr/file/index/docid/430051/filename/LEMNA_WP_200936.pdf
9	Allnut et al. (2012), Comparison of Marine Spatial Planning Methods in Madagascar Demonstrates Value of Alternative Approaches, PLoS One, Vol. 7: 2
10	Anning D., Dominey-Howes D., Wthycombe G. (2009), Valuing Climate Change Impacts on Sydney Beaches to Inform Coastal Management Decisions, Management of Environmental Quality: An International Journal, Vol. 20: 4, pp. 408 - 421
11	Blankespoor B., Dasgupta S., and Laplante B. (2014), Sea-Level Rise and Coastal Wetlands, Royal Swedish Academy of Sciences
12	Christensen O.B., Goodess C.M., and Ciscar J. (2011), Methodological Framework of the PESETA Project on the Impacts of Climate Change in Europe, Climate Change, Vol. 112, pp 7-28
13	Costanza R., Perez-Maqueo O., Martinez H.L., Sutton P., Anderson S.J. and Mulder K., (2008), The Value of Coastal Wetlands for Hurricane Protection, Journal of the Human Environment, Vol. 37:4, pp. 241-248
14	Dixon R., Smith J., and Guill S. (2003), Life on the Edge: Vulnerability and Adaptation of African Ecosystems to Global Climate Change, Mitigation and Adaptation Strategies for Global Change, Vol. 8, pp. 93-113
15	Bruggeman et al. (2012), Wicked Social-Ecological Problems Forcing Unprecedented Change on the Latitudinal Margins of Coral Reefs: The Case of Southwest Madagascar, Ecology and Society, Vol. 17:4, pp. 47
16	Bunce M., Brown K., and Rosendo S. (2010), Policy Misfits, Climate Change and Cross-Scale Vulnerability in Coastal Africa: How Development Projects Undermine Resilience, Environmental Science & Policy, Vol. 13, pp. 485-497
17	Cinner JE, Bodin O¨. (2010), Livelihood Diversification in Tropical Coastal Communities: A Network-Based Approach to Analyzing 'Livelihood Landscapes', PLoS ONE, Vol. 5:8
18	Kebede A.S. and Nicholls R.J. (2012), Exposure and Vulnerability to Climate Extremes: Population and Asset Exposure to Coastal Flooding in Dar es Salaam, Tanzania, Reg Environ Change, Vol. 12:2, pp. 81-94
19	Lange G. and Jiddawi N. (2009), Economic Value of Marine Ecosystem services in Zanzibar: Implications for Marine Conservation and Sustainable Development, Ocean and Coastal Management Vol. 52, pp. 521-532
20	Remoundou K., Koundouri P., Kontogianni A., Nunes P.A.L.D. and Skourtos M. (2009), Valuation of Natural Marine Ecosystems: An Economic Perspective, Environmental Science and Policy, Vol. 12, pp. 1040-1051
21	Pérez-Maqueoa O., Intralawana A., and Martíneza M.L. (2007), Coastal Disasters from the Perspective of Ecological Economics, Ecological Economics, Vol. 63, pp. 273-284

22	Rakatobe, T., Holmes, C. and Ralison, F. (2012) Climate change in the Western Indian Ocean: A situation assessment and policy considerations. WIOCC
23	Bunce, M., Rosendo, S. and Brown, K. Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. Environ Dev Sustain (2010) 12:407–440
24	Liquete C, Piroddi C, Drakou EG, Gurney L, Katsanevakis S, et al. (2013) Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. PLoS ONE 8(7): e67737. doi:10.1371/journal.pone.0067737
25	Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S. and Roberts, D. (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization published online 6 March 2013
26	Sauter R., ten Brink P., Withana S., Mazza L., and Pondichie F. (2013), Impacts of Climate Change on all European Islands, A report by the Institute for European Environmental Policy (IEEP) for the Greens/EFA of the European Parliament, Final Report, Brussels http://www.ieep.eu/assets/1292/Final_report_EP_CC_impacts_on_islands_FINAL_clean.pdf

Annexure 2: Review of Existing Literature

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
	Web-based research									
1	Arndt C., Strzepeck K., Tarp F., Thurlow J., Fant C., and Wright L. (2010), *Adapting to Climate Change: An Integrated Biophysical and Economic Assessment for Mozambique*, Working Paper No. 2010/101, UNU-WIDER http://www.wider.unu.edu/stc/repec/pdfs/wp2010/wp2010-101.pdf	Cash	2003 (Discounted)	US$		1. -0.09% to -0.38% change in average annual real per capita absorption rate, (2003-2050) 2. US$2.3 billion to US$7.4 billion between 2003 & 2050.	Focuses on impacts on 4 sectors: energy (hydropower), infrastructure (road network), crops (crop losses) & loss of agricultural land (sea level rise). Used 4 climate change scenarios to reflect full variation of global and local climate projections: Global dry & wet; and local dry & wet. Used number of models to estimate changes as result of climate change: • General Circulation Models (GCM) - temperature & precipitation. • River Basins Model (CLIRUN) - runoff and floods. • Water Resource Models (WRM) – stream flow and evapotranspiration. • Crop Models (CLICROP) - crop yields. • Hydropower models (IMEND) – energy supply. • Infrastructure models (CLIROAD) – road network length. • (DIVA) – land inundation from sea level rise Impacts were then passed through Dynamic Computable General Equilibrium (DCGE) model to estimate economic impacts of climate change on socio-economic variables such as economic growth and welfare. Calculated economic costs by comparing to a baseline scenario with no climate change.	Stream flow; Water availability; Flooding; Temperature; Precipitation; Sea level rise.	Mozambique	Coastal economic impact costs would be a subset of the total cost estimate.
2	Stockholm Environment Institute (2009), *Economics of Climate Change: Kenya*, Project Report, Oxford		2009-2030 2030-2050	US$		1. Economy - Loss of 2.6% of GDP each year by 2030 (additional to existing variability.	***Top Down Aggregated Estimates***	Temperature (1 – 3.5°C); Rainfall (avg. increase);	Kenya	Kenya currently experiences high economic costs due to climate variability and

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
	http://www.sei-international.org/mediamanager/documents/Publications/Climate-mitigation-adaptation/kenya-climatechange.pdf					2. Coastal zones – Coastal flooding as result of sea level rise will affect 10,000 to 86,000 people a year by 2030. In 2030, economic costs estimated to be $7 - $58 million per year (current prices, no discounting). By 2050, these costs increase to $31 - $313 million per year. 3. Health – Increase risk of Malaria by 36% - 89% by 2050s, affecting an extra 2.9 – 6.9 million people. Direct economic costs of $45 to $99 million annually. With indirect costs (e.g. loss of productivity), costs increase to $144 - $185 million annually. 4. Agriculture – Assuming there is an annual drought, the total value of agricultural land decreases by 33%. Assuming in long term wetter conditions prevail, the value of central zones increases by 10%. 5. Extreme events – Due to population and economic growth, direct economic costs of periodic floods and droughts could increase fivefold by 2030 to $5 - $10 billion. Climate change likely to increase economic costs of these	Used Global Climate Models (GCM) and top-down aggregated assessments. ***Sector (bottom-up) Assessments*** Used climate socio-economic projections. Focused on following key sectors: 1. Coastal zones (i.e. sea level rise); 2. Health (i.e. Malaria); 3. Agriculture (i.e. Drought and wetter conditions); 4. Extreme events (i.e. periodic floods and droughts). 5. Water resources (i.e. Modelling of Tana River Basin. Focussed on hydropower, irrigation and drinking water); 6. Energy (i.e. energy demand with increase in number of hotter days). 7. Ecosystem services (i.e. local studies looking at sea level rise in Mombasa, flood events, vulnerable groups and iconic ecosystems).	Extreme events (increase in droughts and floods).		extreme weather events. These costs are predicted to increase in future fivefold due to population and economic growth in the absence of climate change. With climate change, these costs are likely to increase further. This study has been used as baseline for most the other readings.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						events e.g. reduce return period of larger events. 6. Water resources – Ranges from $2million benefit to cost of $66 million; 7. Energy demand – Demand for cooling increases by 240% - 340% in Mombasa by 2050.				
3	Republic of Kenya (2013), *National Climate Change Action Plan 2013 - 2017*, Nairobi http://cdkn.org/wp-content/uploads/2013/03/Kenya-National-Climate-Change-Action-Plan.pdf			US$		1. Economy wide – estimated that climatic events currently cost the economy as much as $500 million a year (2.6% of GDP), which impacts on long-term growth. For example, the 1998-2000 droughts led to economic loss of $2.8 billion due to loss of crops and livestock, forest fires, damage to fisheries, and reduced hydropower generation. 2. Agriculture – backbone of Kenyan economy contributing 24% to GDP, and 65% of informal employment in rural areas. As it is mostly dryland cultivation, farmers are vulnerable to effects of climate change e.g. number of famers requiring food assistance increased from 650,000 in 2007 to 3.8 million in 2010.			Kenya	Kenya is extremely vulnerable to impacts of climate change as its economy is dependent on climate sensitive sectors i.e. agriculture, tourism, and energy (50% hydropower). No specific statements on coastal impacts. Coastal tourism would be a subset of the total tourism estimates.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						3. Tourism – contribute 12% to GDP and 12% to foreign exchange earnings. Vulnerable as tourism is largely nature-based. 4. Energy – 50% of Kenya's energy generated through hydropower.				
4	Indian Ocean Commission (2012), *Mapping and Inventory of the Access and Use of Climate Change Related Financing in the Eastern Southern African - Indian Ocean region.*					1. Comoros Vulnerable as majority of population live in towns in coastal areas, majority of infrastructure is below 6m of elevation, majority of homes built using natural materials, high dependence on agriculture and fisheries, and access to clean drinking water. Impacts include 1°C increase in temperature since 1960, sea level rise of 0.4mm per year, increase in frequency of cyclones.			Comoros	
5	Tanzania (2003), *Initial National Communication under the United Nations Framework Convention on Climate Change*					Marine fisheries constitute 25% of total fisheries catch by weight. With sea level rise of 0.5m – 1m, a total of 247km² and 494km² of coastline will be inundated respectively. Furthermore, with 1m sea level rise, 258km² of mangroves, 105km² of sand/mud, 40km² of seasonal swamps, 35km² of tidal marshes, and 28km² of salt pans will be inundated.	Based on sea level rise scenarios developed by IPCC in 1990.		Tanzania	
6	Brown S., Kebede A.S., and Nicholls R.J. (2011), Sea-Level					***Previous studies:***	Used DIVA (Dynamic Interactive Vulnerability Assessment) model. Four		All	While Africa is not the most exposed region in

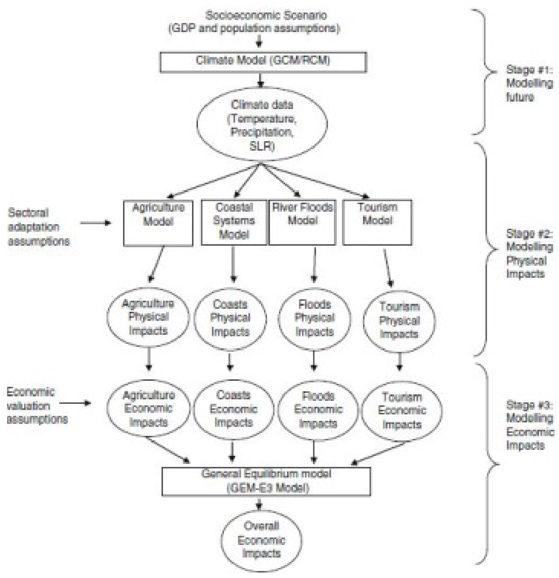
No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
	Rise and Impacts in Africa, 2000 to 2100, University of Southhampton, Southhampton					1. With a 1m rise in sea level, 351,000 people and US$ 5.3 billion worth of assets could be exposed in Dar es Salaam, Tanzania. 2. With a 0.3m sea level rise (without adaptation), it is estimated that 17% (4,600ha) of the Mombasa district will be submerged. Similarly, in the Tana delta, it is estimated that about 400 people (7% of population) and 481km^2 (5.7%) of the delta area could be lost between 2000 and 2050. 3. With a 1m sea level rise, it is estimated that 26km of beaches on west coast of Mauritius could be inundated, and that flooding could affect local housing, and tourism and infrastructure facilities. 4. In Seychelles, it is estimated that rising sea levels will result in greater erosion, and increase number of landslides on steep hills of the granitic islands. Furthermore, beaches would be inundated and rising ground water levels would threaten aquifers. 5. In the Tanga region of Tanzania, it is estimated	scenarios of sea level rise was used in conjunction with three socio-economic scenarios describing population density and GDP. Impacts were determined without adaptation, so that the benefits and costs of adaptation could be considered.			the world when compared south-east Asia, sea level rise still poses significant threat due to growing population in coastal zone and low adaptive capacity.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						that 3,520ha of land is vulnerable to 0.5m sea-level rise and 1,025ha of mangroves would also be at risk. Similarly, in the Mtwara region, 2,780ha of mangroves would be at risk from 0.5m sea-level rise. It is estimated that with a 1m sea-level rise, 9km^2 could be lost due to erosion and 2,117km^2 de to inundator. 6. In Dar es Salaam, 247km^2 of land and infrastructure costing US$82 million would be at risk with a 1m sea-level rise. ***DIVA Results:*** 1. By 2030, with a 0.1m sea-level rise, 647,000 people in Tanzania, 582,000 people in Mozambique, and 20,500 people in Kenya would be flooded per year. Furthermore, the total costs of residual damage would be US$146 million in Tanzania and US$16 million in Mozambique. 2. By 2030, with a 0.1m sea-level rise, the annual loss of wetland value would be US$30.7 million to Seychelles and US$18.3 million to Mauritius. 3. By 2100, with 0.43m sea-level rise, 3.96				

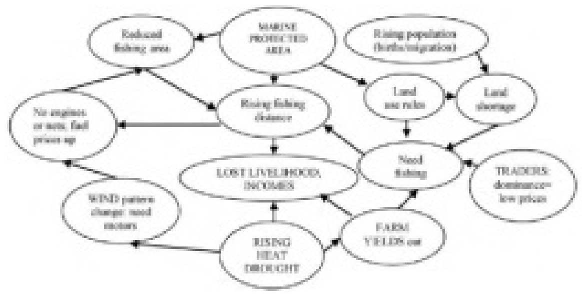
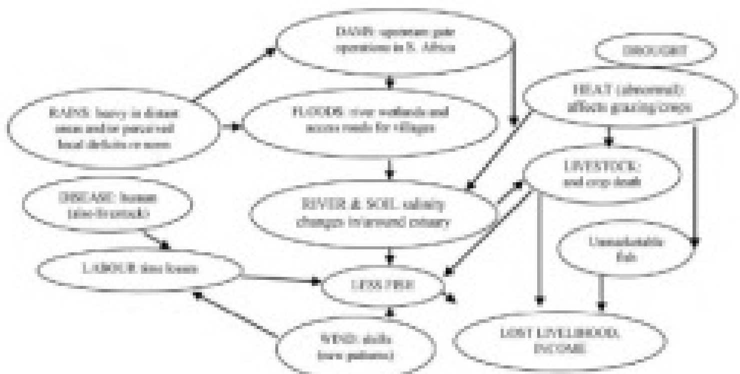
No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						million people in Mozambique, 1.18 million people in Tanzania, and 0.27 million people in Kenya would be flooded per year. Furthermore, the total costs of residual damage would be US$0.38 billion in Mozambique. 4. By 2100, with 0.43m sea-level rise, the annual loss of wetland value would be US$2.53 billion to Seychelles and US$1.9 billion to Mauritius.				
7	European Union (2014), The Economic Impact of Climate Change and Adaptation in the Outermost Regions, European Union, Belgium http://ec.europa.eu/regional_policy/activity/outermost/doc/impact_climate_change_en.pdf	Monetary	2000	€	Flows		The economic analysis took two forms: 1. Higher-level assessment of the impact of climate events on the macroeconomic trajectory of each country. Resource-diversion approach was used for this analysis. 2. Sector-level analysis focussed on agriculture, fisheries and tourism as good, comparable economic data was available for these sectors.			Due to lack of sufficient economic data, the construction of a complete economic model could not be justified. Limited or no data available for small island states, and therefore regional or global data has to be used.
8	Robinson et al. (2009), Impacts of Climate Variability on the Tuna Economy of Seychelles, Working Paper EA 4272, Université de Nantes, France https://hal.archives-ouvertes.fr/file/index/docid/430051/filename/LEMNA_WP_200936.pdf	Monetary	2006	€	Flows	European-owned purse-seine tuna fishers catch between 250,000 and 400,000 tons annually in the exclusive economic zone of the Seychelles. In 2006, the Seychelles received €6.5 million to allow these fishers access to their waters. Majority (90%) of catch is landed and transhipped in Port Victoria. The tuna	Spill over effects of expenditures by tuna fishers were estimated using an input-output model and a multiplier approach. Principal component analyses (PCA) was used to determine the relative importance of seasonal versus inter-annual effects. Co-integration approach was used to determine relationship between cargo handling costs and landings.	Increase sea temperature	Seychelles	It is expected that with climate change, the strong ocean warming event in 1998 could occur more frequently. Demonstrates vulnerability of Seychelles, and other SIDS, that are reliant of fisheries to impacts of climate change.

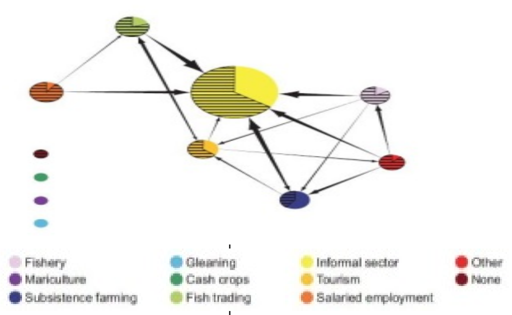
No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						cannery at Port Victoria is one of the biggest in the world and employs 1,975 local workers and 826 expatriates. The cannery accounts for 19% of formal employment and 90% of national exports, supplying 13% of Europe's canned tuna. Using a multiplier approach, it was estimated that the strong ocean warming event of 1998 reduced the direct, indirect and induced economic benefits of the tuna industry, by 58%, 34% and 60% respectively. Using a contingent time-series model, it was estimated that the event resulted in 40% decline in tuna landings and transhipment at Port Victoria, and 34% loss for the economy.	Multivariate Markov-Switching model (MS-VECM) was then used to assess the influence on climate variability on relation between cargo handling costs and landings.			
	Journal articles									
9	Allnut *et al.* (2012), Comparison of Marine Spatial Planning Methods in Madagascar Demonstrates Value of Alternative Approaches, *PLoS One*, Vol. 7: 2	Tons	2012		Reduction in fishing 6,340 – 14,410 tons / year with establishment of Large Closures for protection of biodiversity.			Coral bleaching	Madagascar	Exposure (i.e. coral bleaching) as result of climate change was one of 3 inputs used to develop conservation and management priorities for Madagascar's western coastal region. One of the techniques used (i.e. MARXAN) to identify high value conservation areas avoided areas with high levels of exposure. This meant that fisherman were likely to only be left with fishing areas that

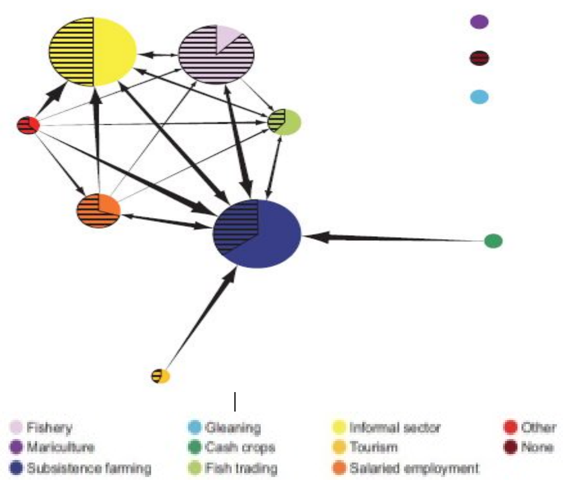
No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
										would experience coral bleaching in the future. As a result, the reduction in fishing catch is likely to be much greater due to impacts of climate change.
10	Anning D., Dominey-Howes D., Wthycombe G. (2009), Valuing Climate Change Impacts on Sydney Beaches to Inform Coastal Management Decisions, *Management of Environmental Quality: An International Journal*, Vol. 20: 4, pp. 408 - 421	Monetary		AUS$	Annual values		Combined results from following survey methods with estimates of value of ecosystem goods and services (using Benefit Transfer Method) to determine Total Economic Value of Sydney's beaches. 1. Hedonic Pricing Method – determine housing market impacts. 2. Combined travel cost and contingent valuation method – determine impact of condition of beaches and tourism revenue e.g. beach erosion. 3. Willingness to pay – determine cultural and non-use values. 4. Additional methods – visitor counts etc.	Sea level rise	Australia	Very few studies have been done to determine the economic value of beaches. Capturing the cultural and non-use values is a challenge. Not capturing the cultural and non-use values can result in significant undervaluing of a resource.
11	Blankespoor B., Dasgupta S., and Laplante B. (2014), *Sea-Level Rise and Coastal Wetlands*, Royal Swedish Academy of Sciences	Monetary	2000	US$		Area of wetlands lost as % of total wetland area: • 72.5% of freshwater marsh, • 26.7% of swamp forest • 54% of GLWD coastal wetlands • 99.9% of brackish / saline wetlands Economic value of lost wetlands by type (million): • Freshwater marsh US$ 18.5 million, • Swamp forest US$ 0.1 million; • GLWD coastal wetlands US$ 10.3 million;	Calculated areas of wetlands lost by overlaying current wetlands with an inundation layer. Also took into account wetland migration potential. Determined value of wetlands using Brander et al. (2006).	Sea level rise	Sub-Saharan Africa	The assessment does not appear to deal with the replacement habitat.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						• Brackish / saline wetlands US$ 32.5 million Total: US$ 61.4 million				
12	Christensen O.B., Goodess C.M., and Ciscar J. (2011), Methodological Framework of the PESETA Project on the Impacts of Climate Change in Europe, *Climate Change*, Vol. 112, pp 7-28	Monetary	2011 (Undiscounted)	€			Based on IPCC SRES scenarios A2 and B2. The PERSETA project uses a combination of 'top-down' economic approach and 'bottom-up' sectoral approach. The 'bottom-up' approach estimated sectoral impacts using high-resolution data to drive physical impact models. A General Equilibrium Model (GEM) was then used to integrate results and assess impacts – see below Figure:  Used a comparative static framework to estimate damages if the climate of 2080s would occur today.		Europe	
13	Costanza R., Perez-Maqueo O., Martinez H.L., Sutton P., Anderson S.J. and Mulder K.,	Monetary	2004	US$	Annual	Calculated that 1h of coastal wetland lost	Used a regression model to calculate relationship between wetland area		USA	

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
	(2008), The Value of Coastal Wetlands for Hurricane Protection, *Journal of the Human Environment*, Vol. 37:4, pp. 241-248					increases storm damage by on average US$ 33,000. Taking into account the probability of storm events, and varying intensities, it was calculated that the value of storm protection offered by coastal wetlands ranges from US$ 250 – US$ 51,000 /ha/yr, with a median of US$ 8240 /ha/yr.	and damages caused by 34 major US hurricanes since 1980. Using this relationship, and taking into account the probability of a storm event and varying intensities, the annual value of wetlands in terms of storm damage protection was calculated.			
14	Dixon R., Smith J., and Guill S. (2003), Life on the Edge: Vulnerability and Adaptation of African Ecosystems to Global Climate Change, *Mitigation and Adaptation Strategies for Golbal Change*, Vol. 8, pp. 93-113	Monetary Normative statements	1998	US$	Stock	Estimated the value of coastal infrastructure (e.g. buildings, roads and bridges) due to 0.5 – 1m sea level rise to be US$70 – US$121 million respectively. Estimated cost of protecting vulnerable coastline sections in Dar es Salaam from sea level rise to be US$ 380 million. Marine and estuarine fisheries will likely be warmer and the change in thermal niches will alter species distribution and productivity. Estuarine fisheries are likely to be affected by sea level rise, which could inundate wetlands and allow salt water to move inland.	Undertaking Aerial Videotape-Assisted Vulnerability Analysis along the whole coastline of Tanzania and assessing the impacts due to sea level rises and storm surges. Valuation of all the vulnerable structures along the entire coastline.		Tanzania Mauritius	
15	Bruggeman *et al.* (2012), Wicked Social-Ecological Problems Forcing Unprecedented Change on the Latitudinal Margins of Coral Reefs: The Case of Southwest	Kg / day			Flow	In 1959, high fish catch yields were reported (>50kg/day and >1,000kg/day) for hand lines and seine nets respectively. By 1989, reported fish yields had	Surveys	Rising sea temperatures; Increase in frequency of severe cyclones; Rising air temperatures;	Madagascar	Rising air temperatures, diminishing rainfall and greater rainfall variability has increased migration from arid hinterland to coast, and switch from agriculture to fisheries.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
	Madagascar, *Ecology and Society*, Vol. 17:4, pp. 47					decreased to 4.8 – 10.6k/day per fisherman depending on equipment used. 20 years later, fish yields had decreased by as much as 50% to 5.5kg/day per fisherman, regardless of equipment used. As a result, majority of fisherman now use seine nets. Between 1972 and 1988, the number of fisherman in Toliara province increased by 57% due to in-migration from arid hinterland.		Diminishing rainfall;		Climate change impacts likely to be co-stressors contributing to demise of coral communities. Other stressors include increasing number of fisherman and changes in fishing practices.
16	Bunce M., Brown K., and Rosendo S. (2010), Policy Misfits, Climate Change and Cross-Scale Vulnerability in Coastal Africa: How Development Projects Undermine Resilience, *Environmental Science & Policy*, Vol. 13, pp. 485-497	Mental model			Flow	Tanzanian mental model of stressors and impacts:  Mozambican mental model of stressors and impacts: 	Interviews and focus groups.	Infrequent and erratic rainfall; Rising temperatures and heatwaves; Floods (severity and severity); Wind change; Declining fish catches.	Tanzania and Mozambique	

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
17	Cinner JE, Bodin O¨. (2010), Livelihood Diversification in Tropical Coastal Communities: A Network-Based Approach to Analyzing 'Livelihood Landscapes', *PLoS ONE*, Vol. 5:8	Livelihood profile				The mean number of household occupations per community ranged from 1.1 to 2.5. In peri-urban communities, the informal sector is the biggest and most connected node. Note however that while informal sector is central feature of economy, it is largely a supplementary activity (i.e. incoming links). While fishing is a very small node, it is well-connected and important for those that engage in the activity (i.e. outgoing links). 			Kenya	Livelihood portfolios are an important consideration in natural resource management and people's responses to disasters as it will influence whether or not they switch from one occupation to another.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
						In rural communities, agriculture and fisheries are the most connected nodes, with ingoing and outgoing links with most sectors (except food crops and tourism which only had outgoing links). 				
18	Kebede A.S. and Nicholls R.J. (2012), Exposure and Vulnerability to Climate Extremes: Population and Asset Exposure to Coastal Flooding in Dar es Salaam, Tanzania, *Reg Environ Change*, Vol. 12:2, pp. 81-94	Monetary	2005 (Not discounted)	US$		Between 2005 and 2070, the number of people affected by a 1:100 year flood event with sea level rise could increase from 30,000 to 210,000. Similarly, the damage to assets as result of such an even could increase from US$35 million to US$ 10 billion.	Analysis uses exposure (number of people and value of assets with no defence or adaptation) rather than risk (estimates of the expected annual damage with the benefits of defences and adaptation) i.e. worst case scenario. 1:100 year flood event and sea level rise values based on IPCC SRES scenarios (2000). Estimated value of assets using technique used by insurance industry where value of exposed assets is a	Sea level rise; Extreme storm event;	Tanzania	With sea level rise, the number of people and value of assets effected by a 1:100 year storm event increases significantly.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
							function of the exposed population and national per capita GDP purchasing power parity.			
19	Lange G. and Jiddawi N. (2009), Economic Value of Marine Ecosystem services in Zanzibar: Implications for Marine Conservation and Sustainable Development, *Ocean and Coastal Management* Vol. 52, pp. 521-532	Monetary	2007	US$	Flow	1. Tourism – Generates US$ 119 million or 25% of GDP. 47% of tourism earnings go to Zanzibari's, with 20% to local communities, 15% to government (taxes etc., and 12% to Zanzibari's outside local communities. 2. Fishing – in 2007, there were 26,233 mainly small-scale, artisanal fishers. While fishing only contributes 6% to GDP, it is an important part of coastal livelihoods. It is estimated that US$ 26 million goes to fishers and US$ 3 million to those involved in marketing and processing. 3. Seaweed farming – In 2007, there were 16,206 growers which on average earn US$ 200 per annum. Important industry as contributes 13% to foreign exchange earnings. 4. Mangrove harvesting – Minor activity due to strict regulations to protect remaining forests. Contribution to GDP US$ 28,000.	Used national accounting approach to quantify the contribution of marine ecosystem services to the macro-economy of Zanzibar (GDP, employment, foreign exchange earnings). Also estimated the distribution of income among different stakeholders (compensation of employees and gross operating surplus/mixed income). Focused on provisioning services (fishing, seaweed farming, and mangrove harvesting) and cultural services (tourism). Used existing databases and surveys to collect data inputs.		Tanzania - Zanzibar	The economic value of tourism is 5 times greater than the other services assessed. However, local communities generally benefit very little from tourism due to the type of tourism i.e. 'Club'. Furthermore, with the establishment of MPAs to the benefit of the tourism industry, local communities are further marginalised through loss of fishing grounds.

No.	Reference	Unit	Pricing year	Currency	Stock / Flow	Net / Gross Value	Valuation method	Impact causal agent	Location	Comments
20	Remoundou K., Koundouri P., Kontogianni A., Nunes P.A.L.D. and Skourtos M. (2009), Valuation of Natural Marine Ecosystems: An Economic Perspective, *Environmental Science and Policy*, Vol. 12, pp. 1040-1051	Monetary	2008	€	Flow	1. WTP for change from present fishing practices ranges from €1,005 to €2,456. 2. Total improvements in welfare of €3,415,820 or €1,379 /yr for residents and €745 /yr for non-residents. 3. WTP to improve infrastructure on island S. Erasmo ranges from €36 (non-users) to €56 (users). 4. WTP to improve WWTW that discharges into Thermaikos Bay was €15.23 per 4-monthly water bill, for 5 years. 5. WTP for improvements in marine water quality to acceptable levels was €7.69. 6. WTP for conservation of Mediterranean monk seal was €11.7. 7. Economic value of dolphin fish fishery in Sicily, with profit rates of between 30% and 46%. 8. ROI minus the risk free rate was 8.54% for demersal fisheries of the Adriatic Sea.	1. Conjoint analysis – fisherman's WTP for alternative clam fish management practices in Venice Lagoon. 2. Contingent valuation – Welfare improvements resulting from reduction in discharge of industrial pollutants into Venice Lagoon. 3. Contingent valuation – dichotomous choice. 4. Contingent valuation – open ended. 5. Contingent valuation – payment card. WTP to avoid episode of gastroenteritis. 6. Contingent valuation – open ended. 7. Market based valuation – producer surplus. 8. Market based valuation – producer surplus. 9. Contingent valuation – binary choice. 10. Bio-economic model.		Mediterranean and Black Sea	Limited studies that have been undertaken to value marine ecosystems. These studies are also lengthy and costly to undertake. Benefit transfer can be used to value marine ecosystems where no information is available.

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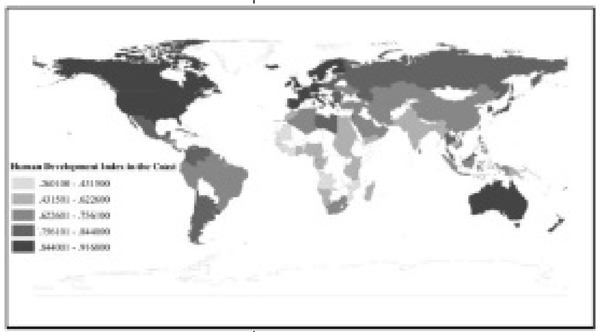
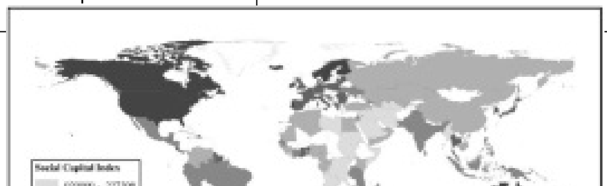
						9. WTP to combat sea pollution in Istanbul was €28.64 and for ozone protection was €25.86. 10. Decrease in economic profits from €12.29 million to €0.217 million per year due to invasive species in Black Sea. 11. Increase in revenues of €2.57 million annually with increased harvest resulting from decreased nutrient enrichment in Black Sea.	11. Bio-economic model.			
21	Pérez-Maqueoa O., Intralawana A., and Martíneza M.L. (2007), Coastal Disasters from the Perspective of Ecological Economics, *Ecological Economics*, Vol. 63, pp. 273-284					Human & built capital index:  Social capital index: 	Multiple regression analysis.	Hurricanes	Global	While natural capital plays an important role in reducing damage caused by hurricanes, the number of deaths in dependent on level of degradation and GDP. Thus in order to reduce damages and loss of life, relatively well-preserved natural capital and adequate built infrastructure is required.

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						Natural capital index:				
22	Rakatobe, T., Holmes, C. and Ralison, F. (2012) Climate change in the Western Indian Ocean: A situation assessment and policy considerations.		2012			A country level discussion on vulnerability of the coastal communities to climate change impacts. The table below outlines the key economic data collated. Can add value to this with the inclusion of future population estimates and some benefit index combining demand with supply, or vulnerability.	Macro-economic and social statistics used to compile quantitative data on vulnerability. Qualitative indications and discussions on the vulnerability of marine resource users.	sea level rise, salt water intrusion, coral bleaching, changes in precipitation, cyclone impacts, coastal storm surge, elevated run-off and sedimentation, mangrove growth and coral reefs already stressed by human impacts,	All states	Key points made: A gap identified was that only the Seychelles government perceived natural capital to be a resource for promoting climate change resilience. Other states are not doing so. Degraded natural capital, specifically coral reefs, did not regenerate well after climate change events. Marine and coastal assets generally in poor condition, which raises the issues of climate change additionality.

Country	Population in millions	% dependent on coast	Population growth	GDP pc	Human development index
Comoros	0.8	41%	2.5%	1183	0.433
Kenya	41.6	9%	2.7%	1573	0.509
Madagascar	21.3		2.8%	1004	0.48

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								bleaching a serious additional stress		Observations: no statement of impacts on wellbeing, or the magnitude of the impact in terms of population numbers. No clear statement of the role of marine ecosystems in reducing climate change impacts.
23	Bunce, M., Rosendo, S. and Brown, K. Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. Environ Dev Sustain (2010) 12:407–440		2010			Perceived declines in fisheries, agriculture, water and health due to climate change. Note the 'double impact' of climate change, with biophysical and chemical changes to the marine environment generating a decline in coastal ecosystem a services, and a declining terrestrial agricultural productivity generating a migration to the coast with elevated demands on a declining services supply. Report on a general trend in Africa of stressed communities moving out of farming incomes and into marine resource use. Water resources threatened by salt water ingress. Raise the concern that identifying the additionality of climate change to currently stressed social-ecological systems is problematic.	Participatory research, using surveys of peoples' perceptions and mental modelling of climate change and impacts on livelihoods.	Sea level rise	Mozambique and Tanzania	
24	Liquete C, Piroddi C, Drakou EG, Gurney L, Katsanevakis S, et al. (2013) Current Status						A systematic review of published literature of marine and coastal ecosystem services.		Global	A useful summary of research into the field of

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	and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. PLoS ONE 8(7): e67737. doi:10.1371/journal.pone.0067737									marine and coastal ecosystem services. Key gaps in information required to systematically map marine and coastal ecosystem services include: insufficient habitat mapping, the ambiguity of maritime boundaries, the complexity of three dimensional environments in a single spatial unit (e.g. pelagic and benthic), and the complexity of marine connectivity. In terms of ecosystem services indictors or metrics, whilst there are numerous metrics for provisioning services, there are limited metrics for other services. Little research into ocean ecosystem services with much research on mangroves and coastal wetlands. Observation: very uneven understanding of ecosystem services generated by marine and coastal habitats, and therefor value transfer approaches problematic.
25	Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S. and Roberts, D. 2013. Economics of climate change adaptation	Monetary and benefit index	2012	USD		In summary, the benefit cost analysis showed that interventions based on institutional and human capacity developed were	A benefit cost analysis of clusters of climate change adaptation options. A novel approach was used to compare the costs of actions with their relative human benefits or welfare. A human		South Africa	Observation: This method of comparing monetary costs with a benefit index will be useful to prioritise

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	at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization					the most effective, followed by ecosystem-based adaptation, with infrastructural-based adaptation showing the lowest benefit-cost ratio.	benefit index was used instead of a monetary unit, given the skewed wealth distribution in RSA society, poor data available, uncertainties of future events, or the attribution of benefits to interventions is not clear. The number of people benefiting and the magnitude of the benefit on their lives were used to develop a composite benefit index. The approach also included the use of a suite of scenarios to account for a range of possible climate change and sustainable governance futures.			interventions given the great disparity between metrics associated with coastal livelihoods and monetary or GDP based metrics.
26	Sauter R., ten Brink P., Withana S., Mazza L., and Pondichie F. (2013), *Impacts of Climate Change on all European Islands*, A report by the Institute for European Environmental Policy (IEEP) for the Greens/EFA of the European Parliament, Final Report, Brussels http://www.ieep.eu/assets/1292/Final_report_EP_CC_impacts_on_islands_FINAL_clean.pdf					1. Alien invasions – predicted that climate change will favour expansion of opportunistic invasive species. This is significant given that alien invasive species are already the greatest threat to biodiversity. No economic impact assessments have however been done. 2. Rising sea temperatures are already impacting on fishing resources and coral reefs. It is estimated that the recovery rate of coral reefs in Reunion has decreased from 47% to 27%. It is that estimated that the coral bleaching event in 1998 resulted in economic damages of between US$608 million and US$8,026 million for the entire Indian Ocean region. According to the IPCC, by 2050 similar events could be experienced very other		Rising temperatures; Climate variability; Increased rainfall; Sea-level rise;	Reunion	No studies have been done to assess economic impacts of climate change with regards to spread of alien invasive species and agriculture.

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						year. Furthermore, the trade of reef fish food and ornamental fish is important sector of the Seychelles economy which is valued at US$1,110 million annually. 3. Landslides and erosion risks are generally high in the steeper inland areas. It is estimated that on average 20 tons of soil matter per hectare is washed away annually due to heavy rains. In the coastal areas, there has been a notable decline in yields in the last 50 years due to increased number of droughts. 4. It is estimated that the increasing air temperatures in coastal zone could disrupt predator-prey insect interactions and dynamics of insect populations, reducing effectiveness of biological control of pests. 5. Saltwater intrusion has already been observed on the Western Coast. With rising sea levels, it is projected that contamination of soil, groundwater and drinking water sources could be accelerated.				

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						6. The majority of Seychelles population (82%) and infrastructure is located in the coastal zone, and therefore at risk to rising sea-levels and extreme weather events. For example, Hyacinthe Cyclone in 1980 resulted in loss of 25 lives, 7,500 people being displaced, and €85 million in damages. Similarly, Dina Cyclone in 2002 destroyed 500 buildings with €95 million in damages.				