NATIONAL CLIMATE CHANGE ACTION PLAN

REPUBLIC OF KENYA

Adaptation

Technical Report 3

Synthesis of Costing Information

AUGUST 2012

LTS INTERNATIONAL

ACCLIMATISE
building climate resilience

Disclaimer

The views expressed in this publication are not necessarily those of the agencies cooperating in the National Climate Change Action Plan process. The designations employed and the presentations do not imply the expression of any opinion whatsoever on the part of the Government of Kenya or cooperating agencies.

Mention of a commercial company or product in this publication does not imply endorsement by the Government of Kenya. The use of information from this publication concerning proprietary products for publicity or advertising is not permitted.

CDKN Climate & Development Knowledge Network

This document is an output from a project funded by the UK Department for International Development (DFID) and the Netherlands Directorate-General for International Cooperation (DGIS) for the benefit of developing countries. However, the views expressed and information contained in it are not necessarily those of or endorsed by DFID, DGIS or the entities managing the delivery of the Climate and Development Knowledge Network*, which can accept no responsibility or liability for such views, completeness or accuracy of the information or for any reliance placed on them.

* The Climate and Development Knowledge Network ("CDKN") is a project funded by the UK Department for International Development (DFID) and the Netherlands Directorate-General for International Cooperation (DGIS) and is led and administered by PricewaterhouseCoopers LLP. Management of the delivery of CDKN is undertaken by PricewaterhouseCoopers LLP, and an alliance of organisations including Fundación Futuro Latinoamericano, INTRAC, LEAD International, the Overseas Development Institute, and SouthSouthNorth.

Report prepared by:

LTS International
Pentlands Science Park, Bush Loan, Penicuik, EH26 0PL, UK
Tel: +44.131.440.5500
Fax: +44.131.440.5501
Skype: LTSInternational
Website: www.ltsi.co.uk

Acclimatise
Hexgreave Hall, Farnsfield, Newark, Nottinghamshire
NG22 8LS, UK
Tel: +44 (0) 1623 884347
Website: www.acclimatise.uk.com

Contents

Abbreviations

ASALs	Arid and semi-arid lands
CBA	Cost-Benefit Analysis
CCRA	Climate Change Risk
CER	Cost-Effectiveness Ratio
DALY	disability- Adjusted Life Years
DEFRA	UK Department for Environment, Food and Rural Affairs
DIVA	Dynamic Interactive Vulnerability Assessment
EbA	Ecosystem- based Adaptation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographical Information Systems
GOK	Government of Kenya
ICT	Information Communication Technology
I&FFs	Investments & Financial Flows
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRS	Indoor Residual Insecticide
KMD	Kenya Meteorological Department
KSH	Kenyan shillings
MTP	Medium Term Plan
NAdP	National Adaptation Plan
NAPA	National Adaptation Plan of Action
ATAR	Adaptation Technical Analysis Report
NCCRS	National Climate Change Response Strategy
OECD	Organisation for Economic Cooperation and Development
R&D	Research & Development
SEI	Stockholm Environment Institute
SLR	Sea Level Rise
T21	Threshold 21
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
UK	United Kingdom
UKCIP	UK Climate Impacts Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Glossary of terms and acronyms

Adaptation. Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC AR4 WGII, 2007).

Adaptive capacity (in relation to climate change impacts). The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (IPCC AR4 WGII, 2007)

Baseline/reference. The baseline (or reference) is the state against which change is measured. It might be a 'current baseline', in which case it represents observable, present-day conditions. It might also be a 'future baseline', which is a projected future set of conditions excluding the driving factor of interest. (IPCC AR4 WGII, 2007)

Benefits of adaptation. Adaptation benefits refer to "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures". (IPCC AR4 WGII, 2007)

Capacity building. In the context of climate change, capacity building is developing the technical skills and institutional capabilities in developing countries and economies in transition to enable their participation in all aspects of adaptation to, mitigation of, and research on climate change, and in the implementation of the Kyoto Mechanisms, etc. (IPCC AR4 WGII, 2007)

Cost- benefit analysis. Analysis which quantifies in monetary terms as many of the costs and benefits of a project as possible, CBA is designed to show whether the total advantages (benefits) of a project or policy intervention exceed the disadvantages (costs). This essentially involves listing all parties affected by the policy intervention and then valuing the effect of the intervention on their well- being as it would be valued in monetary terms by them. It may include items for which the market does not provide a satisfactory measure of economic value. (Metroeconomica, 2004)

Cost- effectiveness analysis. A tool with which to minimise the cost of achieving a specified environmental or economic objective. For example, in the acid deposition field the objective might be to meet a target loading of sulphur at minimum cost over a large region, taking into account that control costs vary from industry to industry, and that the cost of control increases with increasing severity of control. Cost effectiveness analysis ignores benefit side of cost benefit analysis but concentrates on the cost side. (Metroeconomica, 2004)

Climate change. Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC AR4 WGI, 2007)

Climate threshold. The point at which external forcing of the climate system, such as the increasing atmospheric concentration of greenhouse gases, triggers a significant climatic or environmental event which is considered unalterable, or recoverable only on very long time-scales, such as widespread bleaching of corals or a collapse of oceanic circulation systems. (IPCC AR4 WGII, 2007)

Climate variability. Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). (IPCC AR4 WGI, 2007)

Costs of adaptation. Adaptation costs are "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs. (IPCC AR4 WGII, 2007)

DALY. Disability Adjusted Life Years refers to the sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.

Downscaling. Downscaling is a method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses. Two main methods are distinguished: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution or high-resolution global models. The empirical/statistical methods develop statistical relationships that link the large-scale atmospheric variables with local/regional climate variables. In all cases, the quality of the downscaled product depends on the quality of the driving model. (IPCC AR4 WGI, 2007)

Ecosystem services. Ecological processes or functions having monetary or non-monetary value to individuals or society at large. There are (i) supporting services such as productivity or biodiversity maintenance, (ii) provisioning services such as food, fibre, or fish, (iii) regulating services such as climate regulation or carbon sequestration, and (iv) cultural services such as tourism or spiritual and aesthetic appreciation. (IPCC AR4 WGII, 2007)

Emission scenario. A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships. (IPCC AR4 WGI, 2007)

Extreme weather event. An extreme weather event is an event that is rare at a particular place and time of year. Definitions of *rare* vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. (IPCC AR4 WGI, 2007)

Greenhouse gas (GHG). Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. (IPCC AR4 WGI, 2007)

Hard and soft adaptation. "Hard" adaptation measures usually imply the use of specific technologies and actions involving capital goods, such as dikes, seawalls and reinforced buildings, whereas "soft" adaptation measures focus on information, capacity building, policy and strategy development, and institutional arrangements (World Bank website, Adaptation Guidance Notes - Key Words and Definitions)[1]

Impacts. The effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts:

- **Potential impacts:** all impacts that may occur given a projected change in climate, without considering adaptation.

- **Residual impacts:** the impacts of climate change that would occur after adaptation. (IPCC AR4 WGII, 2007)

Likelihood. Likelihood refers to a probabilistic assessment of some well-defined outcome having occurred or occurring in the future, and may be based on quantitative analysis or elicitation of expert views, (IPCC AR4 WGII, 2007).

Maladaptation. Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead. Spending a disproportionate amount of effort and investment focussed upon adaptation beyond what is required. (Adaptation Sub-Committee, 2010).

Mitigation. A human intervention to reduce the sources or enhance the sinks of greenhouse gases. (IPCC AR4 WGI, 2007)

Resilience. The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change. (IPCC AR4 WGII, 2007)

Sensitivity. Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise). (IPCC AR4 WGII, 2007)

SRES scenarios. The storylines and associated population, GDP and emissions scenarios associated with the Special Report on Emissions Scenarios (SRES) (Nakićenović *et al.*, 2000), and the resulting climate change and sea-level rise scenarios. Four families of socio-economic scenario (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns, and global versus regional development patterns. (IPCC AR4 WGII, 2007). The following terms are

[1] See http://climatechange.worldbank.org/climatechange/content/adaptation-guidance-notes-key-words-and-definitions

relevant for a better understanding of the structure and use of the set of SRES scenarios (IPCC AR4 WGI, 2007):

- **Scenario family Scenarios** that have a similar demographic, societal, economic and technical change storyline. Four scenario families comprise the SRES scenario set: A1, A2, B1 and B2.

- **Illustrative Scenario.** A scenario that is illustrative for each of the six scenario groups reflected in the Summary for Policymakers of Nakićenović and Swart (2000). They include four revised scenario markers for the scenario groups A1B, A2, B1, B2, and two additional scenarios for the A1FI and A1T groups. All scenario groups are equally sound.

- **Marker Scenario.** A scenario that was originally posted in draft form on the SRES website to represent a given scenario family. The choice of markers was based on which of the initial quantifications best reflected the storyline, and the features of specific models. Markers are no more likely than other scenarios, but are considered by the SRES writing team as illustrative of a particular storyline. They are included in revised form in Nakićenović and Swart (2000). These scenarios received the closest scrutiny of the entire writing team and via the SRES open process. Scenarios were also selected to illustrate the other two scenario groups.

- **Storyline.** A narrative description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution.

Storm surge. The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. (IPCC AR4 WGI, 2007)

T21. Threshold 21 – a dynamic, quantitative planning tool which has been uniquely customised for long-term integrated development planning in Kenya, incorporating scenario analyses of adaptation options under uncertainty. It is housed in the Ministry of Planning. (The Millennium Institute Website: http://www.millennium-institute.org/integrated_planning/tools/T21/)

Threshold. The level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels. (IPCC AR4 WGII, 2007)

Total Economic Value. a framework for considering various constituents of value, including direct use value, indirect use value, option value, quasi-option value, and existence value. Direct-use value (of ecosystems) refers to the benefits derived from the services provided by an ecosystem that are used directly by an economic agent. These include consumptive uses (e.g. harvesting goods) and non consumptive uses (e.g. enjoyment of scenic beauty), whereas indirect-use value (of ecosystems) corresponds the benefits derived from the goods and services provided by an ecosystem that are used indirectly by an economic agent. For example, the purification of drinking water filtered by soils. Existence value: the value that individuals place on knowing that a resource exists, even if they never use that resource (also sometimes known as conservation value or passive use value). (TEEB, 2010)

Uncertainty. An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts. (IPCC AR4 WGI, 2007)

Vulnerability. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC AR4 WGII, 2007)

REFERENCES: Adaptation Sub-Committee (2010). How well prepared is the UK for climate change? Committee on Climate Change, London.

IPCC AR4 WGI (2007). Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Glossary available online: http://www.ipcc.ch/pdf/glossary/ar4-WGI.pdf

IPCC AR4 WGII (2007). Climate Change 2007 - Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Glossary available online: http://www.ipcc.ch/pdf/glossary/ar4-wg2.pdf

ISO/IEC (2002). Guide 73: Risk management – Vocabulary – Guidelines for use in standards, pp16.

Nakićenović, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Gaffin, K. Gregory, A. Grübler, T.Y. Jung, T. Kram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Raihi, A. Roehrl, H.-H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R. Swart, S. van Rooijen, N. Victor and Z. Dadi, (2000). Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, and New York, 599 pp.

1. Introduction

1.1. Context and objectives

The Kenyan economy is already vulnerable to current climate variability. Past droughts and floods clearly illustrate the important economic burden of existing climate-related events on key economic and non-economic sectors. For example, the 1998-2000 droughts were estimated to have economic costs of USD 2.8 billion from the loss of crops and livestock, forest fires, damage to fisheries, reduced hydro-power generation, reduced industrial production and reduced water supply.[i] Overall, its cost was around 16 percent of Kenya's GDP in the period 1998–2000 (see Table 1). The 1997/98 El Nino floods are considered as one of the largest flood losses in the country over the last 50 years. Total economic costs were estimated between USD 0.8 to 1.2 billion arising from damage to infrastructure (roads buildings and communications), public health effects (including fatalities) and loss of crops. According to the SEI study, extreme floods and droughts, such as the ones presented above, have the potential to reduce the country's GDP by about 2.4% per annum.[ii] This is a significant impact when past and expected future economic performance is factored in. Kenya's annual growth rate has been approximating 3.5% over recent years (World Bank, World Outlook data) with IMF projected annual GDP growth rates ranging from 5.3% to 6.6% for 2011-2016.

Table 1. Costs arising from 1998-2000 La Nina- drought (rounded to 2 significant figures).[i]

			Estimated Cost ('000,000)	
Attribute	**Effects**	**Associated Costs**	**Ksh**	**$**
Drought	Loss of crops	(a) Crop loss[a]	19,000	241
	Loss of livestock[b]	(a) Livestock deaths[c]	5,800	73
		(b) Veterinary costs	93	1
		(c) Reduced livestock production[d]	5,100	64
		(d) Conflict management[e]	6	
	Forest fires	(a) Forest destruction and damage[f]	29	
	Damage to fisheries	(a) Reduced aquaculture production[g]	19	
	Reduced hydro-power generation[h]	(a) Increased cost of generation[i]	51,000	632
		(b) Increased import substitutes[j]	806	10
	Reduced industrial production[k]	(a) Loss of production[l]	110,000	1,400
	Water supply			
		(a) Increased water collection time—ASALs[m]	5,100	64
		(b) Increased water collection time—Nairobi[n]	4,400	55
		(c) Time loss due conflict management meetings[o]	3	
		(d) Cost of vendor water in Nairobi[p]	22,000	270.
Total			220,000	2,800

The current socio-economic trends (i.e. GDP and population growth) could, even without climate change, increase the economic costs of large scale flood or drought events by as much as a factor of 5 by 2030.[ii] This implies direct economic costs of USD 5 to 10 billion per each large-scale event. A key priority therefore is to increase the resilience of Kenya to cope with these extreme events. Climate change is likely to exacerbate these estimates through increased frequency and severity. Future costs of climate change were estimated to reach around 2.6% of GDP each year by 2030.[ii]

In light of these findings, this report explores the costs and benefits of adaptation to provide guidance on what it takes to adapt to a changing climate, with implications for the source and level of finance required. It also demonstrates what the most cost effective adaptation actions are at the sectoral level. This is particularly relevant to a resource-constrained country such as Kenya. Collecting sector-specific evidence of the potential economic costs of climate change impacts and benefits of investing in adaptation is a key step in mainstreaming adaptation to a changing climate into national and sectoral planning and decision-making and as such, plays a central role in informing the Kenyan National Adaptation Plan (NAdP). This is also particularly important to provide decision makers with the economic implications arising from a changing climate and to inform them of the consequences for the delivery of development objectives. By so doing climate change adaptation can be more readily integrated into decision-making processes.

1.2. Methodology

Adaptation costs and benefits for specific measures have first been identified from a comprehensive literature review.

In our review of the existing evidence, we use the following IPCC definitions[iii]:

- Costs of adaptation: "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs"; and
- Benefits of adaptation: "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures".

The ultimate objective is to inform the NAdP, by providing a set of cost-effective adaptation actions across the MTP themes, enabling the prioritisation of adaptation actions in Kenya.

We understand cost-effectiveness as the identification of "the least-cost method of reaching a prescribed target or risk reduction level".

The cost estimates identified in this synthesis were then referenced against the 20 MTP themes (as agreed with the Task Force and Thematic Working Group):

1. Economic pillar / Agriculture, Livestock and Fishing;
2. Economic pillar / Business Process Outsourcing*;
3. Economic pillar / Financial Services*;
4. Economic pillar / Manufacturing*;
5. Economic pillar / Tourism*;
6. Economic pillar / Wholesale, Retail and International Trade*;
7. Social pillar / Environment, Water and Sanitation;
8. Social pillar / Health;
9. Social pillar / Population, Urbanisation and Housing*;
10. Social pillar / Gender, Vulnerable Groups and Youth*;
11. Social pillar / Education and Training*;
12. Political pillar / Decentralisation*;
13. Political pillar / Governance and the Rule of Law*;
14. Foundations for national transformation / ICT*;
15. Foundations for national transformation / Infrastructure;
16. Foundations for national transformation / Human Resource Development, Labour and Employment*;
17. Foundations for national transformation / Land Reforms*;

18. Foundations for national transformation / Public Sector Reforms*;
19. Foundations for national transformation / Science, Technology and Innovation*; and
20. Foundations for national transformation / Security, Peace Building and Conflict Resolution*.

This approach has the added advantage of linking more easily into those Government Ministries and other key stakeholders who have a direct responsibility for ownership of specific adaptation actions. However, limited evidence of cost estimates have been specifically identified for 16 out of 20 MTP themes (themes marked as * above). As such, some themes were combined for better clarity, e.g. Manufacturing; Wholesale, Retail and International Trade; Business Process Outsourcing (section 2.1.3 on Private Sector).

A systematic review of relevant economic literature[iv] (including World Bank, 2010; Parry et al. 2009) was also undertaken to assess both the coverage and robustness of existing economic evidence. This aims to identify potential overarching adaptation actions that address knowledge gaps and limitations with regards to the state of knowledge about adaptation costs and benefits.

Several global reviews of adaptation costs have been undertaken, such as, the OECD study on the 'Empirical estimates of adaptation costs and benefits'[v] and the study[iv] on 'Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates'. At the regional level, the AdaptCost project[vi] has produced a range of estimates for adaptation costs in Africa. The study was primarily based on review, but also commissioned specific model runs (with integrated assessment models) as well as some new sector modelling assessments, notably for coastal zones. Another similar study is AfDB (2011) 'the Cost of Adaptation to Climate Change in Africa' prepared by Vivid Economics.[vii] Our report reviews these lines of evidence, as well as incorporating other studies (including regional and global) providing estimates of relevance to the Kenyan context (see Table 2). Unfortunately, knowledge of the benefits of climate change adaptation is sparse, as many of the studies have focused on the costs of adaptation rather than comparing costs and benefits, particularly at the sectoral level. As a consequence, when the benefits of options are not reported or quantified in monetary terms, an overview of their cost-effectiveness can be found based on published evidence.

Furthermore, reviewed studies use a wide range of costing methods and varying perspectives. It is important to understand the purpose for which the cost is being evaluated and recognise the fact that many benefits and costs are not subject to market transactions and therefore do not have readily observed values. Many of the estimates provided originate from CBA which are generally conducted from the perspective of a single economic agent (e.g. a farmer). Estimates are expressed in USD unless specified otherwise (e.g. KSH, KSH billion). Please note that these are reported estimates from existing literature and thus are unadjusted for inflation. Identified knowledge gaps and methodological challenges from the literature review are presented in Section 3.

Table 2. Overview of reviewed economic studies.

Study	Type of study	Report focus	Sectors
Kabubo (2007,[viii] 2009)[ix]	Ricardian approach at the farm- level	Effects on net revenue and stocks from livestock- production. Assessment of the marginal impacts from climate change	Agriculture- livestock production

Kabubo (2008)[x]	Econometric model (probit and multivariate) at the farm-level	Assessment of the changes in choices of livestock species and substitution effects as a result of a changing climate. Simulate the expected effects of climate scenarios on future livestock choice decisions (marginal effects).	Agriculture- livestock production
Mati (2008)[xi]	Field and stakeholder-based assessment of adaptation costs	Case-study on initial investment costs needed for 8 smallholder irrigation schemes in Kenya	Agriculture (irrigated)
NAPAs	Lists of projects and total costs	Identification and costing of priority activities by LDCs for adaptation that focus on urgent and immediate needs	All sectors plus cross-sectoral coverage.
Ngigi (2005)[xii]	CBA of rainwater harvesting at district level (Laikipia)	Expected seasonal net benefits of rainwater harvesting versus conventional irrigation system at the farm-level	Agriculture (irrigated)
SEI (2009) [xiii] **including Otiende (2009),**[xiv] **Kebebe et al. (2009),**[xv] **Droogers et al. (2009) and agro-forestry case study**[xvi]	Country-level across most vulnerable sectors. Top-down and bottom-up including IAMs (FUND), I&FF and sector impact assessments (modelling & case studies)	Economic costs of climate change, costs and benefits of adaptation and low carbon growth in Kenya. Use of adaptation signatures for costing based on sectoral modelling/ case studies and NAPA estimates	Coastal zones (sea-level rise), malaria incidence, energy demand, infrastructure, water resources, agriculture and loss of ecosystem services.
World Bank (2010) including 8 sectoral reports [xix; xxviii; xxxii; xxxiv; xxxix; xvii; xxvii] **and 3 country reports**	Global assessment with continental disaggregation (I&FF and sector modelling, e.g. DIVA/ IFPRI), including a number of country-level studies, aimed at improving upon the UNFCC (2007)	Focus on the costs of adaptation (USD/ year for up to 2050). No consideration of benefits and limited residual damage estimates, as adaptation returns welfare to pre-climate levels. High transferability for functions and adaptation cost relationships	Agriculture, coastal, fisheries, health, infrastructure, water, extreme events, ecosystems and forests

1.3. Structure

After a brief overview of the aggregated economic estimates from the economic literature, emphasis will be placed on the evidence about the costs and benefits of adaptation measures for each of the MTP themes. Conclusions about the costs and benefits or cost- effectiveness of specific adaptation actions will be summarised in each of the following sections. Finally, an overview of main knowledge gaps and methodological challenges in the literature is presented in Section 3.

2. The costs of adaptation

2.1. Overview of top-down aggregated estimates

Investing in adaptation is required to reduce the largely expected economic burden of climate change on the country as explored in Section 1. According to Threshold 21, adapting is associated with a potential payback period ranging between 3- 10 years.[xviii] The National Climate Change Response Strategy (NCCRS) estimated the total costs of adaptation around USD 38 billion or Ksh 1,300 billion. Between 2011 and 2030, this implies investments of USD 2.7 billion per year and close to 2% of GDP invested on average until 2020 (T21, *in progress*).

Similarly, the SEI study provides a conservative estimate of immediate needs for addressing current climate as well as preparing for future climate change of USD 500 million per year for 2012. By 2030, this figure is likely to increase to USD 1- 2 billion per year (see Table 2). The study's estimates are differentiated in the two following categories:

- Development- related activities include accelerating development to cope with existing impacts (e.g. integrated water management, electricity sector diversity, natural resources and environmental management), as well as increasing social protection (e.g. cash transfers to the most vulnerable following disasters, safety nets for the most vulnerable).
- Climate change- specific activities involve building adaptive capacity and institutional strengthening (e.g. developing meteorological forecasting capability, information provision and education) and enhancing climate resilience (e.g. infrastructure design, flood protection measures).

Because they often provide partial coverage of sectors and ignore cross- sectoral impacts, these estimates are probably underestimating the true costs of climate change. However even with the underestimation comparing the SEI estimate of 2.6 % of GDP per year by 2030 (costs of inaction) and the total costs of adaptation based on the NCCRS (i.e. 2% of GDP per year by 2020), provides an irrefutable strong economic rationale for adaptation to a changing climate.

Table 3.Top-down aggregated estimates.[ii]

Adaptation strategies	**Adaptation needs (USD million/year)**	
	2012	2030
Development- related	USD 500 million/year	USD 500- 1,000 million/year
1) Accelerating development		
2) Increasing social		

protection		
Climate change specific	USD 100- 150 million/year	USD 250- 1,000 million/year
1) Building adaptive capacity		
2) Enhance resilience		

2.2. Sectoral (bottom-up) estimates

This section provides cost estimates for adaptation across the MTP themes, using a bottom-up approach (i.e. case studies and sectoral models). This enables greater insight into sectoral planning and the associated costs and benefits or cost-effectiveness of adaptation measures. Kenya specific estimates are provided whenever information is available. However, it should be noted that the evidence base on the economic efficiency of adaptation remains limited and fragmented in Kenya. It has been necessary to supplement and enhance the cost estimates using regional and global studies. It should be also noted that aggregation and comparability across the literature should be undertaken with caution as costing approaches are not necessarily standardized and assessments are often incomplete.

2.2.1. Economic pillar / Agriculture, Livestock and Fishing

2.2.1.1. Agriculture and Livestock

The SEI assessment estimated required Investment and Financial Flows (I&FFs) for adaptation in the sector from USD 60 million per year by 2012, nearing USD 380 million per year by 2030 (inclusive of development-related activities). Half of the latter estimates are thought to be climate change specific.[ii] This aggregated estimate is seen as a proxy for the costs of adaptation for Agriculture and Livestock. Further information on the SEI estimate is presented in Information Box 1.

Information box 1: I&FFs required for adaptation in Kenyan Agriculture and Livestock.[ii]

The annual costs of adaptation in Agriculture and Livestock are estimated by the SEI study to range from USD 60 million in 2012 to 380 million by 2030. These aggregated estimates are underpinned by project- level cost estimates from NAPAs and a new case-study on agro forestry commissioned by SEI (see Information box 2). They provide an overview of the order of magnitude of what it takes for Kenya to adapt in this sector. This includes the following adaptation strategies:

- Community based agricultural improvement to reduce impacts of climatic variability,
- Catchment rehabilitation, land use and environmental services;
- Climate early warning and information systems; rangeland management and livestock services;
- Agricultural research, extension and farm demonstration;
- Livelihood support, micro-finance and disaster risk reduction, national market development, land tenure and sectoral policy;
- Food supply chain management integrating pest control, transport losses and consumer utilization.

The SEI study also commissioned a case study on an investment project in Agroforestry in Kisumu on the shores of Lake Victoria.[xvi] Annual costs were estimated in the order of USD 9,595 per house-hold. The study also assessed the total budget needed to upscale the project nationwide up to USD 260 million by 2019.[xvi] This figure increases up to USD 59-73 million if semi-arid areas are included.[xvi] In this respect, carbon finance was found to be a key source of funding to cover those costs (see Information box 2 for further details or the report on private sector engagement).[xvi]

Information box 2: A case- study on agroforestry investment projects, an illustration of the costs of agricultural extension services.[xvi]

The SCC Vi Agroforestry case study from SEI (2009) provides cost estimates of a single adaptation action, agro-forestry extension service in Kisumu, Western Kenya. This provides an order of magnitude of investments required in extension services to promote agroforestry practices among farmer households in the rural areas. Annual costs were estimated in the order of USD 9,595 per household. This includes staff costs, capacity building, administration and management which part of it is to subsidize service delivery costs to the households (see Table 4 below).

Table 4. Cost of agricultural extension services.[xvi]

	Item	Annual costs (USD)
1	Implementation costs	17 USD/household per year
2	Capital costs (staff, admin. Management, motorbike)	9,595
3	Training & community empowerment services	3*capital costs
4	Monitoring & evaluation	2-3% of the budget

In addition to sustainable development benefits, this study provides a business case to scale up agroforestry and sustainable agriculture land use management (SALM) innovations across Kenya. Although, scaling up is far more complex than simply transferring information and planting material; carbon finance is a potential source of funding. Agroforestry practices are based on sustainable agricultural land use management practices that mitigate atmospheric carbon and reduce vulnerability of farmers through enhancing their adaptive and resilience capacities to cope with impacts of climate change. SCC-Vi Agroforestry has been able to upscale the activities that manage land in western Kenya through carbon funds, which eventually mitigate greenhouse gases and enable farmers adapt to effects of climate change. The carbon funds target establishment of soil, tree and agriculture biomass carbon pools for direct and indirect climate change mitigation as well as livelihood values (improved agricultural productivity) or benefits reducing communities' vulnerability to climate variability risks such as drought, diseases and floods.

The NGO estimates that the total budget needed to reach all sub-locations in the country up to 2019 is USD 260 million. This figure increases up to USD 59-73 million if semi-arid areas are included.

The World Bank (2010d) globally estimated the costs of adaptation in the sector in the range of USD 7.1–7.3 billion annually between 2010 and 2050 to restore childhood nutritional levels worldwide (including agricultural research, irrigation expansion and rural roads). Over 40% accrue to Sub-Saharan Africa, mostly for rural roads investment.[xix] Parry et al. (2009) conclude that increases in agriculture investment in R&D, has potential large benefits in terms of agricultural productivity with an average rate of return of 43% across 1673 studies worldwide. Summary box 1 provides cost estimates for specific adaptation measures in irrigated and rain-fed agriculture, based on individual case-studies.

Summary box 1: The costs of adaptation in irrigated and rain- fed agriculture.

- **Case study- Irrigation schemes**: Initial investment costs of USD 198 – 1,744 per hectare for small-holders. Earnings range from USD 200 to 1,200 per month for major crop enterprises.[xi]

- **CBA- Rainwater harvesting**: Expected net benefits of USD 150 versus conventional system and a payback period of about 4 seasons or 2 years (in 1 year with a 100 m^3 farm pond).[xii]

- **CBA for millet production in The Gambia**: Increased production yields from irrigation could eliminate the need for commercial cereal import/food aid, resulting in substantial foreign exchange savings that could be reinvested in agriculture development. For example, roughly USD 22 million in savings could fund the development for 7,500 hectares of millet using diesel-pumped groundwater. However, net losses or a benefit- cost ratio close to 0 was associated with irrigation water delivery for specified price of millet.[xx]

- **CBA- Rainwater harvesting**: Positive NPV of just under Ksh 20,000 (using an 8% discounting rate). Benefit cost ratio of 1.14. Savings of Ksh 13,845 (USD 213) annually. Capital costs of Ksh 135,000 (USD 2076.9) and operating costs of Ksh 500 (USD 8) per year.[xxi]

One of the most apparent outcomes from this review is the comprehensive amount of research that has been undertaken to explore climate change impacts on agriculture. The planned costs of adaptation are, however less documented. It should also be noted that livestock production is often assessed in parallel to crop production as part of the broader agricultural sector. The Eritrea's NAPA assessed the project- level costs to improve rangeland for sustainable livestock production at USD 7,230,000.[xxii]

Published studies range in complexity, from quantified analyses utilising global crop models (e.g. IFPRI, World Bank), to reviews of the investment costs or cost-benefit analysis at the farm-level. A general finding is that adaptation is frequently cost-effective, and can significantly reduce potential impacts. Most studies highlight the possible adaptation benefits of improved agricultural productivity and associated infrastructure investments, primarily irrigation. Finally, little research has examined the higher-order costs and inter-linkages between adaptation in water and sanitation, agriculture and health sectors.

2.2.1.2. Fishing

In contrast, understanding of the costs of adaptation in the fishing sector is extremely limited in Kenya. A study from the World Bank explores the costs of adaptation in marine capture fisheries.[xxiii] The main findings from this global assessment are provided in Information Box 3. Other segments of the industry, such as freshwater capture, aquaculture and mariculture, are largely unexplored areas.

Information box 3: The costs of adaptation in marine capture fisheries.[xxiii]

The fishing sector may suffer billions of annual loss in landed value across climate projections, resulting in potential losses occurring to coastal communities. The study estimated the costs of adaptation in the form of household endowment to offset the impacts of climate change in the range of USD 7- 30 billion per year globally, with estimates about 2–3 times higher in developing countries. While this level of aggregation does not allow for a national-level extrapolation, this gives an overview of the potential range of economic losses faced by Kenya fisheries. In addition, it demonstrates that adaptation is more cost-effective when fisheries are more sustainably exploited (relative to an overexploitation scenario); whereas costs are lower under the overexploitation future scenario, as there are less fish to be affected by climate change.

2.2.2. Economic Pillar / Financial Services

Limited evidence was found on the costs of adaptation in Financial Services (insurance and banking) in Kenya. This may be due climate change being largely perceived as an opportunity rather than a risk by the sector. In particular, as insurance claims are likely to increase as climate changes, insurance companies may provide new products and services to countries, companies and individuals with cover against the increased risk of climate change-related droughts and extreme weather events. It is also important to note that investment in adaptation will not avoid all damages, hence, demonstrating the need for risk pooling as an adaptation tool. Although new commercial opportunities (e.g. development of index- based or hybrid products) are likely to arise, portfolio risk profiles may change and uncertainty increases as low probability- high impact events become more frequent and severe and the geographical and distributional effects are altered. Finally, climate change may put at risk regional and national macroeconomic stability, and thereby affect investment flows and current efforts to support the growth of capital and insurance markets across Kenya.

2.2.3. Economic Pillar / Private Sector

The costs of adaptation in relation to the Private Sector are seldom explored in the existing economic literature. Apart from agriculture, little research appears to have been undertaken on the vulnerability of the private sector to the impacts of climate change apart from Agriculture and Livestock. It is also important to note that data and information from individual companies are not publicly available due to confidentiality issues. Information box 4 presents some of the findings from the report on the private sector.

Although establishing a priori costs of private sector adaptation in Kenya is an emerging theme, the lack of information on the costs borne by single private agents or autonomous adaptation (which is mainly implemented by the private sector) will pose challenges for establishing these costs. This is likely to be a function of the lack of research taking place in this field more generally. The need for further research on this sector is similarly supported by the SEI study. Most of the economic estimates that are given in other sections refer to the costs to the society as a whole (i.e. social costs). Nevertheless, cost-benefit analyses at the project- or farm- level can be regarded as partially borne by individuals (e.g. farmer) or businesses. Assessing and disentangling costs and benefits borne solely by the private sector, is beyond the scope of this report.

Potential climate risks and opportunities faced by the private sector are explored in more details in Technical Report 4. Two case studies on a single adaptation action, agro-forestry extension service and the Muhoroni Sugar Company provide estimates of annual costs that a project developer or company may incur in similar projects to deal with climate risks.

Information box 4: The costs of adaptation for Muhoroni Sugar Company.[xxiv]

The Muhoroni Sugar Company has implemented a series of projects to adapt to climate change. This includes agro- forestry projects, cane fires protection, soil and land conservation). This case study provides indicative estimates of annual costs (see Table 5 below) that a company may incur in similar projects to deal with climate risks.

Table 5. The Costs of Climate Change Adaptation, Muhoroni Sugar Company

Project	Details	Cost/yr (Ksh.)
Agro – Forestry Projects	Planting 15,000.00 tree seedlings along Nyando River Banks	0.60 Million.
Cane fires Protection Project	Hiring 40 employees to guard the Nucleus Estate cane against accidental fires throughout the year.	5.00 Million
Soil Conservation Project	Enriching the depleted soil in Nucleus Estate plots with cane filter mud.	3.20 Million
Land Conservation Projects	Continuous rehabilitation of the feeder roads and drainages within Muhoroni cane catchment region.	25.0 Million

2.2.4. Economic Pillar / Tourism

There were no cost estimates identified in the literature with specific reference to tourism. However, this is likely to be a function of the lack of research taking place in the field of adaptation economics on tourism and the private sector more generally.

2.2.5. Social Pillar / Environment, Water and Sanitation

2.2.5.1. Water and Sanitation

The SEI study commissioned a sectoral assessment in the water sector using a water planning model, WEAP.[ii] However, inclusion of riverine flood protection costs is likely to increase these adaptation costs significantly. Demand- side measures, such as enhancing end-user efficiency, were associated with higher net benefits even under more favourable climate scenarios. Further information on the SEI model output is presented in Information box 5. In contrast, a cost- benefit analysis on South Africa's Berg River Basin erred in favour of supply- side measures. According to this same study, increased reservoir storage capacity was more cost- effective than using water markets and marginal cost pricing to allocate water under different climate scenarios.[xxv] This demonstrates the need to handle figures with caution as consideration of local context and water market characteristics may influence the robustness of any economic analysis. Here, we will favour conclusions from SEI (2009) as it was undertaken in Kenya.[xxvi]

The World Bank study evaluated the adaptation costs for riverine flood protection in the industrial and municipal water supply sector. Riverine flood protection net costs alone represent USD 3.5-5.9 billion for all developing countries over a total of USD 13.3- 16.9 billion (including municipal and industrial water supply).[xxvii] This represents an increase in costs between 25-35%.[xxviii] A cost- benefit analysis on South Africa's Berg River Basin found that increased reservoir storage capacity more cost- effective than using water markets and marginal cost pricing to allocate water under different climate scenarios.

Based on our literature review, a general finding is that adaptation is frequently cost-effective and should be prioritized as an early opportunity that can significantly reduce potential impacts in the water and sanitation sector. Nonetheless, it is particularly important to recognise the cross-linkages with other sectors such as Agriculture, Livestock and Fishing, as well as the Private Sector. Irrigation accounts for most of the water demand in Kenya. For example, costs of improving the irrigated agriculture (e.g. switching to improved crop varieties) were estimated around USD 500 per hectare (see Section 2.2.1). Similarly, improvements in water supply and sanitation and their associated costs have a large potential in terms of health benefits (see Section 2.2.6).

Information box 5: I&FFs required for adaptation in Kenyan water sector.[xxvi]

The WEAP model was run for the Tana River basin to assess the costs of integrated adaptation strategies and the results were scaled up to the national level, by simply multiplying by 5 to cover the 5 major river basins of Kenya. This catchment-level model provides a robust evidence base for adaptation in Kenyan water industry. Net benefits across multiple climate scenarios are presented for the following actions:

- Demand- side measures : Improve irrigation efficiency; Improved urban water consumption;
- Supply- side measures : Domestic water harvesting; increased reservoir storage capacity;
- Ecosystem interventions: Erosion control sustainable land management techniques; Improved rain-fed agriculture water use.

Key findings are:

- Demand- side measures are found more cost- effective, with net benefits of USD 11 million to USD 29 million for low and high climate scenarios
- In contrast, supply- side measures and ecosystem interventions have net benefits only under adverse climate futures
- 68% of the overall costs are incurred on the supply side. Costs of expanding water storage by constructing new reservoirs are estimated between USD 1-5 million per million m^3, while de-siltation may be 10 to 20 times cheaper.

In light of the growing demand from irrigated and rain-fed agriculture and urban areas, these recommendations reflect the current development needs in Kenya. The economic value of the 5 major water towers is presented in Table 6 below. Please note 13 new water towers have now been created (Kenya Gazette April 2012).[xxix]

Table 6. Economic value of Kenya's water towers.[xxx]

Towers	Area (Ha)	Major Rivers	Economic Value
Mt. Kenya	199,558	Tana	Hydropower generation and irrigation
Aberdares	103,315	Thika, Malewa and Athi	Major water supply for city of Nairobi and irrigation
Mau Complex	400,000	Mara, Sondu, Njoro and Nyando	Serves Massai Game Reserve, production of hydropower and tourism
Mt. Elgon	73,089	Nzoia	Paper and pulp industry, sugar industry Uncontrolled flooding causing wastage of storm water
Cherangani	128,000	Nzoia river system	Agricultural activities

2.2.5.2. Environment

The SEI assessment has also mapped the potential ecosystem services in Kenya, but has not provided any quantitative estimates on the potential additional pressures from climate change.[xxxi] The lack of data and inability to cost natural ecosystems inevitably leads to making important assumptions and potentially unreliable extrapolations. Case studies of various conservation actions, however, provide cost estimates that are also appropriate for adaptation. A cost-benefit analysis assessed the hypothetical construction of three alternative corridors for linking two forest reserves in the Mbaracyau Forest Biosphere Reserve in Paraguay. Costs varied from USD 37,000 to USD 115,000, and overall net benefits range from USD 1.67 to 1.45 million, although local benefits-costs were negative (USD 90,000–9,000) due to equity issues.[vi] Conservation of migration corridors by the Wildlife Foundation were costed USD 10 per hectare per year.[vi] Likewise, economic valuation of ecosystem services and biodiversity provides a strong business case for EbA through initiatives such as Payments for Environmental Services or PES (see Information box 7 on mangroves in Gazi Bay).

At the regional level, priority projects identified in NAPAs provide good estimates of the cost of ecosystem- based adaptation (EbA), as almost all identify projects based on terrestrial ecosystems as priority projects for climate adaptation. Although costs differ across countries, they indicate an average cost of USD 3.8 million per country for priority EbA projects.[vi] This includes agro-forestry projects, whose costs for up scaling up to the national level are estimated to range between USD 260 and 730 million per year (if semi-arid areas are included). Further information on the SCC Vi Agroforestry project are available in Section 2.2.1 on Agriculture, Livestock and Fishing. In addition, cost estimates associated with forestry are presented in Information Box 6.

Information box 6: The costs of adaptation in timber production.[xxxii]

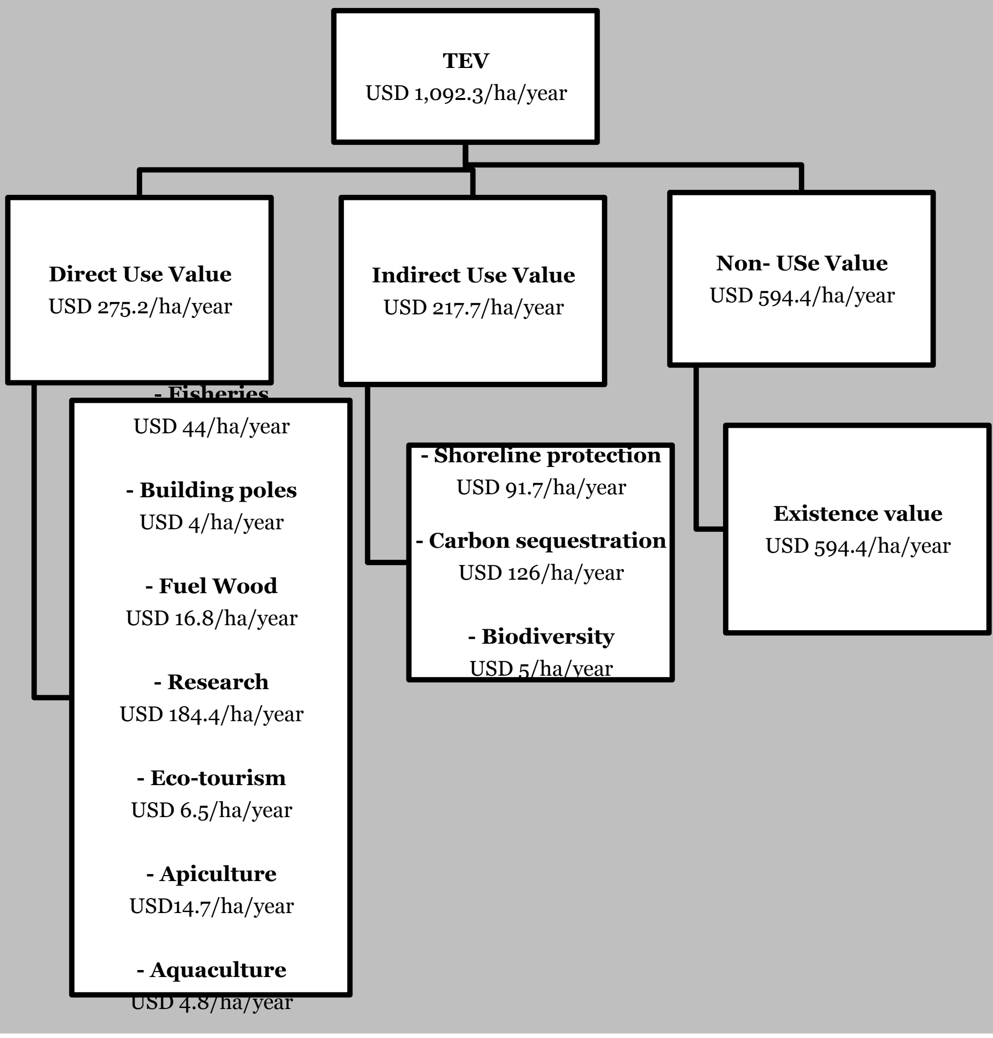
The costs of establishing a new tree plantation approximate USD 1,000 per hectare for a new site (including the land price). Relocating a plantation after harvest is approximately one-half of that. Thus, the incremental costs of relocating plantations are roughly USD 500 per hectare. According to the same study, rehabilitating an existing forest is likely to be more expansive at about USD 666 per hectare. In contrast, a fire suppression project was put at USD 1.4 million. Those estimates are likely to be higher if adjusted for inflation. Site-specific factors including land price also affect their accuracy. At the regional level, a case-study estimated the present value of a hectare of South African plantation forest in the neighbourhood of USD 10,000. This relatively low figure should be handled with caution as site preparation costs and labour costs are quite low in South Africa.

Information box 7: A case study in Gazi Bay, the economic value of mangrove forests.[xxxiii]

This case study estimates the Total Economic Value (TEV) of the mangroves in Gazi Bay to reach USD 1,092.3 hectare/ year. Direct uses (e.g. fisheries, fuel wood, and research) account for around 25 per cent of the TEV. Mangroves should be used in a sustainable way to guarantee preservation for future generations and the conservation of the indirect uses, particularly shoreline protection and carbon sequestration. These uses will diminish in value if the forest is not managed sustainably.

Indirect uses represent 20 per cent of the TEV. This share is likely to increase in the future as the issue of carbon sequestration becomes more and more important. The market for carbon credit is expanding rapidly and could become the biggest global commodity market in the near future. Additionally, sea-level rise threatens the distribution of mangroves, leading to an increase in the value of shoreline protection. The non-use value contributes the biggest share to the TEV of about 55 per cent. This figure should be reconsidered since no primary data is available. The application of the contingent valuation method (CV) could result in a more accurate figure. The TEV for the mangrove forest of Gazi bay is summarised in Figure 1 below.

Figure 1. Total Economic Value of the mangrove forest in Gazi bay (USD/hectare/ year).



2.2.6. Social Pillar / Health

Most of the evidence on the costs of adaptation in the health sector relates to the treatment and prevention of malaria incidence. This is closely linked to the large body of literature on the climate-related impacts leading to a geographical distributional shift of the disease to higher latitudes. SEI (2009) is the only national study that assesses both the costs and benefits of adaptation of the additional cases of climate-related malaria occurrence.[ii] This provides strong evidence of the net benefits of malaria- related interventions, as shown in Information box 8.

Information box 8: I&FFs required for adaptation in Kenyan health sector.[ii]

The SEI study assesses the additional costs of treatment and prevention of malaria epidemic incidence, approximating USD 23 million per year. This includes diagnosis and prevention (USD 15 million) associated with IRS and annual cost for treatment of additional cases (USD 8 million). Potential avoided damages (benefits) range between USD 48- 99 million and 144-185 million per year by 2050 (if direct costs are included). The following set of interventions were assessed and found very cost effective:

- IRS coverage in low endemic and potential epidemic areas (shifting to higher altitudes due to climate change);
- Distribution of bed nets for the additional population at risk;
- Additional medical tests for new population at risk;
- Preventive treatment of pregnant women; and
- Treatment (direct) costs for additional malaria cases.

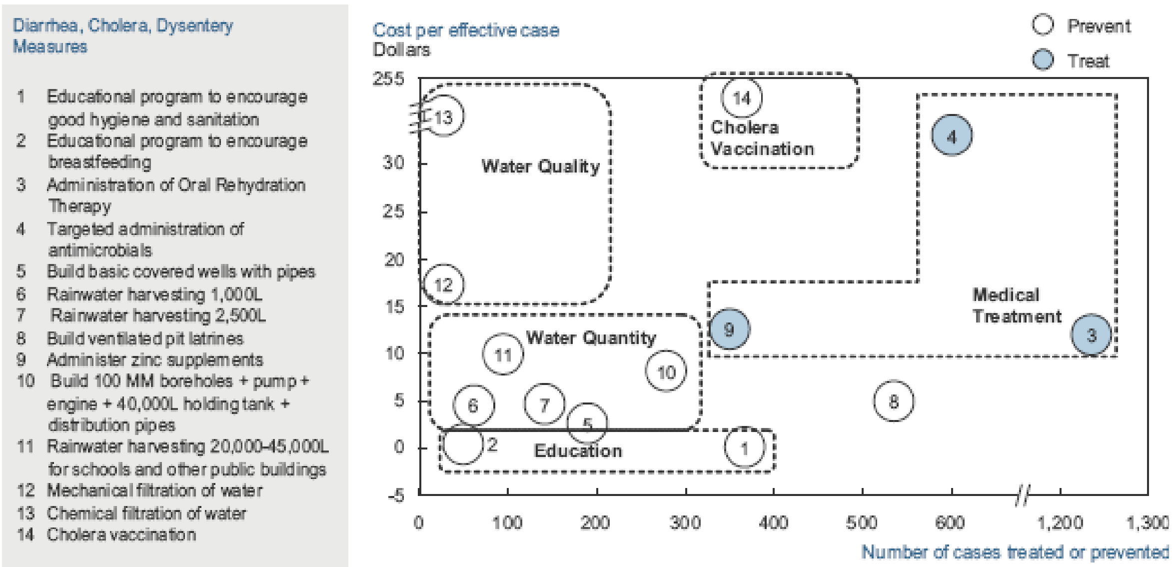
At the global level, in addition to malaria, the World Bank study (2010d) provides estimates of the costs of adaptation to diarrheal disease.[xxxiv] The potential cost of interventions for malaria and diarrheal disease were based on currently deployed cost-effective interventions (cost per DALY averted and incidence). However, measures that would have wider benefits, such as more general water and sanitation facilities (e.g. basic sanitation) are found often very cost-effective for diarrhoeal disease and are essentially no regret actions as they increased development and had health benefits (even without climate change). Treatment options selected were the same as used in Ebi (2008), primarily based on cost estimates from the project 'Disease Control Priorities in Developing Countries'.[xxxv] They were converted to 2005 USD for consistency with the rest of the World Bank study and applied to the additional incidence of diarrheal disease. As Table 7 shows, the costs of interventions for child health, while requiring large investments to meet the millennium development goals, result in costs per child that are relatively low. In general, water and sanitation interventions are highly cost-effective. Unsafe water and sanitation is closely associated with a wide range of disease (trachoma, schistosomiasis, ascariasis, trichuriasis and hookworm), but diarrhoea represents the majority of the death toll and is expected to increase as a result of climate change. Potential interventions include increasing access to improved water supply and sanitation facilities, increasing access to in house piped water and sewerage connection, and providing household water treatment.[xxxvi]According to the same study, the Cost-Effectiveness Ratio (CER) of key water and sanitation measures varied between USD 20 per DALY averted for disinfection at point of use to USD13, 000 per DALY averted for improved water and sanitation facilities. Increasing access to piped water supply and sewage connections on plot is associated with the largest health impact across all sub-regions, but would be associated by important investment and operating costs. However, it should be recognised that improvements in water supply and sanitation, and other environmental interventions, have multiple benefits beyond health (e.g. for education and welfare) and are often disregarded.

Table 7. Overview of the costs of intervention sets on malaria, diarrheal disease and malnutrition.[xxxv]

Outcome	**Intervention sets**	**2001 USD Average cost (unadjusted for inflation)**
Diarrhoeal disease	Breastfeeding promotion, rotavirus and cholera immunisation	USD 15.03 per child
	Improvement in water supply and sanitation	USD 53 per child
Malaria	Insecticide-treated bed-nets plus case management with artemisinin-based combination therapy	USD 57 per DALY
	Indoor residual insecticide (IRS) spraying plus above	USD 148 per DALY
Malnutrition	Breastfeeding promotion, child survival programmes, nutritional programmes, growth monitoring	USD 17.40-23.09 per child

Educational programmes and water quality improvements (rainwater harvesting) were the most highly cost effective measures in Tanzania.vi Figure 2 shows the ranking in terms of cost-effectiveness of alternative measures to reduce drought-related health impacts (diarrhoea, cholera, dysentery).

Figure 2. Cost- effectiveness ranking of climate- related interventions in the Tanzanian health sector.vi



Most of the literature reiterates the fact that health adaptation costs will be relatively low compared to some other sectors, and that action is therefore very cost-effective. However, Parry et al. (2009) warns that studies tend to focus on only two or three health endpoints (diarrhoeal diseases, malaria and malnutrition) and therefore, represent potential underestimates of total health adaptation costs.[iv] In addition, according to the same author, there is still considerable uncertainty around the cost-effectiveness of some interventions relevant to climate- related impacts. While some have been relatively well researched, such as insecticide-treated bed-nets, there is less economic evidence available on others (e.g. indoor residual insecticide spraying). The effectiveness of others (e.g. heat-health warning systems) is not underpinned by any robust evidence.[iv]

Evidence from NAPAs suggest that financial requests for specific health projects range from USD 22,000 to USD 600,000 for disease-control, early-warning information systems to USD 7 million for a major project in Bangladesh.[vi] However, such estimates typically address current disease control issues, usually for malaria. Cost estimates from the literature review are outlined in Summary box 2 below. Aggregated costs for malnutrition-related interventions are provided in section 2.2.1 to reflect the strong cross-linkages with agriculture-based adaptation.

2.2.7. Social Pillar / Population, Urbanisation and Housing

No evidence was found on the costs of adaptation in Population, Urbanisation and Housing. However, the Infrastructure theme (see section 2.2.10) provides readily available cost estimates for urbanisation and housing- based adaptation, considering the strong cross-linkages between the two MTP themes.

2.2.8. Social Pillar / Gender, Vulnerable Groups and Youth / Education and Training

Limited evidence was found on the costs of adaptation in Gender, Vulnerable Groups and Youth, as well as Education and Training. Yet, female education and empowerment are shown to play a key role in reducing weather-related losses.[xxxvii] Likewise, Di Falco et al. (2011) find that access to credit and knowledge about the climate was a critical determinant of whether Ethiopian farmers decided to make agricultural adaptation investments.[xxxviii] Further research should explore the costs of adaptation measures in these fields.

2.2.9. Foundations for national transformation / ICT

Limited evidence was found on the costs of adaptation in ICT. This strongly reflects the cross- linkages with other MTP themes and in particular, infrastructure which include telecommunication network (see next section on Infrastructure).

2.2.10. Foundations for national transformation / Infrastructure

This section presents evidence of the costs of adaptation to major infrastructure (e.g. transport, electricity). However, much of the relevant knowledge base focuses on the costs to infrastructure services. In particular, the costs of adaptation to coastal flooding are explored, considering the larger body of evidence in this field. All Disaster Risk Reduction (DRR) activities are similarly reviewed as its appears that disentangling adaptation costs strictly related to coastal infrastructure and generally associated with hard adaptation measures (e.g. sea dykes) from the wider sets of DRR measures is inherently difficult. Indeed, most flood assessments tend to explore a combination of both soft and hard adaptation. Likewise, other infrastructure types are partially covered by other sections, such as in water, sanitation and health.

Global estimates of the costs to upgrade port ground levels were evaluated in the World Bank report on coastal zones at USD 18.5 million per km^2 to raise ground levels by 1 metre (USD

0.185 million per km^2 to raise ground levels by 1 cm).[2;xxxix] Overall, according to the same study, climate-proofing existing infrastructure would represent no more than 2.3 % of the total cost of the infrastructure (given the baseline level of infrastructure provision). In Kenya, the SEI assessment, using the DIVA (Dynamic Interactive Vulnerability Assessment) model[3], investigated the additional effects of sea level rise on coastal zones. Costs of the impacts are in the neighbourhood of USD 7- 58 million per year by 2030 and USD 31- 313 million per year by 2050. Costs of adaptation include coastal defences, realignment of coastal defences landwards, abandonment, measurement to reduce the energy of near-shore waves, currents and coastal morphological management and resilience building strategies. This study was complemented with a detailed GIS-based case study, investigating the economic costs of sea level rise in Mombasa. The city appears to be already significantly exposed to coastal flooding. Although adaptation costs are recognised as potentially high, they remain limited in comparison to potential economic assets and population at risk from sea level rise. Summary box 2 highlights key findings from the SEI assessment.

Arguably, the effectiveness of DRR in the context of a changing climate has been seldom explored. A case study commissioned by the SEI study[xxvi] evaluated the costs of extreme floods and drought events at 8.4% of annual GDP by 2030 (including 2.4% for current variability and 3-5% for climate change- related impacts). Costs associated with flood forecasting and early warning systems are believed to be lower as compared to other structural interventions. Generally, flood risk management has the potential of reducing flood damages and losses resulting to huge economic savings. The government in particular stands to spend less on responding to emergency flood disasters and can invest this in other long-term national development projects, but would require highly specialised technical and institutional capacities with a high cost implication for its effective implementation. In addition to poverty reduction credentials, additional income at household level may be generated through community involvement in flood risk management projects. Furthermore, the SEI assessment for coastal zones[xv] provides quantitative estimates of assets and population at risk. However, while they look at the costs of climate change impacts, these studies are not complemented by adaptation actions and associated costs.

Summary box 2: The costs of adaptation in relation to coastal flooding

- **Coastal adaptation:** By 2030, USD 28-56 million per year, rising to USD 80 million by 2050. High benefits when compared to the costs even under current exposure with more than 210,000 people and USD 500 million in assets at risk. Under the worst case scenario (i.e. high sea level rise and rapid urbanisation), this will increase to more than 426,000 people and infrastructure worth around USD 17 billion by 2080.[xxvi]
- **Coastal flooding in Mombasa- Case study**: Increasing economic costs of sea level rise from USD 7-58 million per year by 2030 to USD 31-313 million per year by 2050.[xv]

2.2.11. Foundations for national transformation / Human Resource Development, Labour and Employment

Limited evidence was found on the costs of adaptation in Human Resource Development, Labour and Employment. Nonetheless, literature has shown that economies with higher literacy rates, stronger institutions, higher per capita income, higher openness to trade etc.

[2] The study adjusted the IPCC (1990) estimate of USD 15 million per km2 to raise port ground levels by 1m to take into account inflation.
[3] Coastal integrated assessment model that assesses biophysical and socio-economic impact.

are more resilient to the impacts of natural disasters.[xl] Likewise, Vivid Economics (2010), in a report for the UK DFID, explored the relationship between policies to stimulate economic growth and those to adapt to climate change.[vii] It found that of the nine key factors for strong growth, six are also associated with good adaptation. It concludes that: "'deficiencies in health and sanitation systems, poor levels of primary education and underdeveloped state institutions, among other factors, make it more difficult for poor countries to deal with climate risks."[vii] Further research in this field is recommended.

2.2.12. Foundations for national transformation / Land Reforms and Public Reforms

Limited evidence was found on the costs of adaptation in Land Reforms. This is due to the lack of publicly available data and information on the costs of the on-going process of land reforms in Kenya and more generally, the lack of research on climate change and land use and planning. Similarly, no research exists on the costs of adaptation in Public Reforms. This is certainly a critical area for further research as the development of county- level adaptation plans will be central in delivering effective and efficient measures aiming to build local resilience.

2.2.13. Foundations for national transformation / Science, Technology and Innovation

There is a lack of evidence regarding the costs of adaptation in Science, Technology and Innovation. This largely reflects the cross- linkages with other MTP themes as science, technology and innovation- related measures underpinning adaptation activities in each of the MTP themes.

2.2.14. Foundations for national transformation / Security, Peace Building and Conflict Resolution; and Political Pillar / Governance and the Rule of Law

Limited evidence was found on the costs of adaptation in Governance and the Rule of Law, as well as Security, Peace Building and Conflict Resolution. This is likely to be due to the general lack of research conducted on the inter-linkages between climate change and security and governance issues. Further research would be valuable in understanding and quantifying potential costs of adaptation to the sector, such as measures to settle climate-induced conflicts (including armed conflicts). Foresight (2011) is the only study that presents estimates of the costs of climate change in this field, even though it covers all the potential international issues from a UK perspective arising from a changing climate.[xli] The study aims to inform the UK CCRA process led by DEFRA that will enable all UK Administrations to understand the level of risk posed by climate change for the UK, prioritise adaptation policy and assess the costs and benefits of adaptation actions.

Estimates about the costs of the Darfur crisis to the UN and African Union budget is estimated at USD 1.8 billion per year. In Kenya, other economic implications can be drawn as a consequence of increasing water scarcity and state interests in the Nile Basin Initiative.[4] Furthermore, the report confirms that "there is some evidence that food and water scarcity driven by climate change has the potential to exacerbate existing drivers of tension and regional conflict between groups and within nations".[xli]

---

[4] The stated aim of the treaty is to achieve "sustainable socio-economic development through the equitable utilisation of, and benefit from, the common Nile Basin water resources" and "promote regional peace and security. More information on the Nile Basin Initiative may be found at: http://www.nilebasin.org/newsite/ (last accessed 05/04/2012).

3. Recommendations for further research

3.1. The state of knowledge

The UNFCCC acknowledges the difficulty in the estimation of adaptation costs and attributes it to the heterogeneity and widespread nature of climate change impacts.[xlii] Effective adaptation measures are highly dependent on specific, geographical, institutional, political, and financial and climate risk factors. Sources of differences in adaptation cost estimates, which could be due to conceptual, methodological or practical issues, include how much to adapt (whether it is full adaptation compared with the situation without climate change); whether to include soft (institutional and policy issues) or hard (capital intensive) adaptation measures; whether to include public (planned) or private (autonomous or spontaneous) adaptation; how to include benefits associated with climate change; how to handle uncertainty in climate projections, future technologies and prediction of impacts of climate change; and what aspects of adaptation costs to consider. It should also be noted that aggregate modelling techniques to assess costs and benefits of adaptation may mask residual damages, or negative net benefits that occur at micro and sectoral levels.

This section reviews main knowledge gaps and methodological limitations, as shown in Table 5, of existing economic evidence based on our literature review. It should be noted that only economic estimates and robustness are considered here, irrespective of other methodological issues (e.g. climate science). Furthermore, the lack of data is often seen as the primary limitation of most studies. This makes it difficult to conclusively ascertain the effectiveness of certain measures in a changing climate, as the evidence base used to determine economic efficiency (i.e. benefits net of costs of adaptation) remains limited and fragmented.[xliii] In addition to the rather small number of studies available, there are also important limitations of these assessments.

Table 8. The state of knowledge on the costs and benefits of adaptation actions in key sectoral themes. Note: High coverage (***), medium (**) and low coverage as (*).

Sectoral themes	Analytical coverage	Cost estimates	Benefit estimates	Comments on methodology
Agriculture	Comprehensive – Sectoral assessment and CBA on crops / livestock	***	*	Focus on irrigation and rainwater harvesting. Ricardian approach focusing on climate change impacts on ASALs/ livestock
Water resources	Comprehensive – covers Tana River basin including sectoral modelling (national scaling for 5 catchment basins)	***	***	Simple up-scaling to represent 5 river basins in Kenya. Lack of understanding of cross-linkages with agriculture, energy and health
Physical infrastructure	Cross- cutting issue – covered partly in agriculture, water resources and coastal zones	**	**	Sectoral assessment using DIVA. Other climate impacts are not considered apart SLR. Emphasis on coastal zones/ Mombasa. Lack of in country-evidence

				on rural roads for agriculture, port upgrade, EbA versus hard adaptation
Health	Limited – mainly covers malaria.	**	**	Global estimates for malnutrition and diarrhoea. In Kenya, focus on malaria
Energy	Limited – mainly increasing demand for cooling in cities such as Mombasa	*	*	No quantified estimates in SEI study. Overall, lack of evidence
Biodiversity and ecosystems	Very limited – limited economic valuation apart forestry and EbA projects	*	*	SEI based on literature review. Regional or global CBA for specific interventions and EbA in NAPAs.
Tourism and other Private Sector	Very limited – Indirectly covered by other sectors	*	*	Most estimates look at costs borne by society as a whole and not by single private agents (except farm-level Ricardian or CBA studies). No evidence on tourism (global estimates focus on winter tourism)
Government, Security and Conflicts	Very limited – No evidence	*	*	No evidence found based on published literature, apart from the Foresight study on the international dimensions of climate change partially covering governance and security issues but from a UK- based perspective

3.2. Recommendations

Better economic information is important for optimal allocation of investment into adaptation. It is important to continually and iteratively analyse the adaptation costs so as to support the development of an effective and appropriate national and sectoral response to the adverse effects of climate change. Our review of the economic costs of adaptation demonstrates that adaptation has potentially very large benefits in reducing present and future damages across the wide range of sectors. However, it is only if costs and benefits of the different options are clearly determined, that Kenya will be able to allocate its resources efficiently between different adaptation strategies.

Collecting country-specific evidence of the potential economic costs of climate change impacts and the benefits of investing in adaptation is therefore a key step in mainstreaming adaptation to a changing climate. This is also central to ensure allocation of sufficient financial resources for policy measures in support of climate change adaptation. As a consequence, there is a need for more detailed and systematic assessments of these costs, including case studies of costs of adaptation in specific places and sectors. Creating frameworks to generate effective, comparable and detailed cost estimates is crucial to achieve this. The creation of T21[5] Kenya with the Ministry of Planning equips the national government with a dynamic and fully integrated tool to appraise climate change interventions (both adaptation and mitigation) and associated benefits for national planning, using a scenario- based approach ('what-if' tool). The model also allows for the quantification of net benefits of government investments in adaptation activities and therefore, provides evidence of the efficiency of appraised adaptation measures. An appraisal of recommended measures included in the NCCRS[6] is currently underway and will contribute to emphasise the relevance of climate change issues within all departments and agencies at the national level.xviii This should provide valuable information to support the next phases of the NAdP (including policy and programme formulation and implementation). Further discussion on how to improve and update estimates from the SEI study based on the T21 modelling results is on-going.

The economics of adaptation remains an area of early research and there is a need for further analysis on the costs, benefits and effectiveness of adaptation at national and sub-national levels to validate economic prioritization of adaptation options at national and sub-national levels. The SEI study proposed a follow-on stage aiming to provide improved estimates. This implies a broader consideration of additional risks (e.g. within existing sectors, for additional sectors, cross-sectoral issues and indirect effects), as well as a more comprehensive analysis per sector to provide in-depth evidence of both detailed adaptation costs and I&FF analysis per sector, in an attempt to assess the needs for additional finance and prioritise government investments in adaptation activities. In this respect, discussions are currently underway with the GoK, development partners and the T21- Ministry of Planning team. This will also have potential implications for informing the Kenyan adaptation process (including the following phases of the NAdP).

Key recommendations are summarised below and elaborated in Chapter 5 of the core ATAR report:

- Conducting sectoral assessments of I&FFs to understand the magnitude and scale of investment needs for efficient and effective implementation of the NAdP in each sector;
- Improving and updating estimates from the SEI study on the costs of adaptation, addressing existing knowledge gaps and working in close collaboration with the T21 team on modelling results and data requirements;
- Strengthen the existing adaptation assessment framework, by building on the T21-Kenya framework. This will help sectoral decision-makers to understand the impacts of specific measures on key areas of interest and their net benefits. This also involves strengthening existing flows of information (including cost estimates) between the T21 team and all the relevant ministries/ agencies.
- Develop a robust and comprehensive assessment framework for use at the county level, building upon the national T21- Kenya model. County- level officials will be appointed to mainstream and promote the use of the newly developed county tool. This will be also accompanied by an extensive training programme directed to selected county teams.

---

[i] World Bank (2006). Climate variability and water resources degradation in Kenya: improving water resources development and management, World Bank Working Paper No. 69, 2006. Washington.

---

[5] Further information on the T21 modelling tool is available at : http://threshold21.com/integrated_planning/tools/T21/

[6] Although it should be noted that the NCCRS recommended actions are not based on a full option appraisal.

[ii] SEI. (2009). Economics of Climate Change in Kenya. Stockholm: Stockholm Environment Institute. Downing, T., et al. Report for DFID and DANIDA. Available at: http://kenya.cceconomics.org/. (Accessed August 2011).

[iii] IPCC AR4 WGII (2007). Climate Change 2007 - Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Glossary available online: http://www.ipcc.ch/pdf/glossary/ar4-wg2.pdf

[iv] Martin Parry, Nigel Arnell, Pam Berry, David Dodman, Samuel Fankhauser, Chris Hope, Sari Kovats, Robert Nicholls, David Satterthwaite, Richard Tiffin, Tim Wheeler (2009) Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London.

[v] Agrawala S and Fankhauser S (eds.). 2008. Economic Aspects of Adaptation to Climate Change. Costs, Benefits and Policy Instruments. Paris: OECD.

[vi] AdaptCost project (2011). Review of the costs of adaptation in Africa Project. UNEP, Nairobi. Accessed on 01/02/2012 at: http://www.unep.org/climatechange/adaptation/EconomicsandFinance/AdaptCost/tabid/29587/Default.aspx

[vii] Vivid Economics (2010). Protecting economic growth while the climate is changing. July 2010.

[viii] Kabuko-Mariara J. and Karanja, F. (2007). The Economic Impact of Climate Change: A Ricardian Approach. World Bank Policy Research Working Paper 4334 , 1-40.

[ix] Kabubo-Mariara, J. (2009). Global warming and livestock husbandry in Kenya: Impacts and adaptations. Ecological Economics, 68, 1915–1924.

[x] Kabuko-Mariara, J. (2008). Climate change adaptation and livestock activity choices in Kenya: An economic analysis. Natural Resources forum 32, 131-141.

[xi] Mati B. M. (2008). Capacity development for smallholder irrigation in Kenya. Irrig. and Drain. 57: 332–340.

[xii] Ngigi S.N.N. (2005). Hydro-economic evaluation of rainwater harvesting and management technologies: Farmers investment options and risks in semi-arid Laikipia district of Kenya. Physics and Chemistry of the Earth 30 (2005) 772–782

[xiii] Droogers et al. (2009). Climate Change and Hydropower, Impact and Adaptation Costs: Case Study Kenya. Report Future Water: 85. September 2009. Wageningen.

[xiv] Otiende, B. (2009). The Economic Impacts of Climate Change in Kenya: Riparian Flood Impacts and Cost of Adaptation. Case Study. Economics of Climate Change, Kenya, 2009.

[xv] Kebede, A. et al. (2009). Impacts of Climate Change and Sea Level Rise: A case study of Mombasa, Kenya. Retrieved December 22, 2010 from http://kenya.cceconomics.org: http://kenya.cceconomics.org/kedo/kenya-mombasa-and-sea-level-rise.pdf

[xvi] SEI (2009). Economics of climate change adaptation for Kenya. A case study of SCC-Vi Agroforestry project in Kisumu.

[xvii] World Bank (2010h). Economics of Climate Change Adaptation- Ecosystem Services. Discussion Paper number 4. August 2010. Glenn-Marie Lange with Susmita Dasgupta, Timothy Thomas, Siobhan Murray, Brian Blankespoor, Klas Sander, and Timothy Essam. Washington.

[xviii] T21 (*in progress*). Strengthening Institutional Capacity for Integrated Climate Change Adaptation & Comprehensive National Development Planning in Kenya. July 2011. Final Report. Millenium Institute.

[xix] World Bank (2010a). The Costs of Agricultural Adaptation to Climate Change. Development and Climate Change. Discussion Paper number 4.August 2010. Gerald C. Nelson, Mark W. Rosegrant, Jawoo Koo, Richard Robertson, Timothy Sulser, Tingju Zhu, Claudia Ringler, Siwa Msangi, Amanda Palazzo, Miroslav Batka, Marilia Magalhaes, Rowena Valmonte-Santos, Mandy Ewing, and David Lee. Washington.

[xx] Nkomo, J.C. and Gomes, Bernard (2006). Estimating and comparing costs and benefits of adaptation projects: Case studies in South Africa and The Gambia. A final report subimitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 47.

[xxi] AEA Technology Plc. (2008). Kenya: Climate Change Screening Information and Exchange. London: DFID. CBA Section. Appendix 5.

[xxii] State of Eritrea (2007). National Adaptation Programme of Action. April 2007. Ministry of Land, Water and Environment. Department of Environment. Asmara.

[xxiii] World Bank (2010f). The Costs of Adapting Fisheries to Climate Change. Discussion Paper number 3. August 2010. Ussif Rashid Sumaila and William W. L. Cheung. Washington.

[xxiv] LTS International and Acclimatise (in progress). The private sector engagement in climate change adaptation in Kenya. Final draft report, 25 May 2012. Draft.

[xxv] Callaway, John, Louw, Daniel, and Hellmuth, Molly (2009). "Benefits and costs of measures for coping with water and climate change: Berg River Basin, South Africa", In Ludwig (eds.), *Climate Change Adaptation in the Water Sector*. Chapter 14.

[xxvi] SEI (2009). Climate adaptation economics Kenya water sector. Dyszynski, J., Droogers, P. And Butterfield, R. Oxford.

[xxvii] World Bank (2010g). Costs of Adaptation Related to Industrial and Municipal Water Supply and Riverine Flood Protection. Discussion Paper number 6. August 2010. Philip J. Ward, Pieter Pauw, Luke M. Brander, Jeroen, C.J.H. Aerts and Kenneth M. Strzepek. Washington.

[xxviii] World Bank (2010b). The Economics of Coastal Zone Adaptation to Climate Change. Development and Climate Change. Discussion Paper number 10. August 2010. Robert Nicholls, Sally Brown, Susan Hanson and Jochen Hinkel. Washington.

[xxix] The Kenya Gazette, Nairobi, 20th April 2012. Vol. CXIV No. 31.

[xxx] Kenya SIP (2009), Sector investment plan for the water and sanitation sector in Kenya, Ministry of Water and Irrigation, February 2009.

[xxxi] SEI (2009). Review of the Economic Impacts of Climate Change in Kenya, Rwanda and Burundi. Ecosystems Chapter, Kenya.

[xxxii] World Bank (2010c). Adaptation of Forests to Climate Change. Discussion Paper number 3. August 2010. Roger A. Sedjo. Washington.

[xxxiii] UNEP (2011). Economic Analysis of Mangrove Forests: A case study in Gazi Bay, Kenya, UNEP, iii+42 pp.

[xxxiv] World Bank (2010d). The Costs to Human Health in Developing Countries of Adaptation to Climate Change. Discussion Paper number 11. August 2010. Kiran Pandey. Washington.

[xxxv] Ebi, K.L., 2008: Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030. Globalization and Health, 6, 9. Accessed on 31/03/2012 at: http://www.globalizationandhealth.com/content/pdf/1744-8603-4-9.pdf

[xxxvi] Haller, L., G. Hurton and J. Bartram (2007). Global costs and health benefits of water and sanitation improvements. Journal of Water and Health. 05.4, 2007. Accessed on 31/03/2012 at: http://www.iwaponline.com/jwh/005/0467/0050467.pdf

[xxxvii] Wheeler, D., B. Blankespoor, S. Dasgupta, B. Laplante, (2009) The Economics of Adaptation to Extreme Weather Eventsin Developing Countries.

[xxxviii] Di Falco, S., M. Veronesi and M. Yesuf, 2011, Does Adaptation to Climate Change Provide Food Security? A micro-perspective from Ethiopia, American Journal of Agricultural Economics, March.

[xxxix] World Bank (2010e). The Costs of Adapting to Climate Change for Infrastructure. Discussion Paper number 3. August 2010. Gordon Hughes, Paul Chinowsky and Ken Strzepek. Washington.

[xl] Noy, 2009, The macro-economic consequences of disaster, Journal of Development Economics, No. 88, (221-231)

[xli] Foresight International Dimensions of Climate Change (2011). Final Project Report. The Government Office for Science, London.

[xlii] UNFCCC (2009). Potential costs and benefits of adaptation options: A review of existing literature. Technical Report. 7 December 2009. FCCC/TP/2009/2. Bonn, Germany.

[xliii] Hallegatte et al. (2011). Designing Climate Change Adaptation Policies: An Economic Framework. Policy Research Working Paper 5568. World Bank.