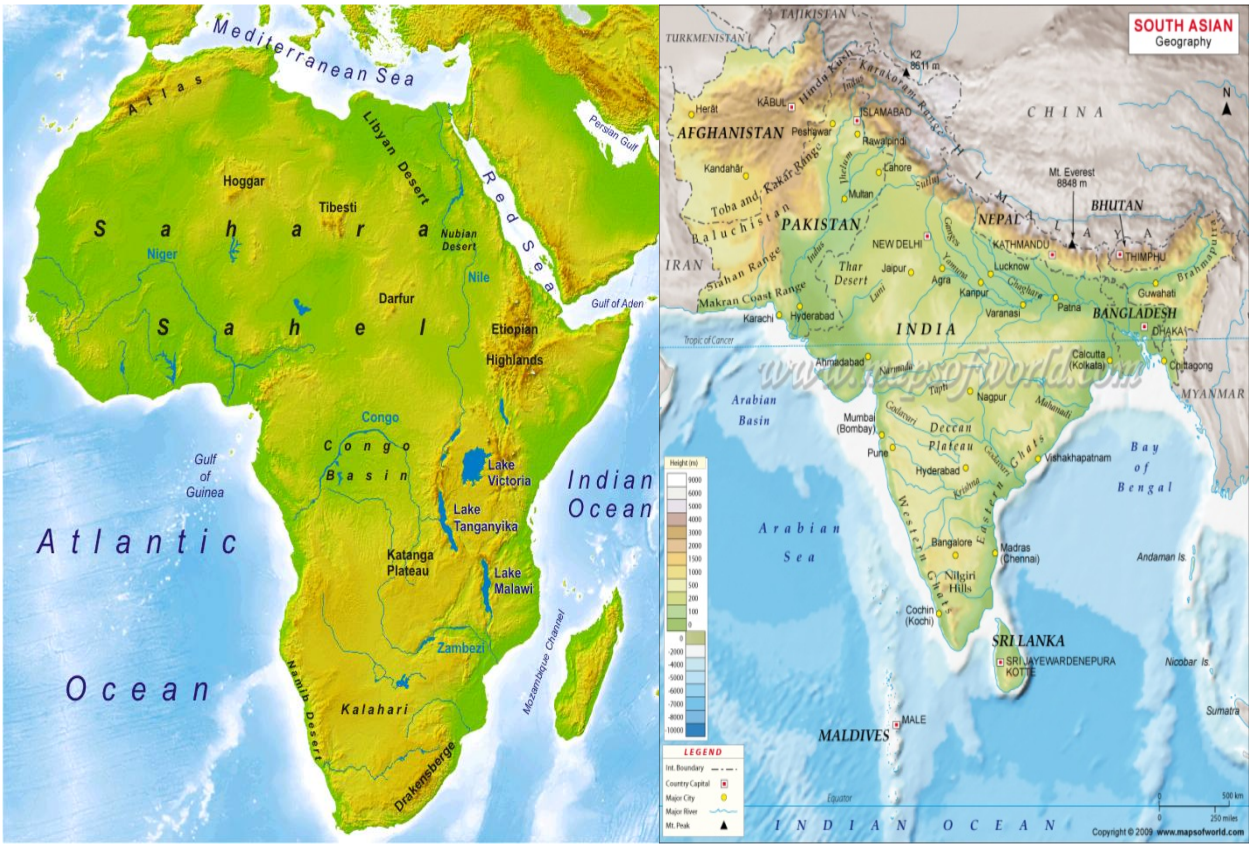
REVIEW OF METHODS FOR THE ECONOMIC ANALYSIS OF CLIMATE CHANGE ADAPTATION

A Survey of Methods, Institutions and Results to inform the CARIAA Program



By

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Acronyms

BCR	Benefit Cost Ratio
CARIAA	Collaborative Adaptation Research Initiative in Africa and Asia
CBA	Cost Benefit Analysis
CEA	Cost Effective Analysis
CGE	Computable General Equilibrium
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
DFID	Department For International Development
DICE	Dynamic Integration model of Climate and the Economy
EAA	Economics of Climate change Adaptation
EACC	Economic Adaptation to Climate Change
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
IAM	Integrated Assessment Methods
IDRC	International Development Research Centre
IFF	Investments and Financial Flows
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel for Climate Change
IRR	Internal Rate of Return
KES	Kenyan Shilling
LAPA	Local Adaptation Plan of Action
MCA	Multi criteria Analysis
NAPA	National Adaptation Plan of Action
NGO	Non-Government Organisation
NPV	Net Present Value
ODA	Overseas Development Assistance
PES	Payment for Ecosystem Services
PSROI	Participatory Social Return on Investment
RICE	Regional Integration Model of Climate and the Economy
SFCBA	Stakeholder Focused Cost Benefit Analysis
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar
WTP	Willingness To Pay

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EXECUTIVE SUMMARY

In its continued effort to contribute to growing body of knowledge, The International Development Research Centre (IDRC) has been supporting the creation and the consolidation of regional environmental economics research and capacity building networks. UKAID and IDRC recently launched the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), a program which aims to build climate change resilience in Africa and South Asia through research which informs effective adaptation policy and practice. The CARIAA program identified three climate change "hot spots" where four research consortia will focus their work using the criteria of high climate risk and the climate-sensitivity of livelihoods among large populations of poor people. The three hot spots identified are: semi-arid zones of Africa and parts of South and Central Asia; large deltas of Africa and South Asia; and river basins affected by glacier and snowpack melt in the greater Himalayan region. The program has now the opportunity to advance in this direction to give solid grounding to the economics of adaptation in these vulnerability hot spots. The research to be led by the CARIAA consortia, has a strong economic analysis component and consortia will work on a large number of single case studies at the same time, enabling them to make a comparative analysis of the conditions that determine feasibility and costs of similar adaptation options in different countries and areas. In order to inform CARIAA in the design of its research on economics of adaptation, and to discuss a comparable approach across the work of consortia, there is a need to review and compare the research methods used in economics of adaptation with documented discussions on their appropriateness across different hot spots scales and contexts and their success or limitations in informing policy or practice. Using South Asia and Africa, this study documents the methods that have been done in economics of climate change which special focus on the three hotspots. The study further assesses how ecosystem services has been incorporated in economics of adaptation and draws from a number of studies that have estimated payment for ecosystems services in the two regions of Africa and South Asia. Finally, the study evaluates the relevance of these methods in the three hot spots and how the proposed methods by the consortia can be sharpen given the current state of methodologies.

This report is based on desk study. Several literature were sources from the internet for the review. We searched for all available evidence relevant to the questions, whether published or unpublished, including both peer reviewed papers and relevant grey literature.

The review found that methodologies for EAA are diverse and shift when the analysis is scaled down from global to national and local level. The practices and methodologies are evolving but there is an increasing momentum to place adaptation strategies within the national development policies. Sound methodologies for assessing climatic impacts and translating them into anticipated impacts on the agricultural and other economic sectors will be increasingly important in the future as governments

and the private sector aim to increase the resilience of their activities to the consequences of climate change. There have been a number of methods used in studying economics of climate change at global level and in Africa and South Asia. We categorise these methods into three: 1) financial, 2) economic assessment and 3) ecosystem. The first two methods are not mutually exclusive as the financial methods can also be applied and used in the economic approaches. In this review both financial and economic methods estimate the net-benefits of adaptation investment based on the difference between the with-climate change and the without-climate change situations. However, financial analyses of climate change adaptation compare benefits and costs of a specific strategy looking at time and money. On the other hand, economic analyses compare the benefits and costs to part or the whole economy. Economic analysis relies heavily on marginal costs and benefits, i.e. what is the additional return of investing and does that cover the incremental cost given different alternatives and the resources available? In addition to these two approaches, ecosystem methods presented here are also termed environmental valuation methods. The main difference with the first two methods is that the ecosystem methods assess and value goods that are not commonly available on the market and hence do not generally have a known or reliable market price. These goods may however, contribute towards adaptation to climate change and hence are valued using indirect methods.

At global level studies have mainly looked at estimating the total cost of climate change adaptation. These have applied mainly financial methods like Investment and Financial Flows (IFF) and later cost benefits analysis. At national and local level a number of studies have looked at different impact of climate change using a number of economic methodologies including (i) the Ricardian Approach, (ii) the Integrated Assessment Models (IAMs) and the (iii) Structural Approach. Very few studies applied ecosystem valuation methods in climate change adaptation. The common application of the ecosystem approaches has been in payment for ecosystem services studies that did not directly address climate change adaptation.

A number of issues can be drawn from the methodologies that the consortia can adopt and use in their implementation of the program. Below are some important issues to consider.

Estimating non-monetary costs and benefits

Due to this lack of observed market prices, there has been relatively fewer studies done that estimate values that include ecosystem services in climate change economics. Other important issues that affect cost and benefits of adaptation strategies but are not traded on the market include cultural values, social values, future values and ecological values. In addition, because adaptation projects inevitably generate costs and benefits that extend beyond their direct beneficiaries, it is important to examine their non-monetary costs and benefits as well as their economic value. While these negative and positive impacts of certain climate-related events on human lives, livelihoods and ecosystems cannot be monetised, they have financial implications that may amplify or reduce the positive or negative effects of a project. This suggests that non-monetary costs and benefits may determine whether a project is actually worthwhile in the eyes of all stakeholders.

Uncertainty, discount rates and time horizons of adaptation projects

Three critical issues should be considered when estimating cost and benefits of climate change adaptation. Before assessing the costs and benefits of an adaptation project, it is important to identify three critical dimensions of the initiative:

i. First, the degree to which uncertainty can be incorporated into the assessment of adaptation options,
ii. The discount rate that will be used to convert benefit and cost streams into their equivalent present values.
iii. Lastly, the time horizon of the evaluation is directly linked to the discount rate.

These three factors are very critical in comparing and aggregating results. The consortia will make great strides in adopting similar parameters to be used, e.g. discount rates and time horizons for the analysis.

Availability and usefulness of climate data.

More direct climate variable (e.g. Temperature and precipitation) are commonly used in most studies. The most informative climate data would be monthly variance of temperature or rainfall at local level. However, the geographical variation of climate data even within a country makes use of national average figure to mask the actual climate change impact. A single annual digit may not present the actual impact of climate change. However, impact of climate change e.g. humanitarian aid in response to climate change disasters (other than man-made catastrophes e.g. wars and conflicts or natural e.g. earthquakes) is a better indicator or proxy to climate change impacts.

Difference between financial and economic studies.

It is unfortunate that a number of studies on cost and benefits analysis have been termed as economic studies when they have not done any economic analysis and their estimates are based on market prices of inputs and benefits. It will be important for the consortia to separate these and provide well guided and documented methodologies.

1.0 INTRODUCTION.

The prospect of global climate change has emerged as a major scientific and public policy issue. Estimates from global circulation models predict that the projected global average surface warming and sea level rise at the end of the 21st century will be 1.8°C at the best estimate for the low greenhouse-gas emission scenario and 4.0°C at the best estimate for the high greenhouse-gas emission scenario (IPCC, 2007). The potential consequences of climate change include increased average temperatures, greater frequency of extreme temperature events, altered precipitation patterns, and sea level rise. In many part of the world, current trends in climate already show a deviation from what is assumed normal in terms of temperature and rainfall. There are now records of severe dry spells and intensive rainfalls causing floods in many part of the globe.

These changes in climate are affecting the basic elements of life for people around the world e.g. access to water, food production, health, and the environment. Hundreds of millions of people could further suffer hunger, water shortages and coastal flooding as the world warms (Stern, 2007). Between 1990 and 2008, more than 750 million people in South Asia—50% of the region's population—were affected by at least one weather-related disaster, leaving almost 60,000 dead and resulting in about US$45 billion in damages (Onneshan, 2010). The International Food Policy Research Institute estimates that for South Asia, and relative to 2000 levels, agricultural crop yields are projected to decline by 23% (rice), 57 % (wheat) and 36% (maize). These will threaten food security and livelihoods of several millions of people directly and indirectly dependent on agriculture.

With the majority of rural economies closely tied to climate sensitive sectors such as agriculture, the poor are likely to be disproportionately affected by climate change (Damania, 2011). There is an urgent need to respond to the current and future climate impacts mainly among the least developed and vulnerable communities by implementing appropriate adaptation strategies to climate change. The success in the implementation of adaptation plans and mechanisms, and the capacity for them to reach and benefit vulnerable communities critically depends on research being able to produce rigorous evidence for the economic feasibility and opportunity of adaptation interventions. Such rigorous research findings will also highlight the potential profitability of private and public investments in specific cases.

In order to critically contribute to this growing body of knowledge, in the past IDRC has been supporting the creation and the consolidation of regional environmental economics research and capacity building networks. UKAID and IDRC recently launched the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), a program which aims to build climate change resilience in Africa and South Asia through research which informs effective adaptation policy and practice. The CARIAA program identified three climate change “hot spots” where four research consortia will focus their work using the criteria of high climate risk and the climate-sensitivity of livelihoods among large populations of poor people. The three hot spots identified are: semi-arid zones of Africa and parts of South and Central Asia; large deltas of Africa and South Asia; and river basins affected by glacier and snowpack melt in the greater Himalayan region. The program has now the opportunity to advance in the direction of give solid grounding to the economics of adaptation in these vulnerability hot spots, as research led by the CARIAA consortia has a strong economic analysis component and consortia be able to work on a large number of single case studies at the same time, enabling them to make a comparative analysis of the conditions that determine feasibility and costs of similar adaptation options in different countries and areas. In order to inform CARIAA in the design of its research on economics of adaptation, and to discuss a comparable approach across the work of consortia, there is a need to review and compare the research methods used in economics of adaptation with documented discussions on their appropriateness across different hot spots scales and contexts and their success or limitations in informing policy or practice. Using South Asia and Africa, this study documents the methods that have been done in economics of climate change which special focus on the three hotspots. The study further assesses how ecosystem services has been incorporated in economics of adaptation and draws from a number of studies that have estimated payment for ecosystems services in the two regions of Africa and South Asia.

There have been a number of methods used in studying economics of climate change at global level and in Africa and South Asia. We categorise these methods into three categories: 1) financial, 2) economic assessment and 3) ecosystem. The first two methods are not mutually exclusive as the financial methods can also be applied and used in the economic approaches. Financial and economic analyses have similar features. Both estimate the net-benefits of adaptation investment based on the difference between the with-climate change and the without-climate change situations. However, financial analyses of climate change adaptation compare benefits and costs of specific climate change adaptation strategies looking at time and money. On the other hand, economic analyses compare the benefits and costs to the whole economy. Economic analysis relies heavily on marginal costs and benefits, i.e. what is the additional return of investing and does it cover the incremental cost given different alternatives and the resources available? Ecosystem methods presented here are also termed environmental valuation methods. The main difference with the first two methods is that the ecosystem methods assess and value goods that are not commonly available on the market and hence do not generally have a known or reliable market price. These goods may however, contribute towards adaptation to climate change and hence are valued using indirect methods.

The next section presents methodology used in this study the next section outlines financial methods that have been used at global and national level, and giving examples from countries in the three hot spots. Section four presents economic methods and section five presents methods used in assessing ecosystem services. Section six highlights critical issues from the three categories of methods and proposes issues that should be considered when using these methodologies in studying economics of climate change adaptation with special focus on the three hot spots.

2.0 METHODOLOGY USED IN THIS STUDY

As this was mainly a desk study, several literature were sources from the internet for the review. We searched for all available evidence relevant to the questions, whether published or unpublished, including both peer reviewed papers and relevant grey literature. The review commenced with an initial search of leading relevant academic journals (see table 1).

Table 1: List of peer reviewed journals used in this study

African Journal of Agricultural and Resource Economics	Journal of African Economies
Agricultural and Forest Meteorology	Journal of Agricultural and Resource Economics
Agricultural Economics	Journal of Development Economics
Agricultural Finance Review,	Journal of Econometrics
American Journal of Agricultural Economics	Journal of Economic Literature
Applied Economic Perspectives and Policy	Journal of Environmental Economics and Management.
Chilean Journal of Agricultural Research	Journal of Farm Economics
Climate Change Economics	Land Economics
Climate Research	Nature

Ecological Economics	Resources and Energy
Economic Development and Cultural Change	Review of Economic Studies,
Energy Economics	The American Economic Review
Environment and Security.	The Energy Journal,
Environmental Research Letters.	The Handbook of Environmental Economics,
European Association of Environmental and Resource Economists,	The Integrated Assessment Journal
Fertilizer Research	The Integrated Assessment Journal
General for Agriculture and Rural Development	The Journal of Agricultural Science.
Global and Planetary Change,	The Journal of Modern African Studies.
Global Environmental Change.	

- **Publication databases**

  The general search was conducted using the following online databases:
  - ISI Web of knowledge
  - Scopus
  - PubMed
  - Agricola
  - International Development Research Center (IDRC) digital library
  - Scienceindex
  - Public library of science
  - Directory of Open Access Journals
  - COPAC
  - Social Sciences research network
  - Index to Theses Online
  - CAB Abstracts
- **Web search engines**

World Wide Web search of the key words was conducted that yielded more results.

  - http://www.alltheweb.com
  - http://scholar.google.com
  - http://www.scirus.com (all journal sources)
  - http://data.esa.org/
  - http://scientific.thomsonwebplus.com/

- **Organisational website search**

The Websites of established research organizations that work in the economics of adaptation space were searched. Specific searches were conducted using the following websites of organisations specialised in environment and natural resources, agriculture, and climate change. Where possible, only publication sections of the websites were be used for search.

  - http://www.capri.cgiar.org/ webcite
  - http://www.cgiar.org/ webcite
  - http://www.conservation.org webcite
  - http://www.conservationgateway.org/Pages/Advanced-Search.aspx/ webcite
  - http://seslibrary.asu.edu/seslibrary/search webcite
  - https://dec.usaid.gov/dec/home/Default.aspx# webcite
  - http://www.eldis.org/ webcite
  - http://www.fao.org/documents/en/search/init/ webcite,
  - http://www.fao.org/faobib/ webcite
  - http://www.ifad.org/ webcite
  - http://www.iied.org webcite
  - http://www.iucn.org/knowledge/publications_doc/ webcite
  - http://povertyandconservation.info/en/bibliographies webcite
  - http://www.un.org/Depts/dhl/ webcite
  - http://www.undp.org/content/undp/en/home/librarypage.html/ webcite,
  - http://sgp.undp.org/ webcite
  - http://web.undp.org/gef/gef_library.shtml webcite
  - http://www.unep-wcmc.org/ webcite
  - http://www.unep.org webcite, http://ekh.unep.org/ webcite
  - http://web.worldbank.org webcite

Key word search was conducted in the journals for terms “economic analysis of adaptation”, “adaptation costing”, “economics of adaptation” and a variation of these terms. This was then narrowed to studies in Africa and South Asia. The initial screening was followed by search in Google Scholar for similar key words.

Snowballing techniques were used to find studies referenced in other studies. Personal contacts and prior assignment experience in South Asia and Africa also identified other studies. Annex 1 and reference list presents all the studies used in this review.

3.0 FINANCIAL ASSESSMENT OF CLIMATE CHANGE ADAPTATION

A number of methods have been used to estimate costs and benefits of climate change adaptation at global, regional, national, sectoral and project level. The intuitive approach to costing adaptation involves comparing a future world without climate change with a future world with climate change. The difference between the two worlds entails a series of actions to adapt to the new world conditions (World Bank, 2010). However, other variations of this approach are also in use. This section discusses with examples, frequently applied methods that have been used to estimate the financial costs and benefits of climate change adaptation.

3.1 Investment and Financial Flows

This methodology has been applied mainly at national and global levels to estimate climate change cost and is referred to as first generation studies. The first-generation studies rely primarily on climate mark-up methodology that scales different types of investment flows that are sensitive to climate risk. These studies are referred to as Investment and Financial Flows (IFFs). IFFs represent the total funds allocated to any sector, project or program. It includes capital expenditure and on-going operational expenditure. The World Bank pioneered the first-generation of IFFs in 2006 to estimate the costs of adaptation for developing countries. The study applied a mark-up on the total IFFs in the selected categories of investments flows (official development assistance and concessional finance, foreign direct investment, and gross domestic investment) that were considered climate sensitive to "climate proof' these flows. Adaptation costs were considered the costs for climate proofing these flows. Later studies by Stern (Stern, 2007), Oxfam (Oxfam 2007) and Human Development Report (UNDP, 2007) were built on the World Bank methodology of climate mark-up but applied a different proportion of climate sensitivity. The assumptions in the different studies are presented in figure 1 and the summary of the studies in table 1. These methods were generic and applied in all the three hotspots of arid and dry lands, deltas and river catchments. Even though the cost figures estimates generated from using these methods were used in international debates, the methods itself were criticized because:

a) The cost items were based on strong assumptions that did not reflect reality on the ground. For example, the costs of community-level adaptation were extrapolated from just few projects and NAPA proposals.
b) Arbitrary mark-up factor, usually 10%, applied to 'climate proof' investments

c) Subsequent studies borrow heavily from initial World Bank model, creating a misleading convergence of results

d) Significant assumptions used in identifying 'climate sensitive' investments

e) Applies fixed methodology to different sectors

f) Results non-verifiable at the local level.

The World Bank (World Bank, 2006)

Mark up:

2–10% of gross domestic investment (GDI, worth US$1,500 billion a year at the time),

10% of foreign direct investment (FDI, US$160 billion) and

40% of official development assistance (ODA, US$100 billion) would be sensitive to climate change.

Mark-up to climate-proof these investments was 10–20%. Of these assumptions only the ODA figure had any empirical grounding. (Parry et, al., 2009).

The Stern Review (Stern, 2007)

Reduced the mark-up for climate proofing from 10–20% to 5–20%, and the share of climate sensitive ODA from 40% to 20%, but made no further adjustments to the method.

Oxfam (2007)

Also added new cost items to the original infrastructure estimates, viz. the extra cost of NGO work at the community level and the cost of implementing a National Adaptation Programme of Action (NAPA) style programme. Both cost items are based on fairly strong assumptions. The costs of community-level adaptation were extrapolated from just three projects, while the cost of early adaptation was derived from the 13 NAPAs available at the time.

Human Development Report (UNDP, 2007)

Used considerably higher investment data and a different share for climate-sensitive ODA (17–33%) but otherwise adopted the Stern assumptions. In addition, it included the costs of adapting poverty reduction strategies (US$44 billion a year) and strengthening disaster response systems (US$2 billion a year).

Figure 1: The evolution of investment financial flows and their assumptions

Table 2: Adapted from the World Bank EACC report and summarizes the global adaptation costing studies that use the IFF based on the World Bank 2006 methodology.

Institutions	Methodology	Summary
World Bank 2006	IFFs	The first estimate of costs of adaptation to climate change for developing countries was produced by the World Bank in 2006 (World Bank, 2006). Its report defined adaptation costs as the cost of climate proofing three categories of investment flows: official development assistance and concessional finance, foreign direct investment, and gross domestic investment. The study defined the proportion of total investments in each category that was likely to be climate sensitive and then estimated the percentage increases in costs to climate-proof these investments. Adaptation cost estimates ranged from US$9 billion to US$41 billion a year.
Stern 2007	IFFs	Used the same methodology as World Bank 2006 but different values for the proportion of climate-sensitive investments and the increases in costs for climate proofing investments, the Stern Report (Stern, 2007) estimated costs of adaptation of US$4–US$37 billion a year by 2050, somewhat lower than the world bank estimate.
UNDP 2007	IFFs	Human Development Report 2007/2008 (UNDP, 2007)estimated costs of US$5–US$67 billion a year by 2015, somewhat higher than the world bank estimate. In addition to the cost of climate proofing investments, Human Development Report 2007/2008 estimated that US$40 billion a year would be needed by 2015 to strengthen social protection programs and scale up aid in other key areas and US$2 billion a year to strengthen disaster response systems, boosting overall adaptation costs to US$47–US$109 billion a year by 2015
Oxfam 2007	Hybrid / Bottom up approach	In contrast to these top-down approaches, Oxfam international (Oxfam, 2007) used a bottom-up approach, estimating adaptation costs by assessing national action plans for adaptation and the costs of adaptation projects initiated by non-government organizations. Assuming average warming of 2C, the report estimated global adaptation costs of at least US$50 billion a year: US$7.5 billion a year to support adaptation efforts initiated by nongovernmental organizations, US$8–US$33 billion a year to meet the costs of the most urgent adaptation measures being proposed under the national action plans for adaptation, and US$5–US$15 billion a year to address unknown and unexpected impacts. Though richer in the range of potential adaptation measures, this methodology uses a small and likely unrepresentative sample of projects and countries to generalize to all developing countries.

At national level, an example of use of this method is the National Economic and Environmental Development Study (NEEDS 2011) in Pakistan, in the Himalayan River Basin. Owing to the lack of data on climate change and adaptation, especially at the individual sector level, the study adopts a top-down analysis using macro indicators and other relevant local data. Three distinct methods applied to estimate the cost of adaptation based on the IFF are:

1- Derivation based upon GDP

This method uses the IFF based approach of estimating adaptation costs as a percentage of national GDP ranging from 4% in 2010 down to 1.5% in 2040 (anchored on estimates of 1.5% -20% of GDP from Stern 2007 and World Bank EACC 2010). The sliding scale is used as adaptive capacity of the population is expected to increase as the economy develops. The total adaptation costs are expected at USD$ 10.7 billion per year.

2- Per Capita based adaptation

This method uses a linear approach of fixing a certain percentage of the per capita income as adaptation costs and then projected it to 2050. The study uses 5% of the Pakistan GNP of $800 in 2010 as the anchor figure that works out to $40 per person. Multiplying this figure with the projected populations gives the adaptation cost. The study takes a lower end of the range by using the World Bank CSIRO estimate of $18.7 and dividing it by the south Asian population of 1.44 billion to arrive at the estimate of $13 per person.

3- Estimates based on disaster modeling

This method derives adaptation costs estimates from past climate related disasters such as floods and droughts in Pakistan. During past 40 years, Pakistan has faced several extreme events out of which majority are climate related. According World Bank estimates, the total damage costs for climate related events from 1990 – 2010 is estimated at US$ 13.27 billion.

3.2 Cost-Benefit Analysis (CBA)

Cost-benefit analysis (CBA) of climate change adaptation actions has been crucial in designing effective local-level adaptation strategies, and generating information that feeds into national and global climate policy agreements. Identifying which effects of climate change are relevant to particular sectors and formulating adaptive response options is also useful for developing local action plans, which in turn support informed future responses (Sachs *et al*., 1999; Stage, 2010). This method has been applied in number of different geographical areas and climatic situation ranging from policy to specific project evaluations. In simple terms, CBA identifies, quantifies and adds all the positive factors (benefits), and then identifies, quantifies and subtracts all the negatives (costs). The difference between the two indicates whether it is advisable to pursue the planned action. Decisions are determined by indicators such as net present values, benefit/cost ratios, internal rate of return and payback period. This method is relevant when both cost and benefits are available in monetary terms. Where either the benefits or the cost cannot be quantified into monetary terms, this method cannot be used as it strictly depends on monetary values of the cost and benefits.

BOX 1: LIMITATIONS OF CBA

a) A limitation of CBA is that it requires all benefits to be measured and expressed in monetary terms and that there is a particular emphasis on efficiency.

b) CBA does not address those equity considerations related to the distribution of the costs and benefits of adaptation options across stakeholder groups, for example, by not including whether those who benefit from the policy can afford to pay for it.

c) The argument that projects or policies with the best Benefit Cost Ratio are socially desirable rests on the assumption that those who gain can in principle compensate those negatively impacted by a project or policy, and still be better off. However, whether such compensation actually takes place is dependent upon the design of the adaptation policy.

d) Another complexity of CBA is that it must monetize categories of costs and benefits that are experienced at different times. This entails the need for discounting costs and benefits incurred in the future to compute their present value, but doing so requires choosing a discount rate with some difficulties.

Source: UNFCCC, 2012

Steps in assessing adaptation options using cost -benefit analysis as used in climate change adaptation assessments:

i. Agree on the adaptation objective and identify potential adaptation options.
ii. Establish a baseline.
iii. Quantify and aggregate the costs over a specific time period.
iv. Quantify and aggregate the benefits over a specific time period.

v. Compare the aggregated costs and benefits.
   - The net present value (NPV),
   - The benefit-cost ratio (BCR),
   - The internal rate of return (IRR.

This method has been applied extensively across all the three hot spots from policy evaluation to specific project assessment. Annex 1 provides case studies in the semi-arid areas of Kenya and the river basin of Brahmaputra and Ganges.

3.3 Cost-Effectiveness Analysis (CEA).

Cost Effective Analysis (CEA) is applied in assessing adaptation options in areas where adaptation benefits are difficult to express in monetary terms, including human health, freshwater systems, extreme weather events, and biodiversity and ecosystem services; but where costs can be quantified. Cost-effectiveness analysis (CEA) is used to find the least costly adaptation option or options for meeting selected physical targets. Given that CEA is performed when the objectives of the adaptation measures have been identified and the remaining task is to find the lowest-cost option for meeting these objectives, it does not evaluate whether the measure is justified (e.g. by generating a certain benefit-cost ratio or IRR) (UNFCCC, 2012).

Box 2: Strengths and weaknesses of CEA

CEA is a useful alternative to CBA in areas where benefits cannot be quantified monetarily to compare alternative adaptation options with a view to identifying the option which can reach a well-defined objective in the most cost effective way. However, CEA is often not used as a standalone tool for decision support as the benefits are defined in one single dimension only (e.g. cost-effectiveness). Other dimensions such as equity, feasibility or co-benefits are not considered in the primary analysis but could be considered during the selection process of the chosen options. For example, issues such as awareness-raising, gender or networking were considered in parallel.

Source: UNFCCC, 2012

The steps in CEA are :

i. Agree on the adaptation objective and identify potential adaptation options.
ii. Establish a baseline.
iii. Quantify and aggregate the various costs.
iv. Determine the effectiveness.
v. Compare the cost effectiveness of the different options.

An example of an application of this method is in the Nepal where CEA has been used in estimating cost for the NAPA and LAPA. Box below summaries the Nepal case study.

Box 3 : National Adaptation Programmes of Action (NAPA)- Nepal 2010 (Nepal, 2010)

The NAPA is defined as “a strategic tool to assess climate vulnerability, and systematically respond by developing appropriate adaptation measures”. Simply NAPA is a means of prioritizing urgent and immediate adaptation actions at national level. The Nepal NAPA framework was developed by the Ministry of Environment – Nepal’s climate change focal point - with support from the Embassy of Denmark, DFID, Global Environment Facility (GEF) and UNDP-Nepal. The NAPA was ratified by the Government of Nepal in 2010 and was structured according to decision 29/CP.7 and the guidelines developed by the Least Developed Countries Expert Group (LEG) under UNFCCC. The Government of Nepal expects NAPA to serve as a guiding document for all future climate change initiatives in Nepal.

The NAPA developed used six thematic working groups (TWG): Agriculture and Food Security; Forests and Biodiversity; Water Resources and Energy; Climate-induced Disasters; Public Health; and Urban Health and Infrastructure. Starting with broad literature reviews, consultations and on ground assessment, broadly the NAPA adopted the following steps:

Identification of impacts of climate change on priority six major area themes

Prioritization of adaptation options using multi-criteria analysis

Identification of key adaptation needs, existing adaptation practices and options

Grouping of urgent and immediate responses into nine integrated projects

Costing of the nine portfolios. Total cost estimated at US$ 350 million

The NAPA document does not carry out an economic analysis of adaptation for Nepal. It does provide the breakdown of costs for implementation of each of the nine portfolios of action. The actual methodology and steps for costing are not clearly specified in the NAPA document but it mentions use of cost effectiveness as one of the criteria for selection of adaptation priorities. The cost effectiveness criteria includes:

Use of Input Output Ratios

Multiplier effects of investment

Potential to mobilise local resources

Sustainability (expansion potential)

Potential to generate additional resources

Since the Nepal NAPA does not explicitly discuss the costing methodology used, the guiding document used in the preparation of the NAPA- “Guidelines for the preparation of National Adaptation Programme of Action” issued by the Least Developed Countries Expert Group in 2002 (UNFCCC, 2002) is consulted.

The LDC guidelines suggest using CBA, CEA and MCA - the three main costing techniques for selection and prioritization of activities for inclusion in the NAPA. It suggests that because of the diversity of options, one single method cannot handle the costing and combination of techniques can be used. The methods recommended are similar to those used in other development initiative. These costing techniques are discussed in this report.

3.4 Multi-Criteria Analysis (MCA).

This method is used when there a number of objectives to be attained, but very few or even all objectives cannot be monetised. Multi-criteria analysis (MCA) allows assessment of different adaptation options against a number of criteria. Each criterion is given a weighting. Using this weighting, an overall score for each adaptation option is obtained. The adaptation option with the highest score is selected. MCA offers an alternative for the assessment of adaptation options when only partial data is available, when cultural and ecological considerations are difficult to quantify and when the monetary benefit or effectiveness are only two of many criteria. MCA essentially involves defining a framework to integrate different decision criteria in a quantitative analysis without assigning monetary values to all factors. MCA was one of the recommended methods for least developed countries (LDCs) in preparing their NAPAs (UNFCCC, 2012).

Box 4: Strengths and weaknesses of the Multi-criteria analysis

Strengths of MCA

- MCA helps to structure the challenge of selecting an adaptation option by outlining the various objectives of a programme and the criteria to measure those objectives in a transparent manner.
- MCA can accommodate quantitative as well as qualitative information and helps to communicate the strengths and weaknesses of each adaptation option.
- MCA allows for direct stakeholder engagement by allowing the beneficiaries of the adaptation options to be involved in choosing them, which is crucial for creating ownership and subsequent implementation of the adaptation measures.

Weaknesses of MCA

- Difficulties associated with MCA include assigning weights, especially if the number of criteria is large and the criteria are very different in character, and standardizing scores, which leads to losing some information that could be valuable in later stages. Explicit statement of the weight assigned to each criterion can enhance public debate.
- Since it is not always easy to reach agreement among stakeholders on criteria and their relative importance, it is advisable to conduct a sensitivity analysis to determine if the ranking is sufficiently robust to withstand scrutiny.

Source: UNFCCC, 2012

The following steps are used in assessing adaptation options using MCA

i. Agree on the adaptation objective and identify potential adaptation options
ii. Agree on the decision criteria.
iii. Score the performance of each adaptation option against each of the criteria.
iv. Assign a weight to criteria to reflect priorities.
v. Rank the options.

The above three methods can be selected based on the simple flow chart diagram (Figure 2). This was developed by the Nairobi work program of UNFCCC in 2010. This simple flow diagram shows that when both cost and benefits can be monetised, the CBA analysis is appropriate. However, when the benefits cannot me monetised, the CEA is more appropriate. Lastly, when objectives of, say adaptation strategy has more than criteria, i.e. other criteria in addition to maximising monetary befits, a MCA is more appropriate.

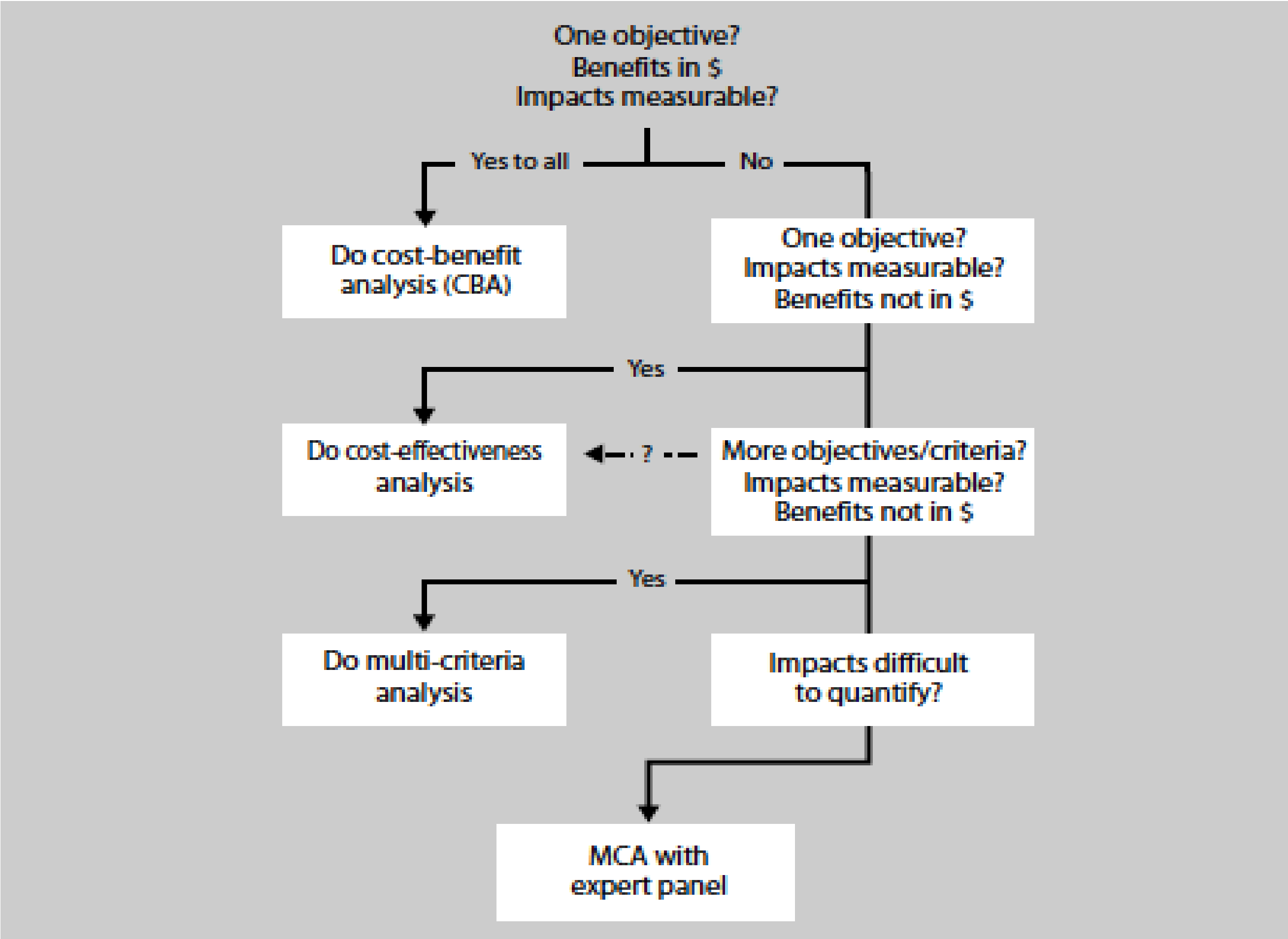


Figure 2: simple flow diagram shows that when both cost and benefits can be monetised
Source: UNFCCC 2010

3.5 Stakeholders focused Cost Benefit Analysis

Stakeholder-focused cost-benefit analysis (SfCBA) can be viewed as a combination of form of CBA and MCA. It basically combines these two methods to take advantage of their strengths. Because decision-making tools are not equally applicable to every group, this larger framework needs to include multiple approaches to ensure that all groups are given sufficient consideration when possible adaptation options are evaluated (Lunduka et al, 2013). SfCBA fulfils a number of purposes. It can be used to:

a) Identify and prioritise adaptation strategies.
b) Adjust the costs and benefits of adaptation, using weights that stakeholders assign to different adaptation strategies.
c) Identify and internalise costs and benefits.
d) Identify and include the non-monetary costs and benefits of adaptation actions.
e) Facilitate negotiations among different stakeholders who would otherwise not interact with each other.

The stakeholders focused cost benefit analysis has six steps and these are

Step 1: Define the adaptation context and purpose of the economic analysis.

Step 2: Assess expected future climatic trends, and use that information to identify the impacts of climate change in the study area.

Step 3: Identify and engage stakeholders.

Step 4: Identify adaptation strategies and actions to include in the analysis.

Step 5: Measure the costs and benefits, and determine how they will be distributed between stakeholders.

Step 6: Ground truth the findings.

The main limitation of the SfCBA is that stakeholders are unlikely able to conceive of the longer-term implications and uncertainties associated with climate change. However, they provide very important and reliable past trends.

[redacted]

Source: Lunduka et al., 2013.

A case study in South Asia (Bangladesh) used this methodology provide very results. In Bangladesh, Khulna city, the main issue was how different stakeholders weight their costs and benefits, and how this weighting could be used to adjust the costs and benefits of adaptation strategies – Box 6.

Box 6 : KHULNA CITY, BANGLADESH

Predicted climate events for Khulna city under future IPCC scenarios A and B show that average monthly temperatures will rise by 1.7°C by 2050 and annual rainfall will increase by 5 per cent, while rainfall intensity (4.3mm/hr) will increase by 4.2 to 5.9 times per year. In addition to rising sea levels, floods are expected to increase and cover almost the whole Khulna area. Nearly 26 of the city's 31 wards are likely to be inundated if the model's predictions are correct. The city's drainage system is expected to be severely affected by floods as it faces the threat of rising sea levels over the next 30 years, higher precipitation in the city area, and increased inflows of water due to rising water levels in surrounding rivers, which are the main drainage channels for the south-west of the country.

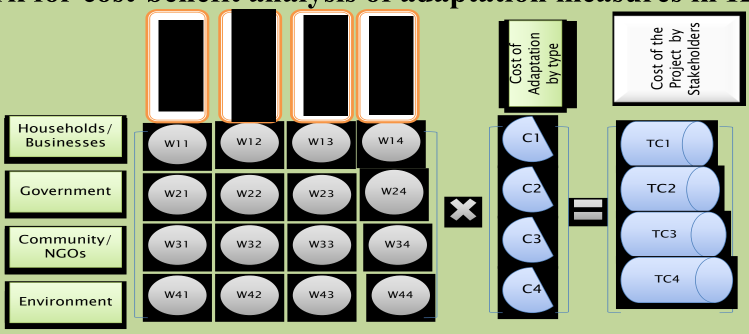
Adaptation strategies

These climate change predictions were used to forecast future drainage blocking in Khulna city, and prepare an adaptation plan to mitigate the effects of climate change on the lives and livelihoods of its millions of inhabitants.

Adaptation activities were classified into four groups:

a) Structural – construction of infrastructures
b) Maintenance – maintaining existing infrastructures in order to deal with climate risks
c) Managerial – requiring changes in the overall management of the city and the roles played by individuals, communities and government institutions
d) Awareness – informing communities and households how to deal with climate risks.

Framework for cost-benefit analysis of adaptation measures in Khulna city



Results of the stakeholder-focused cost-benefit analysis

There was quite a large divergence among the stakeholders in terms of which adaptation measures they preferred. For example, while households preferred only 75 per cent of the structural measures listed in the annex, the government preferred 100 per cent. The community preferred 63 per cent and environmental stakeholders preferred only 25 per cent. The same differences were observed for the repair and maintenance, managerial, and awareness adaptation measures. Community and environment stakeholders seem to prefer the awareness adaptation measures, while households prefer more of a managerial adaptation measure where they also have some say or participation.

3.6 Participatory Social Return on Investment – PSROI

Participatory Social Return on Investment (PSROI) framework values bottom–up cost of climate change adaptation. The PSROI framework does not propose a new valuation technique but recommends a unique participatory approach. PSROI is a structured framework for multi-stakeholder adaptation planning, with participatory processes at community level informing the selection and valuation of appropriate adaptation strategies and interventions.

PSROI aides policy makers in directing funding to initiatives identified and valued by local communities as being in line with their needs and capacities. The PSROI framework builds on the Social Return on Investment (SROI)1 valuation methodology – a modified CBA framework. This measures and accounts for a broader concept of value by incorporating social, environmental and economic costs and benefits. Put simply, it gauges the value created against the initial investment so, for example, an investment of £$100 may return £10 in one year, or a (P)SROI of 10%.

The PSROI four-step valuation framework centres on community participation in the decision making process at each stage of the valuation (Table 2). The community chooses the adaptation theme and intervention, and places a value on that intervention. This valuation, when compared with the potential return of the intervention, can identify key technical and implementation gaps that can be filled to improve the effectiveness of the intervention's design and implementation. The PSROI costing framework can be used by many stakeholders, including donors, local governments, practitioners, extension service providers, private sector suppliers and communities themselves. The PSROI pilot study provides results from the Kenyan field site, Kochiel Village.

The field results show that in the case of Kochiel Village, when the community's estimate of the key input costs and benefits are included, the PSROI valuation drops by 50%. In other words, the community had a much lower perceived value of the intervention than the projected baseline value. The purpose of the comparison of the baseline valuation and community-based valuation is not to choose one result over another, but to quantify and recognize the differences between the two to inform decision-making and appropriate adaptation planning and design. The PSROI framework has been piloted in East and West Africa and South East Asia.

[1] For more information on SROI, visit www.thesroinetwork.org.

Table 3: The PSROI four-step valuation framework and field results using Case Study Site of Kenya

Key steps	Description of methodology	Field results from Kochiel Village, Kenya
Step 1 – Adaptation theme selection	PSROI analysis starts with a participatory approach to identify community-specific environmental challenges and to select appropriate broad adaptation themes such as soil degradation, water issues, etc. Methods can include multi-stakeholder workshops, focus group discussions and individual interviews. Backcasting can be used to select themes, starting with defining a desirable future and working backwards to identify suitable actions in the present.	The community voted for the theme of 'agroforestry' (inter-planting trees with crops) to address the main challenges of soil degradation and income diversification.
Step 2 – Specific intervention designed	An appropriate intervention is selected to match the identified needs of the community. The intervention may be selected from a menu of established and tested interventions, such as World Bank's Sustainable Agricultural Land Management (SALM) practices, or may be newly designed by technical experts.	Under the agroforestry theme, the research team recommended inter-planting of local varieties of trees with crops – a technical intervention to match the community's identified needs.
Step 3 – Baseline valuation	Baseline PSROI valuation of the economic, social and environmental outcomes of the intervention is undertaken based on modified cost-benefit analysis using secondary data from academic literature, industry standards, case studies, key informants etc.	A baseline value of KES (Kenyan Shillings) 47 for each KES 1 invested in the inter-planting intervention was calculated using secondary data (1 GBP = KES 135 – in 2011)
Step 4 – Field testing of PSROI valuation	The baseline valuation of the selected adaptation intervention is validated using community insights generated from detailed interviews. Any discovered costs and benefits are included in the valuation. The testing and feedback process illuminates the community's perceptions of the intervention and allows for better matching of the intervention's design and selection with local needs.	The value decreased by approximately 50% (from KES 47 to KES 26 for each KES 1 invested) when data from field interviews with farmers were incorporated.

Source: Chaudhury, 2011, Sova et al., 2012.

4.0 ECONOMIC ASSESSMENT OF CLIMATE CHANGE ADAPTATION

Economic methods of climate change adaptation have been applied to model behaviour given climate change and the different resources that are available and used as input into the climate change adaptation strategies. Economic methods have been used more in agriculture in the arid and dry land where they have been used to study human behaviour in crop and livestock production. They have been mainly used to assess and understand behaviour of individual farmers in adapting to climate change.

The major crucial issue that is attempted in economic methodologies is linking the specific adaptation strategies to a number of economic factors. These economic factors most time tend to be endogenous i.e. the factors can influence each other. For example, level of income of a household may influences the ability of a household to buy and utilise improved hybrid seeds in crop production. However, due to the higher yields from the improved high crop varieties, the household can also get higher income. The causality-effect can go either way. Therefore, to isolate the influence of such economic factors e.g. improved seeds, complex and advanced econometric technics have been used. This section highlights some complex technics that have been used in assessing adaptation strategies mainly in agriculture with specific case studies in Semi-arid lands of Africa. This section outlines the main issues tackled in the existing literature and provides an understanding of three main methodologies extensively used in the economics literature to assess the impact on climate change on agriculture: (i) the Integrated Assessment Models (IAMs) (ii) the Ricardian Approach and the (iii) Structural Approach. Annex 2 present seminar papers of the three methodologies and annex 3 presents other studies that have used these methods mainly in sub Saharan Africa.

4.1 Integrated Assessment Models (IAMs) -Computable General Equilibrium Model

Integrated assessment modelling studies typically link climate data from climate models with crop growth models to simulate impacts of climate change on crop productivity and then input these productivity changes into economic models that determine economic impacts. These modelling studies typically account for possible autonomous farm-level adaptations by adjusting planting dates and genetic characteristics of crop varieties in crop growth models, and by using economic models that reallocate land to crops according to changes in profitability (Antle and Capalbo, 2010). IAMs include the full range of cause and effect in climate change ("end to end" modelling) (Nordhaus, 2013). Kelly and Kolstad, 1999 define IAM as any model which combines scientific and socio-economic aspects of climate change primarily for the purpose of assessing policy options for climate change control. These models try to take into account the complex interactions between natural and social sciences, linking knowledge of different domains into a single framework (Figure 3).[2] Given this common denominator, several IAMs have been generated to date, which may differ in their structures, algorithms, and assumptions.[3] IAMs have been particularly useful to analyse environmental problems, which are intrinsically ones having strong roots in the natural sciences and require social and policy sciences to solve in an effective and efficient manner (Nordhaus, 2013). For example, the Stern Review (Stern, 2007) uses IAMs to estimate the economic impacts of climate change. Their estimates indicate that the total impact of climate change on the economy is likely to be higher than suggested by the previous literature.[4] Financing for adaptation is a core element in the ongoing international negotiations on climate change. This has motivated a number of recent global and regional estimates of adaptation costs (Agrawala et al., 2011). The major goals of these models are to (1) project trends in consistent manner, (2) assess costs and benefits of climate policies and (3) estimate the carbon price and efficient emissions reductions (Nordhaus, 2013).[5] Figure 3 provides a schematic of IAMs. The integrated assessment models may incorporate, among others, results produced from *agro-economic simulation models*,[6] in order to predict the scale and range of impacts related to the agriculture sector. The two main drawbacks of using IAMs is that most of them have a relatively high degree of computational complexity, and that results may vary depending on the underlying assumptions, rising scope for results' uncertainty.

2 Several of the current IAMs grew out of the energy models of the 1970s and 1980s (Nordhaus, 2013).

3 Kolstad (1998) and Kelly and Kolstad (1999) review 21 different IAMS, developed from 1992 to 1996.

4 Some economists have criticized the Stern Review as recommendations depend decisively on the assumption on the discount rate (Nordhaud, 2007; Weitzman, 2007). The debate over the appropriate rate of time discount highlights that results from IAMs are driven by the critical assumptions of the models, which is one of the main critics to the IAMs.

5 Weyant, et. al., 1996 list three similar goals of IAMs: (1) assess climate change control policies, (2) constructively force multiple dimensions of the climate change problem into the same framework, and (3) quantify the relative importance of climate change in the context of other environmental and non-environmental problems facing mankind.

6 See for example, the agro-economic models developed by Rosenzweig and Parry, 1994; Darwin et al., 1994, Reilly et al., 1994, Dinar and Beach, 1998, along with the models listed in footnote 2. Other methodologies estimating the impacts of climate change on crops productivity can be used as well.

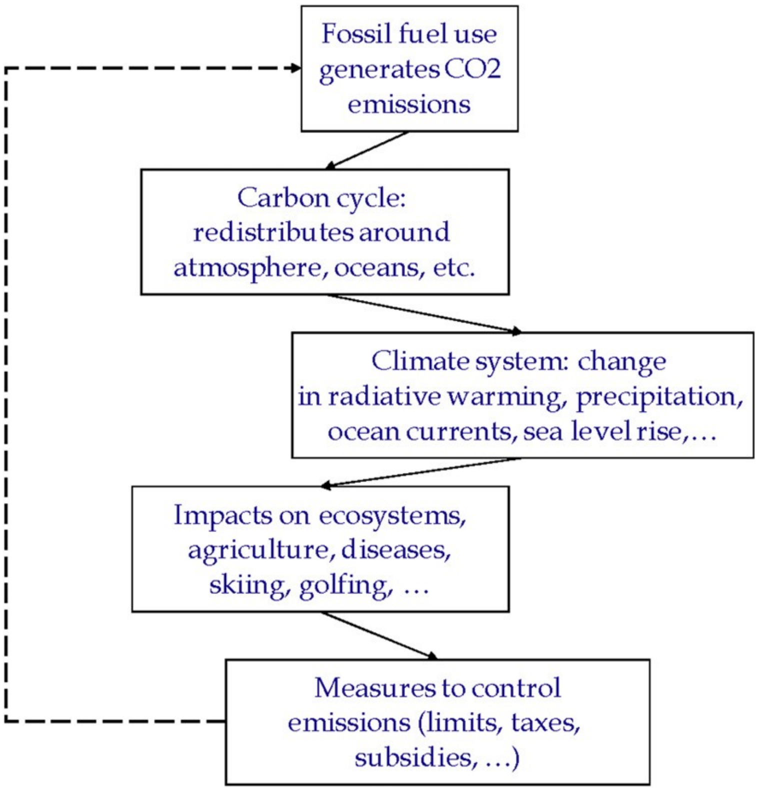


Figure 3: Schematic flow chart of a full IAM for climate change science, economics and policy. *Source*: Nordhaus, 2013

Box :Integrated Assessment Models –The World Bank Study

In 2008, The World Bank initiated a study The Economics of Adaptation to Climate Change (EACC). This study was aimed at developing a global estimate of adaptation costs for informing the international community's efforts in the climate negotiations, and to help decision-makers in developing countries assess the risks posed by climate change and design national strategies for adaptation. EACC study used Integrated Assessment Models (IAM) to bring together a wide set of areas, methods, and studies within a single analysis. Within economic analysis of adaptation, IAM use complex algorithms to predict the impact of climate data on selected socioeconomic models. The World Bank study was done following two parallel tracks (1) a global track—a top-down approach, in which national databases were used to generate aggregate estimates at a global scale, drawing on a wide variety of sector studies; and (2) a country level track—a bottom-up approach, in which sub-national data were aggregated to generate estimates at economy-wide, sectoral, and local levels (World Bank, 2010). Specific steps taken in the study are presented in Box 6.

The most famous family of IAMs is the Dynamic Integrated model of Climate and the Economy (DICE), which is a globally aggregated model, and the Regional Integrated model of Climate and the Economy (RICE), first developed by Nordhaus (1992, 1994a).[7] The DICE/RICE models are primarily designed as policy optimization models.[8] Thus, they assume that economic and climate policies should be designed to optimize the flow of consumption over time (Nordhaus, 1992, 1994a, 2008, 2010; Nordhaus and Boyer, 2000). The latest published versions are the RICE-2010 and DICE-2010 model (Nordhaus, 2013). The following definition is provided in Nordhaus 2013:

> The DICE model views the economics of climate change from the perspective of neoclassical economic growth theory. In this approach, economies make investments in capital, education and technologies, thereby reducing consumption today, in order to increase consumption in the future. This model extends this approach by including the "natural capital"

of the climate system as an additional kind of capital stock. In other words, it views concentrations of greenhouse gases as negative natural capital, and emissions reductions as investments that raise the future quantity of natural capital (or reduce the negative capital). By devoting output to emissions reductions, economies reduce consumption today but prevent economically harmful climate change and thereby increase consumption possibilities in the future (Nordhaus, 2013). In the DICE/RICE models policies are chosen to maximize a social welfare function, W (Equation 1) utility takes the form of a constant elasticity utility function (Equation 2).

$$W = \sum_{t=1}^{Tmax} U[c(t), L(t)]R(t) \tag{1}$$

This function is the discounted sum of the population weighted utility of per capita consumption, where c is per capita consumption, L is population and $R(t)$ is the discount factor.

$$U[c(t), L(t)] = L(t)\frac{c(t)^{1-\alpha}}{(1-\alpha)} \tag{2}$$

The economic well-being of future generations is discounted as follows:

$$R(t) = (1+\rho)^{-t} \tag{3}$$

Where $R(t)$ is the discount factor, ρ is the pure rate of social time preference, (i.e.: the discount rate which provides the welfare weights on the utilities of different generations). The evolution of output over time is represented by function including climate damages and abatement costs.[9,10] The basic assumption is that the damages rise non-linearly from modest levels, with the extent of climate change. In DICE-2010, for example, the aggregate damage curve is built up from estimates of the damages for the 12 regions, including assumed sectorial change and underlying income elasticity of different outputs. The impacts of climate change on agriculture and other sectors are included through a "damage function" which estimates damages to major sectors.

4.2 The Ricardian Approach

Many of the empirical analysis undertaken to date to assess the impact of climate changes on agricultural yields rely upon the Ricardian method developed by Mendelsohn, Nordhaus, and Shaw (MNS), 1994. In its traditional application, this approach is based on the cross-sectional analysis of different performances of the economic unit under consideration (e.g. the farm) across a given territory (e.g. the country, region or basin). Performance is

9 The production process is represented though Cobb-Douglas function.

10 However, there is criticism on the estimations of damages from climate change over the long run.

measured by land values and/or farm revenues, analyzing the impact of climate variables on these (e.g.: Dinar et al.1998; Mall et al. 2006; Cline, 2007; Seo and Mendelsohn, 2008a, 2008b, Deressa and Hassan 2009). MNS, 1994 develop this method to overcome their main critique to the production function approach, at first developed by Just and Pope, 1978 and 1979. Notably, the authors claimed that the production function approach consistently overestimates production damage by omitting the variety of adaptations that farmers customarily make in response to changing economic or environmental conditions.[11] In particular, they highlight the role of adaptation actions in which new activities displace activities no longer (or less) profitable due to changes in climate variables.

Figure 4 illustrates the basic intuition of the Ricardian approach developed by MNS, 1994. The figure shows how the value of wheat, corn, grazing and retirement homes may look as a function of temperature.[12] Taking the example proposed by the authors, when the temperature rises above point C, adaptive and profit maximizing farmers will switch from wheat to corn. The production function approach may associate an increase in temperature to a fall in activity's value to F, while in reality the local farmer has switched the production from wheat to a crop more resistant to temperature increase. The implementation of this adaptation strategy would imply a value of activity corresponding to point D instead of point F (MNS, 1994 p. 754).

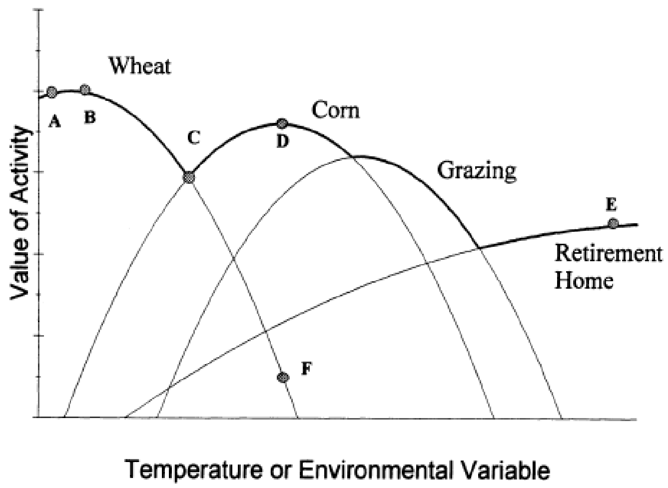


Figure 4: Bias in Production Function Studies, illustrative graph proposed by Mendelsohn Nordhaus, and Shaw, 1994. *Source:* Mendelsohn, Nordhaus, and Shaw 1994 p. 754

11 Mendelsohn et al., 1994 p .754.

12 Value is estimated as net rent in a given location or farm value.

One of the weaknesses of the Ricardian model is the omitted variable problem. The model does not take time-independent location-specific factors such as unobservable skills of farmers and soil quality into account (Barnwal and Kotani, 2010). Other assumptions of the standard Ricardian model criticized in the literature are that of constant prices (Cline, 1996) and costless adjustment to climate change related effects (Quiggin and Horowitz, 1999). Another critic is that although the standard Ricardian model captures adaptation in its measure of impacts, it does not provide any insight into how farmers adapt (Seo and Mendelsohn, 2008b). To overcome this issue, Seo and Mendelsohn, 2008b developed the so called *Structural Ricardian Model*, which explicitly models the underlying endogenous decisions by farmers. This approach compares, through a cross section analysis, the choices of farmers who face different conditions, thus uncovering how farmers adapt. Conditional incomes, using a Ricardian approach, are then estimated for each choice made by each farmer (Seo and Mendelsohn, 2008b). Schlenker and Roberts, 2009 combine historical crop production and weather data in Sub-Saharan Africa into a panel analysis. They highlight that this approach can take care of the omitted variable problem by using Fixed Effects capturing all time-invariant effects for which data are not available (e.g. soil quality) and conclude that a robust model of yield response to climate change emerges for several key African crops. Massetti and Mendelshon, 2011 argue that if panel data is available for the Ricardian method, one should use panel data methods that properly specify which coefficients should vary over time and which should remain stable. The authors claim that repeated cross sections are the wrong estimation method.[13] Kurukulasuriya et al., 2011 apply this method using data from farmers across eleven African countries, aiming at addressing the endogeneity of irrigation. The authors claim that impact models that fail to account for endogenous irrigation are biased.

4.3 The Structural Approach

Key feature of the Ricardian approach presented above is that assume that farmers adapt optimally to climate change. Besides, determining the impact of climatic variables on welfare, it is necessary to understand how the set of strategies implemented in the field by the farmers (e.g., changing crops, adopting new technologies or, soil conservation measures) in response to long term changes in environmental conditions can affect productivity or revenues (Di Falco et al. 2011).[14] In other words, the adaptation choices need to be identified. A growing body of literature has focused on adaptation. In essence, what farmers can do in order to cope with

13 Refer to Massetti and Mendelshon (2011) for detaild justifications of this claim.

[14] It should be noted that the original Ricardian approach assumes that markets function properly. Access to inputs, credit or technology may however be not "perfect."

climate change? Moreover, what are the implications of the adaptation strategy chosen? To deal with this question the literature has provided the so called structural approach. This entails the specification of the adaptation problem in two stages. First stage, estimate what affects the probability of adopting a given adaptation strategy. In the second stage the implications (e.g., productivity, revenues etc.) of such strategy are then estimated. This method is very general as it allows investigating the role of one or more adaptation strategies. It also allows constructing a counterfactual. It is, however, a method that requires quite large datasets (ideally with observations at the plot level to control for unobservable heterogeneity). It also requires exclusion restrictions. That means that some variables that enter the first stage should not enter the second stage. This condition may be in practice difficult to fulfill.

Stage I – Selection Model of Climate Change Adaptation Strategies

In the first stage, let A^* be the latent variable that captures the expected net revenues from implementing strategy j ($j = 1 \ldots M$) with respect to implementing any other strategy k. We specify the latent variable as

(1) $A_{ij}^* = \bar{V}_{ij} + \eta_{ij} = \mathbf{Z_i \alpha_j} + \eta_{ij}$

$$\text{with } A_i = \begin{cases} 1 \quad iff \quad A_{i1}^* > \max\limits_{k \neq 1}(A_{ik}^*) \text{ or } \varepsilon_{i1} < 0 \\ \vdots \qquad\quad \vdots \qquad\qquad\qquad \vdots \\ M \; iff \quad A_{iM}^* > \max\limits_{k \neq M}(A_{ik}^*) \text{ or } \varepsilon_{iM} < 0 \end{cases},$$

that is farm household i will choose strategy j in response to long term changes in mean temperature and rainfall if strategy j provides expected net revenues greater than any other strategy $k \neq j$, i.e., if $\varepsilon_{ij} = \max\limits_{k \neq j}(A_{ik}^* - A_{ij}^*) < 0$. Equation (1) includes a deterministic component ($\bar{V}_{ij} = \mathbf{Z_i \alpha_j}$), and an idiosyncratic unobserved stochastic component η_{ij}. The latter captures all the variables that are relevant to the farm household's decision maker but are unknown to the researcher such as skills or motivation. It can be interpreted as the unobserved individual propensity to adapt.

The deterministic component $\bar{V}_{ij}$ depends on factors $\mathbf{Z_i}$ that affect the likelihood of choosing strategy j such as farmer head's and farm household's characteristics (e.g., age, gender, education, marital status, and farm household size), the presence of assets such as animals, the characteristics of the operating farm (e.g., soil fertility and erosion), past climatic factors[i] (e.g., 1970 – 2000 mean rainfall and temperature), the agroecological zone of the farm household (Dega, Kolla, and WeynaDega), and the experience of previous extreme weather events such as droughts, floods, and hailstorms. Experience in farming is approximated by age and education.

Furthermore, farm households may have access to information on farming strategies before they can consider adopting them, as well as information about climate. Since extension services are one important source of information for farmers, we use access to government and farmer-to-farmer extensions as measures of access to information. We also control for tree planting. Besides providing agroecological benefits, trees provide a very important function: they are a proxy for land tenure security. This has been observed in previous research on sub-Saharan Africa. Perennial crops that can be a way of strengthen claims to land and show to the rest of the community a continuous use of the resource (Sjaastad and Bromley 1997; Besley 1995). As Platteau (1992) noted "the best way of exercising control over land is to plant trees" (p. 166). This view is also documented in Ethiopia by Shiferaw and Holden (1998), Gebremedhin and Swinton (2003), Ayalneh *et al.* (2006) and Mekonnen (2009).[ii]

It is assumed that the covariate vector $\mathbf{Z_i}$ is uncorrelated with the idiosyncratic unobserved stochastic component η_{ij}, i.e., $E(\eta_{ij}|\mathbf{Z_i})=0$. Under the assumption that η_{ij} are independent and identically Gumbel distributed, that is under the Independence of Irrelevant Alternatives (IIA) hypothesis, selection model (1) leads to a multinomial logit model (McFadden 1973) where the probability of choosing strategy j (P_{ij}) is

$$(2)\;\; P_{ij}=P(\varepsilon_{ij}<0|\mathbf{Z_i})=\frac{\exp(\mathbf{Z_i}\boldsymbol{\alpha}_\mathbf{j})}{\sum_{k=1}^{M}\exp(\mathbf{Z_i}\boldsymbol{\alpha}_\mathbf{k})}.$$

Stage II – Multinomial Endogenous Switching Regression Model

In the second stage, we estimate a multinomial endogenous switching regression model to investigate the impact of each strategy on net revenues by applying Bourguignon, Fournier, and Gurgand (2007) selection bias correction model. Our model implies that farm households face a total of M regimes (one regime per strategy, where $j=1$ is the reference category "non-adapting"). We have a net revenue equation for each possible regime j defined as:

$$
\begin{array}{lll}
(3a) & \text{Regime 1:} & y_{i1} = \mathbf{X_i \beta_1} + u_{i1} \quad if \quad A_i = 1 \\
\vdots & \vdots & \vdots \\
(3m) & \text{Regime M:} & y_{iM} = \mathbf{X_i \beta_M} + u_{iM} \quad if \quad A_i = M
\end{array}
$$

where y_{ji} is the net revenue per hectare of farm household i in regime j, ($j = 1 \ldots M$), and $\mathbf{X_i}$ represents a vector of inputs (e.g., seeds, fertilizers, manure, and labour), farmer head's and farm household's characteristics, soil's characteristics, and the past climatic factors included in $\mathbf{Z_i}$; u_{ij} represents the unobserved stochastic component, which verifies $E(u_{ij} | \mathbf{X_i}, \mathbf{Z_i}) = 0$ and $V(u_{ij} | \mathbf{X_i}, \mathbf{Z_i}) = \sigma_j^2$. For each sample observation only one among the M dependent variables net revenues is observed. When estimating an OLS model, the net revenues equations (3*a*)-(3*m*) are estimated separately. However, if the error terms of the selection model (1) η_{ij} are correlated with the error terms u_{ij} of the net revenues functions (3*a*)-(3*m*), the expected values of u_{ij} conditional on the sample selection are nonzero, and the OLS estimates will be inconsistent. To correct for the potential inconsistency, we employ the model by Bourguignon et al. (2007), which takes into account the correlation between the error terms η_{ij} from the multinomial logit model estimated in the first stage and the error terms from each net revenue equation u_{ij}. We refer to this model as a "multinomial endogenous switching regression model" following the terminology of Maddala and Nelson (1975) extended to the multinomial case.

4.4 Adaptation as a risk management tool

One consequence of climate change in sub Saharan Africa is that farmers will be more exposed to environmental risk. More erratic and scarce rainfall and higher temperature imply that farmers will be facing a larger extent of uncertainty. Ethiopia is a prime example. Rainfall variability and associated drought have been major causes of food shortage and famine in Ethiopia. The structural approach can be used in conjunction with risk management methods to identify the role of adaptation on risk exposure. This combined approach can be used to study the risk implications of adaptation to climate change, capturing a fuller extent of risk exposure than previous methods focusing on impact on mean and variance of agricultural yields. The implications of risk exposure on agricultural production has been traditionally studied in the context of the stochastic production function approach developed by Just and Pope (JP) (1978, 1979). This was developed to estimate production risk econometrically and allows risk increasing as well as risk decreasing inputs. This production function consists of two separate general functions: one specifies the effect of inputs on the mean of output and another specifies the effect of input on the variance of output.[15,16] One of the criticisms of the production function approach is that it overestimates production damages by omitting the variety of adaptations that farmers customarily make in response to changing economic and environmental conditions.[17] Another weakness of this approach is that although it allows to investigate how changes in factors like temperature and climate influence the mean and variance of the related items like crop yields, it also restricts the effects of inputs across higher order moments in the way traditional econometric models do across all moments (Chen and McCarl, 2001; Groom et al. 2008). Antle (1983, 1987) criticizes previous production function specifications, as they are not adequate representations of the probability distribution of output because they impose arbitrary restrictions on the moments of output that result in arbitrary restrictions on the behavior of the firm.[18] The structural approach builds on the moment based specification of the stochastic production function (Antle, 1983 and 1987; Antle and Goodger, 1984; Chavas, 2004). Thus it deals with the second criticism, as it shows the importance to consider higher moments, in particular skewness, in the analysis of climate related risk in agricultural production. The use of the third moment of the crop yield distribution (skewness) overcomes one of the problems of considering only the variance of crop yields, which does not distinguish between unexpected good and unexpected bad events. Notably, skewness approximate downside risk exposure: if the skewness of yield increases then it means that downside risk exposure decreases, that is the probability of crop failure decreases (Di Falco and Chavas, 2009). Thus although reducing downside risk does not provide information on the role of adaptation on farmer's welfare, it decreases the asymmetry (i.e. the skewness) of the risk distribution toward high outcome, holding both means and variance constant (Menezes at al., 1980; Di Falco and Chavas, 2008 and 2009).

Several contributions in this literature group use a flexible estimation approach where uncertainty is considered by using moments of the profit distribution as determinant of farmers' decision regarding the input mix. Through the moment based approach, the researcher avoids making strong assumptions on technology parameters, farmers' preferences, and the distribution of the error term. The following equations illustrate the econometric specification for the stochastic production function $y = g(X, v)$ where y is the output produced by a risk

15 Just and Pope, 1979 p. 278

16 The JP production function has mostly been estimated econometrically by Three Step Feasible Generalized Least Square (FGLS) and Maximum Likelihood (MLE) procedures. FGLS and MLE procedures are the ones described and used by the authors themselves (Just and Pope 1978, 1979) for example for assessing the crops yields response to fertilizers' usage.

17 Mendelsohn et al., 1994 p .754.

18 Antle, 1983 p. 192.

averse farmer, X is the vector of inputs and v is a vector of random variables representing risk (i.e. uncontrollable factors affecting output or other measure such as revenue, depending how the utility function of the farmer is represented).[19] Those variables can include climate related variables, prices etc.

The moment based approach consists in assessing the probability distribution of this stochastic production function $g(X, v)$ by representing risk through the moments of the same function. Equation 1 proposes an econometric specification for $g(X, v)$:

$$g(X, v) = f_1(X, \beta_1) + u$$

Where $f_1(X\beta_1) \equiv E[g(X, v)]$ is the first central moment (e.g. the mean) of $g(X, v)$ and $u = g(X, v) - f_1(X, \beta_1)$ is a random variable with mean zero and whose distribution is exogenous to farmers' action. The higher moments of $g(X, v)$ are given by:

$$E\{[g(X, v) - f_1(X, \beta_1)]^k | X\} = f_k(X, \beta_k)$$

For k=2, 3. This implies that $f_2(X\beta_2)$ is the second central moment (the variance) and $f_3(X\beta_3)$ is the third central moment (the skewness).[20] This provides a flexible representation of the impacts of inputs X on the distribution of output under production uncertainty. It goes beyond standard mean–variance analysis by considering the effects of skewness and downside risk exposure. An increase in skewness implies a decrease in downside risk exposure (e.g., a reduction in the probability of crop failure). Through the estimation of functions whose dependent variables are $f_2(X\beta_2)$ and $f_3(X\beta_3)$ it is possible to assess the impact of climatic factors (e.g. temperature, rainfall and wind), inputs (e.g. seeds, fertilizers, plant protection, irrigation water and labor) on the distribution of output under production uncertainty.

This can used to in place of the regimes 3 showed before. A recent application by Di Falco and Veronesi uses in fact this intuition and estimate the endogenous switching regression model of downside risk exposure where farmers face two regimes (1) to adapt, and (2) not to adapt defined as follows:

(4a) Regime 1: $y_{1i} = \mathbf{x_{1i}\beta_1} + \varepsilon_{1i} \quad if \quad A_i = 1$

19 The notation and terminology in this section follows Di Falco and Chavas, 2009.

20 Refer to Kim and Chavas (2003) for a detailed description of the so called sequential estimation procedure. This is used in the literature to derive the first and higher moments (mostly the variance, skewness and kurtosis) of the distribution of profit (or crops yields, depending on the variable considered in the maximization program of the farmer).

(4b) Regime 2: $y_{2i} = \mathbf{x_{2i}}\boldsymbol{\beta}_2 + \varepsilon_{2i} \quad if \quad A_i = 0$

where y_i is the third central moment $f_3(\mathbf{x}, \boldsymbol{\beta}_3)$ of production function (2) in regimes 1 and 2, i.e., the skewness; and $\mathbf{x_i}$ represents a vector of the past climatic factors, inputs, assets, farm head's, farm household's and soil's characteristics included in **z**.

5.0 MARKET ANALYSIS OF ECOSYSTEM SERVICE PROVISION

Application of ecosystem assessment methods into climate change economics has followed environmental economics methodologies. Even though the methodologies in Environmental economics are well developed, their use still faces a number of critics (see table 3 below) mainly because ecosystem goods are commonly not available on the market. Therefore, their values are based on indirect methods or stated values (hypothetical values). It should also be noted that due to this complexity in methodological approach, very few studies have included the ecosystem in their analysis of economics of climate change adaptation.

In most of studies devoted to environment issue, environment quality is perceived as a luxury good that becomes of concern only when basic needs have been met. Thus, poor countries have been perceived to be less likely to exhibit a strong demand for environmental quality than developed ones. However, many studies that have been done in developing countries have neglected the influence of social capital. In fact social capital can positively affect the Willingness to Pay (WTP) i.e. the maximum amount a person would be willing to pay, sacrifice or exchange in order to receive a good or to avoid something undesired, such as pollution, through two main channels, namely information effect and peer effect. Thus, even in low income countries, the WTP for environmental goods can be very high. Using five waves of the World Value Survey (1981-2007) on thirteen African countries, Yogo, 2011 showed that poor countries can exhibit a strong demand for environment quality and therefore a high WTP for environment preservation. Specifically, he argued that social capital as measured by generalized trust has a positive and significant effect on the WTP for environment.

Two main approaches are have been used to evaluate environmental goods. These are

1) Revealed preference- this methods uses real values of goods and services that are available on the market as proxies (or indicators) of values of environmental (including ecosystem services) goods.
2) States preference- These are methods that asks people their values of the environmental good. This is done by creating a hypothetical markets where the individuals are asked how much they are willing to pay or accept compensation for a particular environment good or service.

Table 4: Main economic valuation techniques for ecosystem services

Methodology	Approach	Applications	Data requirements	Limitations
Revealed preference methods				
Production function (also known as 'change in productivity')	Trace impact of change in ecosystem services on produced goods	Any impact that affects produced goods	Change in service; impact on production; net value of produced goods	Data on change in service and consequent impact on production often lacking
Cost of illness, human capital	Trace impact of change in ecosystem services on morbidity and mortality	Any impact that affects health (e.g. air or water pollution)	Change in service; impact on health(dose-response functions); cost of illness or value of life	Dose-response functions linking environmental conditions to health often lacking; underestimates, as omits preferences for health; value of life cannot be estimated easily
Replacement cost (and variants, such as relocation cost)	Use cost of replacing the lost good or service	Any loss of goods or services	Extent of loss of goods or services, cost of replacing them	Tends to over-estimate actual value; should be used with caution
Travel cost (TCM)	Derive demand curve from data on actual travel costs	Recreation	Survey to collect monetary and time costs of travel to destination, distance travelled	Limited to recreational benefits; hard to use when trips are to multiple destinations
Hedonic pricing	Extract effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits	Prices and characteristics of goods	Requires vast quantities of data; very sensitive to specification
Stated preference methods				
Contingent valuation (CV)	Ask respondents directly their WTP for a specified service	Any service	Survey that presents scenario and elicits WTP for specified service	Many potential sources of bias in responses; guidelines exist for reliable application
Choice modelling	Ask respondents to choose their preferred option from a set of alternatives with particular attributes	Any service	Survey of respondents	Similar to CV; analysis of the data generated is complex
Other methods				
Benefits transfer	Use results obtained in one context in a different context	Any for which suitable comparison studies are available	Valuation exercises at another, similar site	Can be very inaccurate, as many factors vary even when contexts seem 'similar'; should be used with caution

Source: Pagiola et al 2004

Table 3 above summarizes the main economic valuation techniques. Some are broadly applicable, some are applicable to specific issues, and some are tailored to particular data sources. A common feature of all methods of economic valuation of ecosystem services is that they are founded in the theoretical axioms and principles of welfare economics. Most valuation methods measure the demand for a good or service in monetary terms, that is, consumers' willingness to pay (WTP) for a particular benefit, or their willingness to accept (WTA) compensation for its loss (Hanneman, 199.

Using the above methodologies a number of schemes have been developed that aim at paying for the ecosystem services in a number or countries as highlighted in the case studies. Payment for ecosystem services (PES) is defines as the instrument that addresses environmental externalities through a variable payment or compensation (cash or in-kind). It involves the interaction of at least two agents: the **provider or seller** of environmental services (individual or group), who responds to the offer of a payment from the **users** of the provided services (from a private company, NGO, local or central government agency), who can be distinguished from the seller and are the one making payments that ensures the environmental services are to be delivered. Participation in the PES scheme must be voluntary on the supply side and the payment must be conditional on previously agreed land use that is expected to provide an environmental service (Muradian et al., 2010, Wunder, 2005). The case studies below presents three main ecosystem services (carbon sequestration, watershed services protection, and biodiversity conservation including beauty of landscape for recreation and cultural purposes), that are provided through agricultural and forest products markets.

Box 7 Examples of state of carbon initiatives in Asia

- NEPAL in early stages for REDD, but major challenges identified in terms of weak forestry sector governance, lack of policy and institutional mechanisms to carry-out periodic forest resource assessment and monitoring, technical gaps to satisfy service demanded by REDD, inadequate internal finances for regular assessment of forests, and integration of forest inventory data from local to sub-national level. There are 6 experimental REDD sites including theTerai Arc landscape Sacred Himalayan, 2009-2013 (WWF/ Winrock International, Friends of Nature); and the 3 watersheds at Chitwan, Gorkha and Dolakha Districts, 2010-2012 (NORAD, ICIMOD, FECOFUN, ANSAB);. Experience shows that local initiatives are simple, doable and adaptive to address drivers of deforestation and degradation. The Rupantaran project, linked to the Livelihoods & Forestry Programme, is currently undergoing international certification for carbon through Plan Vivo.
- PAKISTAN: Early stages in Pakistan - REDD+ Roadmap process launched in 2013 led by ICIMOV/ WWF.
- BANGLADESH: REDD Roadmap in draft, discussed and approved in a workshop in March 2013. Currently research is undersgoing on corruption risk assessment, social impact assessment and monitoring, reporting and verification (MRV),
- INDIA. The country has been instrumental in shaping the REDD+ mechanism by emphasizing the role of conservation and sustainable forest management in mitigating carbon emissions. It has a robust policy and legal framework, as well as several programmes and policies at the national level to address the impacts of climate change in the context of sustainable development. Carbon is seen as a co-benefit, not a primary objective for forests and plantations. (SUD ET AL 2013). Indivial projects also sell (or try to sell) in international carbon credits markets, for example the Khasi Hills, Community REDD+ project; and the Improving Rural Livelihoods through Climate Change Mitigation (Andrah Pradesh)
- BUTHAN. High potential for REDD/PES because of low deforestation and forest degradation rates, political commitment to environmental conservation, but risks for communities need to be assessed. Concern over human-wildlife intractions and how REDD may affect development projects. A consultation workshop was held in early 2013, promoted by the Royal Government of Bhutan.

Box 8: Examples of state of Payments for Watershed Services (PWS) -like initiatives in Africa

SOUTH AFRICA. South Africa leads the way in terms of watershed services schemes in Africa, with the longest-experience in the Working for Water national strategy. Other initiatives seek to add a water/PES component to their protection/conservaiton activities, like the Maloti-Drakensberg Transfontier Project to get long-term funding (limited success so far).

Kenya. No national-level strategy but several local schemes. For example: (1) Rehabilitation Mau Ecosystem (IARME) project - active from 2010 linking international donors, government organisations (water and forestry), NGOs and local communities. (2) Eastern Kenya Integrated Ecosystem Project (2005-2010) -WB/GEF funded experimental project seeking to improve the productivity and sustainability of land use systems in selected watersheds (3) Green Water Credits - despite in-depth studies on the benefits of S&W conservation from farmer groups in Tana Basin the proposal/ did not make it to experimental due to lack of institutional support.

Uganda has some research experience in trying to implement PWS projects at the local level, but it has not materialised into actual ongoing projects so far.

Tanzania. Several research projects in the area try to support equitable PWS at the local level. For example, the WWF/CARE led project in the Uluguru Mountains of Tanzania. Significant funding from buyers has yet to materialised.

6.0 DISCUSSION OF THE METHODOLOGIES

6.1 Drivers and knowledge process;

Drivers of application of the methodologies vary from global to national level. At global level the main drivers of the methodologies and mostly the financial approaches, has been the need for raising funds for climate change adaptation. Climate negotiations at global level have created the demand for figures with which countries could use as target to raise funds for climate change adaptation. The main proponents have been the Least Developed Countries (LDC) and the developed countries (Annex 1 countries in the Kyoto protocol). Given the now-well-agreed notions that developed countries are responsible for climate change, developing countries have been demanding that the developed countries should contribute funds to finance adaptation programmes in developing countries. To assess how much should be raised to meet the financial demands of climate change adaptation in developing countries, methods like the IFF and cost benefit analysis (CBA) have been spearheaded by the World Bank and modified by a number of institutions to generate the much demanded figure- costs of climate change adaptation.

At national level, the drive for the methodologies has been the need to estimate the total cost of adaptation to climate change and the cost of not adapting to climate change. Policy strategies like the National Adaptation Plan of Action (NAPA) have been at the centre of the methodologies as countries try to cost these actions and develop efficient strategies.

Another driver of the methodologies has been the need to understand the behaviour of smallholder farmers in responding to climate change. Smallholder crop and livestock farmers have autonomously changed their behaviour to adjust to the negative impact of climate change. These changes are for example, opening up irrigation plots, changing crop and livestock species. These have both positive and negative impact on the economy. A good understanding of these will help policy makers to develop good policies that enhance the benefits from the autonomous adaptation strategies.

6.2 Focus of the economic methodologies

The focus of the methodologies has been rapid onset of climate change impacts. Very few methods have included long-term slow impacts as these demand more data and complex computation. In terms of economic activities, agriculture (crop production) has benefited a lot from the methodologies. This is because agriculture is the main economic activity for majority of smallholder farmers. This has also seen most of the economic methodologies like Ricardian model and structural approaches being applied in Africa and Asian rural areas, mainly semiarid and river catchment hotspots. River deltas have not benefits much from the methodologies because in many areas apart from agriculture, deltas have also been developed into urban area. This makes analysis of the delta areas even more complex as water uses extend beyond agriculture to industrial and domestic uses. In the deltas, cost benefits analysis has been used to compare the different strategies in different sectors.

6.3 Success and limitations of the methodologies in informing policy

Given that most developing countries, depends heavily on agriculture, the effects of global warming and climate change on the agricultural sector are likely to threaten both the welfare of the population and the economic development of the country. This is particularly important for prudent agricultural policies. Agricultural policy must have an important role in influencing the developing countries' agricultural sector's ability to adapt successfully to climate change. The Ricardian model and structural approach have been very influential in informing agricultural policy mainly in climate change. For example, La Rovere et al 2010, estimated that adoption of drought tolerant maize varieties of about 3-20% could generate US$0.53 billion from increase in maize grain over a period of 10 years. Such a finding has resulted in a number of countries in the sub Saharan Africa (Semi-arid hotspot) to reform their seed policies to encourage smallholder farmers adopt drought tolerant varieties.

However, it should be noted that the use and application of these methods in developing countries is hampered by lack of capacity. The Ricardian model and structural approach demand high level of expertise and knowledge of quantitative analysis. This is lacking in many Least Developing Countries' government staff. Their application into government policy framework has mainly relied on international institutions working in those countries e.g. the World Bank, IFPRI, CIMMYT etc.

Another influential methodology has been the stakeholder focused cost benefit analysis. Application of this methodology in the Bangladesh, Khuna city, has influenced the reversal of original adaptation plans that focused on structural technologies. The stakeholder focused cost benefit analysis revealed that more benefits could be realised by addressing other 'softer' adaptation technologies.

At global level, the financial methods of estimating cost of adaptation, have been mainly used for lobbying during international negotiations. As these methods are quick and straightforward and mainly use macro-economic indicators e.g. national expenditures, their use at global level has been higher. At national and local level, their use and influence on policy has been minimal due to lack of direct linkage with the local context.

7.0 ISSUES FOR DISCUSSION FOR THE CONSORTIA ON THE METHODS

7.1 Use of current methods in the three hotspots.

It is worth understanding, there exists an extensive and growing literature on the impact of climate-change related effects on agricultural production (Pearce et al., 1996; McCarthy et al., 2001; Tol, 2002). From a supply perspective, most of the regions of the word are experiencing increasing aridity, deterioration of soil quality, water scarcity and precipitation variability. On the demand side, however, population and economic growth along with changing nutrition patterns are leading to increasing food requirements. This combination has fuelled the demand for policy direction with a climate change lens and focus on agriculture which is the main economic driver for majority of the households in sub Saharan Africa and South Asia.

The current literature available in Africa and South Asia has not been specifically done based on this categorisation of hot spots. Most of the studies in economics of climate change focused on a specific adaptation strategy at specific geopolitical level e.g. district of country or cross country level. However, looking at the areas of focus for the current available literature, one can classify them as belonging to any of the three hotspots. Using the three hot spots of river deltas, river catchments and arid and semi-arid regions, this section reviews the coverage of the existing studies.

7.1.1 River Delta

River deltas like Nile, Bramaputra and Ganges, The Zambezi and the Niger, have experienced a number of disasters from flooding prompting studies looking at their vulnerability and assessing damages. Currently, there is a wave of studies that are assessing resilience of such river delta with specific focus on different sectors e.g. the Asian Development Bank (ADB) study on Khulna city in the Bramaputra-Ganges Delta. However, most studies have been in the agricultural sectors e.g. Mainuddin et al 2011 looked at planning and costing of agriculture's adaptation in climate change in the salinity-prone cropping systems of Bangladesh. Studies looking and cross cutting sectors and the linkages between the different sectors in delta region are limited.

7.1.2 River catchments

River catchments have been fairly studied in regards to climate change. This is because these are looked upon as life lines during drought as providers of irrigation water for many crops farming households. There has been a number of studies looking at irrigation, water harvesting and water conservation technologies as the main adaptation strategies adopted at farm level in a number of river cathments (Kurukulasuriya et al. 2011; Deressa et al., 2009; You et al., 2009; Boko et al., 2007; Anley et al., 2007; Awulachew et al.,2007; Bekele and Drake, 2003). Results from these studies show that the impact of climate change on water resources across the African continent, and the related consequences for the agricultural sector, is not uniform. There is evidence that the climate response function of rain fed farms may be quite different from the response function of irrigated farms (Mendelsohn and Seo, 2008b, Agoumi, 2003). Kurukulasuriya et al., 2011 claim that models failing to account for endogenous irrigation are biased and that the choice of irrigation is sensitive to both temperature and precipitation.

Results indicate that the net revenue impact of climate change is not uniformly distributed across the different agro-ecological zones. For example, Barnwal and Kotani (2010) rely on panel data analysis using a Just and Pope stochastic production function and the quantile regression approach to examine the effects of temperature and precipitation on the mean and variance of seasonal rice in Andhra Pradesh, India. They find evidence of heterogeneity in the impact of climate change across different agro-climatic zones and stress the need for more location-specific adaptation policies. This insight evidences the importance of understanding the location specific characteristics of the effect of climate on crop yields in designing effective adaptation policies. Deressa and Hassan, 2009 confirm this claim for Ethiopia, using farm households' data from different agro-ecological zones. Kurukulasuriya et al., 2011 rely on the Structural Ricardian Model using data from farmers across eleven African countries, aiming at addressing the endogeneity of irrigation. Gebremedhin et al., 2006 and

Chavaz and Di Falco, 2012 find evidence that the eastern part of the Tigray region in Ethiopia has the worst conditions in the country for agricultural production.

7.1.3 Arid and semiarid regions

Similar to the two hotspots, arid and semi-arid regions have been characterised by studies in agriculture and most specifically crops choices and yield responses. The arid and semiarid areas are predicted to be most affected by climate change and have been the centre of most research. Climate change related damages are likely to be most heavily concentrated tropical regions such as tropical Africa (Nordhaus, 2013, Kurukulasuriya et al., 2011; Lobell et al. 2011a, 2011b and 2006; Schlenker and Lobell, 2010; Tol, 2009, 2002; Mendelsohn et al., 2006; Mendelsohn and Williams, 2004; Pearce et al., 1996). Africa is one of the most vulnerable continents to climate change and climate variability, a situation aggravated by the interaction of "multiple stresses", occurring at various levels, and low adaptive capacity (Boko et al., 2007). Climate change could be particularly damaging to countries dependent on rain-fed agriculture and under heavy pressure from food insecurity. They often face famine caused by natural disasters and are prone to extremes (e.g. drought and flood) such as Ethiopia (Di Falco and Veronesi, 2013; Di Falco and Bulte, 2013; Chavas and Di Falco 2012; Di Falco et al., 2011; Deressa and Hassan, 2009; Mendelsohn and Tiwari, 2000). It is estimated that, by 2100, parts of the Sahara are likely to emerge as the most vulnerable, showing likely agricultural losses of between 2 and 7% of GDP. Western and Central Africa are also vulnerable, with impacts ranging from 2 to 4%. Northern and Southern Africa, however, are expected to have losses of 0.4 to 1.3% (Boko et al., 2007; Mendelsohn et al., 2000). Effective adaptation of agriculture to climate change is crucial to achieve food security in Sub Saharan Africa (Di Falco and Veronesi, 2013; Lobell et al. 2011b).

Even though, there has been a large number of studies in the semiarid area, and that semiarid areas are home to livestock dependent households, few of the studies have looked at the livestock production systems and climate change. Some authors highlights a research gap in our understanding of climate impacts on livestock systems also claiming that the existing estimates are highly uncertain (Antle, 2010 and Capalbo, Thornton et al. 2009; Seo and Mendelsohn, 2007, 2008b and 2008c, Nienaber and Hahn 2007; Thornton et al. 2009; 2010). Seo (2007) apply a Ricardian model to African data showing that livestock are sensitive to climate; Seo and Mendelsohn (2008b) develop the so called Structural Ricardian Model, applying it to cross section of farmers who own livestock in different countries across Africa.

Seo and Mendelsohn 2007, 2008c showed that a warming of 2.5°C could increase the income of small livestock farms by 26% (+US$1.4 billion).

7.2 Comparison and analysis of the economic approaches of the four CARIAA consortia

7.2.1 General comments on the four consortia proposals

In all the 4 proposed programs, the economic methodologies have a strong focus on the micro level unit of analysis. As in all the proposed areas of study, markets are not well developed, this approach is very good as local context will be taken into the analysis and results will be relevant to the different local situations. This may call for detailed data collection in the micro units e.g. households, but this is important given that climate change is new and most relevant information may not be available in some conventional sources like government data base.

However, in all the four programs there is no clear linkage between economic analysis and climate change. How will climate data be incorporated in the economic analysis? There is a need to have steps on how the physical data will be collected, and how it will be linked to economic sectors. It should be noted that in almost all the countries in the three hotspots where the studies will be done, climate data is very scanty. There is spatial variations and even temporal gaps in cases where data has not been well kept or there were faulty equipment for collecting climate data. This poses a great challenge in linking climate variable to economics activities. Care should be taken when using aggregated (national, or annual) climate variable e.g. temperature or rainfall. Huge variation is lost in the aggregation and the data may not show the critical impacts on economic activities. Historical trend so impacts of climate change e.g., famine, floods and, in extreme cases, humanitarian aid, provide very insightful historical information of climate change impact. Using such localised data in the case studies, past climate impacts can be collected and related to economic activities.

There is also lack of clear economic methods except for the financial analysis (cost benefit analysis). These are implied in the programs methodologies but a clear explicit explanation of the studies would be idea to help replication of the methodologies in other areas and ability to share and compare the results from different hotspots and areas.

On data collection, a number of developing countries have been conducting detailed surveys funded in most cases by the World Bank. These have been termed Living Standard Measurement Surveys (LSMS). These tend to be detailed at household level and can provide good base. They have also been collected a number of times from the same units and provide very insightful panel data sets. The World Bank has always been willing to share this data set. These could provide very good baselines for the programs. The main drawback is that, some specific variable that the consortia may require may have not been collected. In the subsequent surveys the consortia will conduct, it can concentrate on these and add on what has already been collected.

Table 5: Strength and weaknesses of proposed methodologies by the consortia.

Project Name	ASSAR	DECCMA	Hi-AWARE	PRISE
Strengths	Based on well-developed and published methods. This is using mixed methods that will help to triangulate the results. The proposal is to work directly with community and able to get real data. This will help to have the policy proposals based on the actual information from the grassroots, e.g. households.	1) This proposes to model the whole economy hence able to incorporate as many sectors as possible giving the true picture of the economy. 2) It also proposes to project forward to up to 2100 which is important for economic plans. 3) Collecting primary data which will give true picture.	1) Using a variety of methods to triangulate the results. 2) Collecting primary data	Strong on quantitative analysis and promised a large variety of approaches from political to econometrics. This is a very strong and important inclusion as both the political and economic conditions affect economic policies.
Weakness	Even though the issues like wellbeing have been well developed and documented, aggregation between countries and generalisation of the results may be difficult. Wellbeing in one area may be different from wellbeing in	Data at national level is aggregated and mostly likely generalised. This data may have lost a lot of variation within the country. For example northern Ghana and southern Ghana have different impact from climate change and they are also at different economic	There is a huge focus on financial analysis rather like economic analysis. It is possible to include economic analysis in the cost benefit analysis by basing the cost and benefits on economic	Very good results for the quantitative analysis may require more time in data collection. The best quantitative analyse will require panel data i.e. repeated surveys in the same units. This may delay the results of this study

	other area. This may force the team to develop indicators that may not capture all relevant information.	development. Aggregating data from the different regions may be erroneous.	analysis. This will require more time and data.	
Differences	Focusing on social economic issues	Projecting economic levels in future	Focusing on financial analysis	Strong on quantitative analysis
Point of synergy	1) ASSAR can merge benefits a lot from data collected by PRISE in the same countries. PRISE seems to be geared towards good data collection that could be useful for ASSAR. 2) Apart from the DECCMA, the other three will have financial analysis. There is need to harmonise the methodologies that will be used (e.g. cost benefit analysis, the stakeholder cost benefit analysis). The methodologies can be compared if they use similar discount rate, start at similar periods of analysis and use similar time frame. These will help to compare the results from the different hotspots and in cases where there studies are done in same country, this will help to triangulate the results. 3) As baseline data can be collected from the LSMS of the World Bank, a central data management team can be developed that will ensure that all teams get similar data. Such a team would also help to share the data and strengthen data analysis where the teams are not strong. 4) In cases where the teams are working in same country, it would be good to uses same case studies where possible. This will help in resource use and avoid duplication of activities in same country. Linking with policy makers will also be easy rather like having more than one team chasing the same policy makers.			

7.3 Issues to consider.

7.3.1 Estimating non-monetary costs and benefits

The uncertainty surrounding climate change and its impacts makes estimating the costs and benefits of adaptation a very complex and somewhat arbitrary process, in addition to the challenges associated with evaluating physical and ecological changes in monetary terms (World Bank, 2009). These changes do not show in monetary terms and are not traded in the market hence there is no information of their actual cost or benefits. This is common in ecosystem and ecological related studies. Due to this lack of observed market prices, there has been relatively fewer studies done that estimate these values and include ecosystem services in climate change economics. Other important issues that affect cost and benefits of adaptation strategies but are not traded on the market include cultural values, social values, future values and ecological values. In addition because adaptation projects inevitably generate costs and benefits that extend beyond their direct beneficiaries, it is important to examine their non-monetary costs and benefits as well as their economic value. While these negative and positive impacts of certain climate-related events on human lives, livelihoods and ecosystems cannot be monetised, they have financial implications that may amplify or reduce the positive or negative effects of a project. This suggests that non-monetary costs and benefits may determine whether a project is actually worthwhile in the eyes of all stakeholders (for instance, whether a climate change adaptation project will have the expected significant positive effects on surrounding ecosystems).

A number of methods are used to evaluate these. The most common method is the contingent valuation that creates a hypothetic market and asks different stakeholders their willingness to pay for the adaptation strategies or willingness to accept compensation. The main drawback of using this method in low income countries and communities with less integration into the market is that they underestimate the values of the cost and benefits of adaptations. As there are little linkages between values and markets, in many cases ecosystems cost and benefits have been underestimated. However, it provided very good indications of the values but not actual value itself.

7.3.2 Uncertainty, discount rates and time horizons of adaptation projects

The UNFCCC, (2012) highlights three critical issues that should be considered when estimating cost and benefits of climate change adaptation. Before assessing the costs and benefits of an adaptation project, it is important to identify three critical dimensions of the initiative:

iv. First, the degree to which uncertainty can be incorporated into the assessment. Adaptation options, and adaptation measures need to be designed in a flexible manner so that their respective costs and benefits can be reported with a given margin for uncertainty (Parry *et al*., 2009).

v. The second critical parameter is the discount rate that will be used to convert benefit and cost streams into their equivalent present values. Discount rates for projects with short time horizons (20 to 30 years) should not be controversial, as the costs and benefits of adaptation measures are usually felt within a reasonably short time, and the ancillary benefits of investments make projects similar to other public investments (World Bank, 2009).

vi. Lastly, the time horizon of the evaluation is directly linked to the discount rate. This horizon depends on the lifespan of the options under consideration.

These three factors are very critical in comparing and aggregating results. The consortia will make great strides in adopting similar parameters to be used, e.g. discount rates and time horizons for the analysis.

7.3.3 Availability and usefulness of climate data.

More direct climate variable (e.g. temperature and precipitation) are commonly used in most studies. The most informative climate data would be monthly variance of temperature or rainfall at local level. However, the easily available data were national average over a period of e.g. 30 years. This may not be informative and useful for linking climate change to adaptation to different sectors in specific regions. The geographical variation of climate data (temperature and rainfall) even within a country makes use of national average figure to mask the actual climate change impact. Climate variability cannot be captured in a single country mean digit. For example, a drought spell within a crop-growing season may have a large impact on crop output, but total rainfall in the year may be within normal range. However, the impacts of such a drought can be observed in food shortage and demand for humanitarian aid. Another example is where flood cause damage in one part of the country that may even lead to death. Borios et al (2008) reported that using the inter-annual measure of temperature or rainfall variability may be too restrictive to capture the true impact of changes in the variance. In their study they alternatively, calculated the intra-annual variability by using monthly measures of rainfall. Therefore, a single annual digit may not present the actual impact of climate change.

However, humanitarian aid in response to climate change disasters (other than man-made catastrophes e.g. wars and conflicts or natural e.g. earthquakes) is a better indicator to climate change impacts.

Majority of the studies in EEA in developing countries have mainly focused on the implications of climate change on agriculture specifically looking at food consumption and food security of vulnerable populations. The main impact predicted from climate change and crop models is a reduction in overall crop yields, which depends on individual crop productivity (as predicted by climate and crop models) (Winters et al 1998). Increased frequency of extreme weather events also depresses yield by damaging crops at key growth stages (Rosenzweig et al. 2002). Such crop failures end up causing hunger, famine and even death. This introduces a negative shock into the country's economy. Climate change has also caused extreme events (flood and famine) that have led to loss of resources and even death. Therefore, climate change as a shock can be proxied by the variables that indicate these shocks e.g. number of natural disasters and number of victims of disasters or value and cost of humanitarian aid. Humanitarian aid has been a general and quick response to country disasters and catastrophes caused by climate change in a specific region of the whole country.

7.3.4 Difference between financial and economic studies.

It is important to separate between the different assessments a) financial assessment, b) economic assessment, c) social cost and d) environmental cost/benefits (ecosystem services). For the project and local adaptation strategies financial social and ecological assessment can be done easily. However, at national and global levels, economic assessment may be important as they incorporate other sectors of the economy that may have an indirect impact from the proposed or implemented adaptation strategies. How much to adapt and how to allocate resources to adapt to climate change while also meeting other needs is consequently an economic problem. This could be at household community or national level. At households Ricardian and structural models of analysis have been commonly used, while at national level and regional, IAMs and more specifically the CGE have been used and have been most effective. In addition to these methods four main financial methods have been used to prioritise the different adaptation strategies. These are a) cost benefits analysis, b) cost effective analysis, c) multi-criteria analysis and d) stakeholders focused cost benefits analysis. The values for these could be obtained from economic study, e.g. where a structural model is used to partially estimate cost or benefits accrued from a certain adaptation methods holding other factors of production constant. On the other hand, it is unfortunate that a number of studies on cost and benefits analysis have been termed as economic studies when they have not done any economic analysis and their estimates are based on market values of inputs and benefits. Its will be important for the consortia to separate these and provide well guided and documented methodologies.

8.0 CONCLUSION

In conclusion, the methodologies for EAA are diverse and shift when the analysis is scaled down from global to national and local level. The practices and methodologies are evolving but there is an increasing momentum to place adaptation strategies within the national development policies. Sound methodologies for assessing climatic impacts and translating them into anticipated impacts on the agricultural and other economic sectors will be increasingly important in the future as governments and the private sector aim to increase the resilience of their activities to the consequences of climate change (Vergara et al. 2011). Several mathematical programming crop-yields models are available to simulate and assess the impact of climate change on crop yields by defining a production function and assessing how varying one or more inputs (e.g: fertilizers, precipitations etc.) affects the variance of output. This review outlines the main issues tackled in the existing literature and provides an understanding of main methodologies extensively used in the economics literature to assess the impact on climate change at global level and national/progamatic level. Global level studies have mainly looked at estimating the total cost of climate change adaptation. At national and local level a number of studies have looked at different impact of climate change using a number of methodologies including (i) the Ricardian Approach, (ii) the Integrated Assessment Models (IAMs) and the (iii) Structural Approach. A number of issues can be drawn from the methodologies that the consortia can adopt and use in their implementation of the program.

Adaptation projects inevitably generate costs and benefits that extend beyond their direct beneficiaries, it is important to examine their non-monetary costs and benefits as well as their economic value. Some factors are very critical in comparing and aggregating results. The consortia will make great strides in adopting similar parameters to be used, e.g. discount rates and time horizons for the analysis.

Another important issue in applying these methods is the distinction between financial and economic studies. It is unfortunate that a number of studies on cost and benefits analysis have been termed as economic studies when they have not done any economic analysis and their estimates are based on market prices of inputs and benefits. It will be important for the consortia to separate these and provide well guided and documented methodologies.

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Annex 1: Summaries of studies in the three hotspots

Hotspots	Country	Authors	Date of study
Semi-arid zones of Africa and parts of South and Central Asia	Ethiopia	Di Falco and Veronesi	2013
		Di Falco and Bulte,	2013;
		Chavas and Di Falco,	2012
		Di Falco et al.,	2011
		IFPRI,	2010
		Di Falco and Chavas,	2009
		Deressa et al.,	2011 and 2009
		Deressa and Hassan,	2009
		Hassan and Nhemachena,	2008
		Deressa,	2007
		Anley et al.,	2007
		Awulachew et al.,	2007
		Kidane et al.,	2006
		Dercon	2004 and 2005;
		Bekele and Drake	2003
		Dercon and. Krishnan	2000
	Cameroon	Molua,	2009
	Kenya	Andersson Djurfeldt	2012
		Suri	2011
	Tanzania	Dercon, S.	1996
	Nigeria	Cervigni et al.,	2013
		FAO,	2012;
		Mereu and Spano,	2011
		Nwafor et al.,	2010;
		Udry,	1994.
	Zimbabwe	Mutiro and Murwira,	2004.
	Regional Level Studies		
		Kurukulasuriya et al.,	2011;

		Schlenker and Lobell,	2010;
		Kurukulasuriya and Mendelsohn,	2008a and 2008b;
		Seo and Mendelsohn,	2007,2008b 2008c
		Hassan and Nhemachena,	2008;
		Dinar et al.,	2008;
		Boko et al,	2007
		Maddison,	2006;
		Orindi et al	., 2006;
		Stige et al.,	2006
		Adger,	2003;
	(West Africa);	Christianson and Vlek,	1991
	(Zimbabwe, Kenya, Senegal)	Downing,	1992

Hotspots	Country	Authors	Date of study	Methods used	Brief results
Large deltas of Africa and South Asia;	Pakistan **National Economic and Environmental Development Study (NEEDS)**	Malik Amin Aslam	2011	NEEDS is a top-down analysis using macro indicators and other relevant local data. Three distinct methods to estimate the cost of adaptation are used. I) Derivation based upon projected GDP, II) Per capita basis deriving from existing research III) Estimates using disaster modelling based on historical event and their costs.	The study estimates the total cost of adaptation in Pakistan. This is a first national level assessment of the country without any focus on particular vulnerable areas
	Bangladesh **Planning and costing agriculture's adaptation to climate change in the salinity-prone cropping system of Bangladesh**	Khandaker Mainuddin, Aminur Rahman, Nazria Islam and Saad Quasem, Bangladesh Centre for Advanced Studies	2011	Yearly cost benefit analysis (CBA) from using improved rice variety to deal with salinity issues and other non-rice products by farmers. It uses a static yearly analysis without any future projection or calculation of NPV. Projected costs based on current costs incurred by local institutions in supporting adaptation measures on ground upto 2030 without any discounting	Review of key national and global climate change literature, multiple stakeholder consultations with relevant institutions for assessing the adaptation measures and the associated costs for the institutions, and generated primary data from field study in three districts at farm level on local adaptation measures, costs of cultivation, local practices etc.
	Bangladesh **Adapting to Climate Change - Strengthening the Climate Resilience of the Water Sector Infrastructure in Khulna, Bangladesh**	Asian Development Bank (ADB) & Technical Assistance from Consultants Authors from these organizations	2011	To assess the climate change risks and impacts for Khulna, the study used a combination of scenarios and CGM models. Projected climate change from 2030 and 2050. Developed socio economic development scenarios for 2030-2050. Developed and ran three mathematical models using climate and socioeconomic changes. Assesses impacts through geographic information system mapping.	The study i) proposes appropriate adaptation options to be incorporated in the design of ADB funded project to strengthen the water sector in Khulna to climate change ii) Enhance ADB's understanding of climate related risks in urban infrastructure and cost effectiveness of adaptation options.

				Identified and analysed adaptation options.	
	Bangladesh **The Implications of Climate Change on Floods of the Ganges, Brahmaputra and Meghna Rivers in Bangladesh**	M. Monirul Qader Mirza, R. A. Warrick, N. J. Ericksen	2003	Possible changes in the magnitude, extent and depth of floods of the Ganges, Brahmaputra and Meghna (GBM) rivers in Bangladesh were assessed using a sequence of empirical models and the MIKE11-GIS hydrodynamic model. Climate change scenarios were constructed from the results of four General Circulation Models (GCMs) –CSIRO9, UKTR, GFDL and LLNL, which demonstrate a range of uncertainties.	Changes in magnitude, depth and extent of flood discharge vary considerably between the GCMs. Future changes in the peak discharge of the Ganges River are expected to be higher than those for the Brahmaputra River. Changes in land inundation categories may introduce substantial changes in rice agriculture and cropping patterns in Bangladesh.
	India A megacity in a changing climate: the case of Kolkata	Susmita Dasgupta, Asvani K. Gosain, Sandhya Rao, Subhendu Roy, Maria Sarraf	2013	Modest flooding in Kolkota during monsoons at high tide in the Hooghly River is a recurring hazard in Kolkata. Using rainfall data, high and low emissions scenarios, and sea level rise of 27 cm by 2050, this paper assesses the vulnerability of Kolkata to increasingly intense precipitation events for return periods of 30, 50, and 100 years. It makes location-specific inundation depth and duration projections using hydrological, hydraulic, and urban storm models with geographic overlays. High resolution spatial analysis provides a roadmap for designing adaptation schemes to minimize the impacts of climate change.	The modeling results show that de-silting of the main sewers would reduce vulnerable population estimates by at least 5 %.

	Bangladesh **Economics of Adaptation of Climate Change**	Kiran Pandey (Coordinator EACC country studies)	2010	The methodology follows a four-step process: Pick baseline – Development pathway are projected up to 2050 without impact of climate change Choose climate projections- Two climate scenarios are chosen for broader analysis using dry and wet projection models Predict impacts of climate change. Impacts are translated on various economic activities Identify adaptation alternatives and costing – Costs are identified for major sectors	Using data sets with global coverage at the country level, the global track estimated adaptation costs for all developing countries by major economic sectors, including agriculture, forestry, fisheries, infrastructure, water resources, coastal zones, and health. Adaptation for ecosystem services is also discussed qualitatively. Each country case study under the country track consists of a series of studies that examine the impacts of climate change and the costs of adapting to them for select major economic sectors.

Hotspots	Country	Authors	Date of study	Methods used	Brief results
River basins affected by glacier and snowpack melt in the greater Himalayan region	Nepal Economic Impact Assessment of Climate Change in Key Sectors in Nepal	Integrated Development Society (IDS), Nepal, Practical Action Consulting Limited (PAC), Nepal and Global Climate Adaptation Partnership (GCAP), UK Authors from these organizations	2013- On going	Measure of three time periods- . Current costs using combination of approaches (econometric analysis, analogue assessment, meteorological data assessment) to understand the current economic costs of climate variability in the agriculture and water sectors, and the impacts on development costs over the next few years. Medium term costs using Investment and Financial Flow analysis to examine baseline investment and climate risks on current major development plans and polices. Long term focuses uses scenario based impact assessment (regional and sectorial models) to	The approach assesses: The impacts and costs of short-term climate variability (now and the next 5 – 10 years) – focused on current and emerging trends - and the adaptation response of building adaptive capacity and “no and low regrets” actions. The impacts and costs of climate change on development plans and objectives in the medium term (for next 20 years) –

				assess changes in agricultural productivity, hydro-power generation and water-induced disasters over long term	including emerging climate signals – and the adaptation response of building climate resilience into growth and sector development plans. The impacts and costs of medium to long-term climate resilience (2030 to 2060) – looking at the impacts of major climate change – and the adaptation response of identifying areas for early action to address long- term changes.
	Nepal National Adaptation Programme of Action (NAPA) to Climate Change - Government of Nepal - 2010	Government of Nepal Document (Developed by consultants)	2010	Recommended costing methods are Cost Benefit Analysis, Cost Effectiveness Analysis and Multi Criteria Analysis	Identification of impacts of climate change on priority six major area themes Prioritization of adaptation options using multi-criteria analysis Identification of key adaptation needs, existing adaptation practices and options Grouping of urgent and immediate responses into nine integrated projects Costing of the nine portfolios. Total cost estimated at USD350 million.
	Nepal National Framework on Local Adaptation Plans for Action	Government of Nepal Document (Developed by consultants /NGOs)	2011	The final objective of the LAPA (objective 7), requires use of cost-effective adaptation alternatives which entails undertaking costing analysis. Majority of the pilot LAPAs used some form of CBA analysis to justify the selection of certain adaptation initiatives over others. It is not clear which methods will be	The LAPA Framework supports operationalization of policy objectives outlined in the NAPA, by facilitating the integration of climate change resilience into local-to-national development

				used and who will conduct the analysis, as the costing techniques require a certain level of technical competence.	planning processes and outcomes
	India, Nepal, Pakistan Global Climate Financing Mechanisms and Mountain Systems	Authors from ICIMOD Othmar Schwank Anna Bruederle Nicole North	2010	Literature review of the funding mechanisms	The working paper contains a description of global climate financing mechanisms and mountain systems prepared for presentation at the first 'International Expert Consultation Meeting: Mountain Initiative on Climate Change' held 23-24 September 2010 in Kathmandu.
	India and Nepal Policy and Institutions in Adaptation to Climate Change - Case study on flood mitigation infrastructure in India and Nepal	Authors from ICIMOD - Working Paper 2013/4	2013	The study extensively used secondary research, mainly literature, to construct the history of the development of flood management discourses and practices and evaluate existing governance systems. Field research was carried out to obtain community perspectives on various issues. Participatory rural appraisal techniques were used, including informal chats, key informant interviews, transect walks, focus group discussions, and resource mapping. Other tools used were political power mapping, multi-stakeholder analysis, and institutional analysis. The data and the analysis were mainly of a qualitative nature.	Government efforts to protect people from flood waters and mitigate the impacts of flood have largely consisted of structural measures like embankments; however, these have met with mixed success. When properly maintained, flood embankments can protect communities from flooding and enable them to sustain agricultural activities. However, the failure of embankments, often due to poor maintenance can result in devastating floods. This publication explores the governance of flood mitigation infrastructure in

					parts of India and Nepal. It also covers the traditional coping and adaptation strategies of local communities to deal with floods, which are being increasingly challenged due to the changing nature of floods and other water hazards attributed largely to climate change.
	Vulnerability and Capacity Assessment in Mountain Areas	Mirjam Macchi, ICIMOD	2012	This Framework for Community-Based Climate Vulnerability and Capacity Assessments in Mountain Areas provides an analytical framework and methodology for assessing environmental and socioeconomic changes affecting the livelihoods of rural, natural resource dependent communities living in mountainous environments	The framework gives guidance on how to gain a better understanding of the various forces which shape mountain communities' vulnerabilities, and places a special focus on the capacities inherent to these communities for coping with and adapting to environmental and socioeconomic changes
Others	Indonesia, Philippines, Vietnam Economic Analysis of Climate Change Adaptation Strategies in Selected Coastal Areas in Indonesia, Philippines and Vietnam	Maripaz L. Pereza, Asa Jose U. Sajiseb, Jaimie Kim B. Ariasb, Paul Joseph B. Ramirezb, Agus Heri Purnomoc, World Fish	2013	Cost effectiveness Analysis	Vulnerability as an Expected Poverty (VEP) - Development of concept
	Indonesia, Philippines, Singapore, Thailand, and Vietnam (Main focus)	ADB - Supported by Advisory and Steering Committees	2009	A climate model is adopted to estimate future climate change, including temperature rise, precipitation change, sea level rise, and others, based on the projected GHG	Integrated assessment models used and then monetized

	The Economics of Climate Change in Southeast Asia: A Regional Review			emissions and concentrations. A sectorial impact module is used to assess the physical impact of projected climate change on the water resources, agriculture, forestry, and health sectors. Consistent with Stern (2007), the study also made use of the PAGE2002 integrated assessment model to project the economy-wide impact of climate change in monetary terms under different policy scenarios for the study countries.	
	Vietnam, Lao, Thailand, Malaysia, Indonesia, Philippines, Myanmar, Cambodia Desktop Study on Assessment of Capacity Gaps and Needs of South East Asia Countries in Addressing Impacts, Vulnerability and Adaptation to Climate Variability and Climate Change	Southeast Asia Network of Climate Change Focal Points (SEA-CC Net) and the Regional Climate Change Adapaptation Knowledge Platform for Asia	2011	Data and information on socio-economic implications of disasters has been reviewed from the International Disaster Database (EM-DAT, 2009) and the Global Facility for Disaster Risk and Recovery (GFDRR, 2009a).	Review of the existing reports in the country for adaptation and the gaps - Total 15 reports
	China, Guyana, India, Mali, Samoa, Tanzania, the UK, and the US SHAPING CLIMATE-RESILIENT Development - A framework for decision Making	ClimateWorks Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank and Swiss Re. Authors from these organizations	2009	Cost of climate change = sum of cost of adaptation + residual expected losses not averted by adaptation measures. The methodology answers the following there questions: 1. Where and from what are we at risk 2. What is the magnitude of expected loss 3. How can we respond? Areas most at risk from chosen hazard using historical and scientific data are identified. Using probabilistic modeling, expected	The study developed a quantitative decision-making framework built around two sets of tools. 1. Tools to quantify a location's "total climate risk". This includes assessment of the incremental loss to the economy over a 20-year period under a range of

				economic loss is estimated under three future climate scenarios. Size and location of future assets vulnerable to climate hazard are identified and valued. Vulnerability curves are created that links the hazard risk with the identified assets. A balanced portfolio of adaptation measures is built, assessing the loss aversion potential and cost-benefit ratio for each possible adaptation measure to meet the vulnerability	climate change scenarios based on scientific knowledge. 2. Cost-benefit analysis to evaluate a selection of feasible and applicable measures to adapt to the expected risk – spanning infrastructural, technological, behavioural and financial solutions.
	Vietnam Socialist Republic of Viet Nam: Climate Change Impact and Adaptation Study in the Mekong Delta	ADB- Prepared by Peter Mackay and Michael Russell Sinclair Knight Merz (SKM) Melbourne, Australia	2011	This study has adopted a standard 'comparative vulnerability and risk assessment (CVRA) methodology and framework' for estimating aggregate vulnerability for five of dimensions, these being: population; poverty; agriculture and livelihoods; industry and energy; urban settlements and transportation. This approach is based on the generally accepted IPCC approach to vulnerability assessment for natural system, in combination with a risk-based	The primary purpose of this vulnerability assessment study is to identify and evaluate the 'net biophysical and social vulnerability' of Ca Mau and Kien Giang provinces.

		approach for assessing the impacts of natural hazards such as flooding, inundation and sea level rise on human systems.	

ANNEX 2: Examples of studies on cost and benefits with some variations that were done in the Brahmaputra-Ganges valley and the dry lands of East Africa,

Planning and costing agriculture's adaptation to climate change in the salinity-prone cropping system of Bangladesh-

(Mainuddin et al., 2011)

This report is part of a five-country research project on planning and costing agricultural adaptation to climate change, led by the International Institute for Environment and Development (IIED), Stockholm Environment Institute (SEI) and the Global Climate Adaptation Partnership (GCAP). This project was funded by the UK's Department for International Development (DFID) under the Climate Change, Agriculture and Food Security Policy Research Programme.

The study investigates adaptation requirements and their cost implications in the context of coastal agriculture in Bangladesh. The particular objectives of the study are as follows:

1. To investigate the operation of the agricultural production system in salinity-prone areas of Bangladesh and how this may be affected by climate change
2. To devise the necessary adaptation options and investigate the roles different stakeholders at different levels have to play in implementing these
3. To consider how these adaptation measures can be mainstreamed into national development plans
4. To assess the costs of such adaptation measures to the different stakeholders involved

The study methodology consisted of review of key national and global climate change literature including NAPA, Bangladesh Climate Change Strategy and Action Plan (BCCSAP), the National Agriculture Policy (NAP), the Coastal Zone Policy and the IPCC Fourth Assessment Report. It held multiple stakeholder consultations with relevant institutions for assessing the adaptation measures and the associated costs for the institutions. Finally it generated primary data through field study in three districts at farm level on local adaptation measures, costs of cultivation, local practices etc.

The methodology deploys yearly CBA for calculating the net benefits from using improved rice variety to deal with salinity issues and other non-rice products by farmers. It uses a static yearly analysis without any future projection or calculation of NPV. However the analysis projects costs incurred by local institutions in supporting adaptation measures on ground upto 2030 without any discounting.

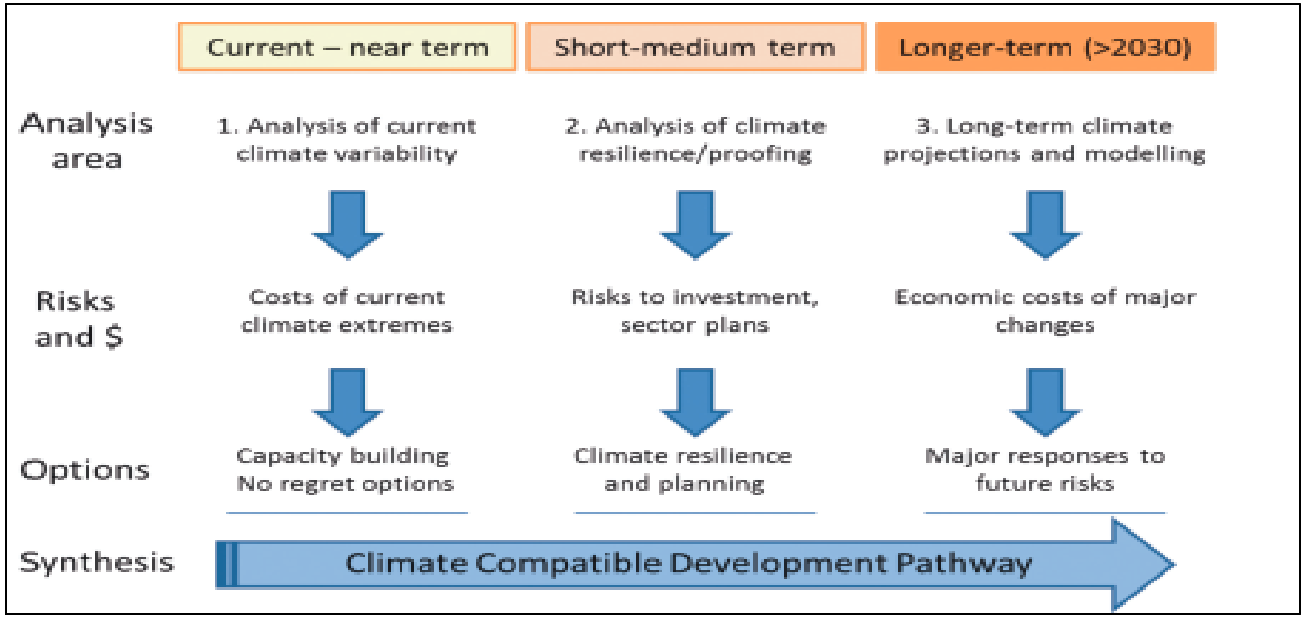
Economic Impact Assessment of Climate Change in Key Sectors in Nepal- 2013 - Published by Government of Nepal Ministry of Science, Technology and Environment (MoSTE) (Nepal, 2013)

The Government of Nepal has initiated a study on 'Economic Assessment of Climate Change in Key Sectors in Nepal" with technical support of CDKN, Integrated Development Society (IDS), Nepal, Practical Action Consulting Limited (PAC), Nepal and Global Climate Adaptation Partnership (GCAP), UK. The study is in the development and implementation stage and hence only the methodology is available without any results.

The primary objectives of the study are reproduced:

1. To provide headline and sectoral estimates of the impacts and economic costs of climate change for the agricultural and water sectors, as an input to the Government's assessment of losses and benefits from climate change.
2. To provide a ranking of climate compatible development options to address risks identified in these areas.
3. To build the capacity of government officials and key stakeholders for economic assessment of climate change impacts and economic costs/losses and damages, and the use of this information for adaptation planning and practice.

The study recognizes that climate change involves evolving risk over future time periods; hence it is divided in three main time periods as reflected in Figure 4 reproduced from the study report.



The study is divided into three work streams.

- The first stream focuses on the impacts and costs of short-term climate variability (now and the next 5 – 10 years) and extremes in Nepal, including emerging trends using a combination of approaches (econometric analysis, analogue assessment, meteorological data assessment) to understand the current economic costs of climate variability in the agriculture and water sectors, and the impacts on development costs over the next few years.

- The second stream focuses on risk to current development plans over medium term period (for next 20 years) and uses Investment and Financial Flow analysis to examine baseline investment and climate risks on current major development plans and polices.

- The third work stream focuses on the longer term impacts (2030 to 2060) and economic costs of climate change in the said sectors using scenario based impact assessment (regional and sectorial models) to assess changes in agricultural productivity, hydro-power generation and water-induced disasters.

The study will provide headline impacts and economic costs of current climate variability and emerging trends through to the longer-term. It will also identify and assess the potential adaptation options across the three time periods, linking these together to provide information on climate compatible growth.

Adapting to Climate Change - Strengthening the Climate Resilience of the Water Sector Infrastructure in Khulna, Bangladesh (ADB, 2011)

This report shares the policy and advisory findings from the technical assistance provided by Asian Development Bank (ADB) to Government of Bangladesh for strengthening resilience of water sector in Khulna to climate change.

Khulna city lies is a deltaic plain in southwest Bangladesh and is only 2.5 meters above mean sea level. The land is flat, poorly drained and over last years the salinity levels have increased due to rising sea level and prolonged dry weather.

The objective of the study is:

1. Propose appropriate adaptation options to be incorporated in the design of ADB funded project to strengthen the water sector in Khulna to climate change
2. Enhance ADB's understanding of climate related risks in urban infrastructure and cost effectiveness of adaptation options

To assess the climate change risks and impacts for Khulna, the study used a combination of scenarios and CGM models. Projected climate change from 2030 and 2050. Developed socio economic development scenarios for 2030-2050. Developed and ran three mathematical models using climate and socioeconomic changes. Assesses impacts through geographic information system mapping. Identified and analysed adaptation option.

ANNEX 3:Summary Tables of seminar papers in the economic methodologies

The Ricardian Approach			
Seminal Paper	Main features & benefits	Critiques	New Developments
Mendelsohn, Nordhaus, and Shaw (1994)	In its traditional application, this approach is based on the cross-sectional analysis of different performances of the economic unit under consideration (e.g. the farm) across a given territory. Performance is measured by land values and/or farm revenues, analyzing the impact of climate variables on these. Ricardian model have the main advantage to capture adaptation in its measure of impacts.	Omitted variable problem: the model does not take time-independent location-specific factors such as unobservable skills of farmers and soil quality into account (Barnwal and Kotani, 2010). A key assumption is that land markets are working properly. Properly working land markets, however, may not be operating in areas of the developing world where land property rights are not perfectly assigned (Di Falco et al., 2011) Assumption of constant prices (Cline, 1996) Assumption of costless adjustment to climate change	Seo and Mendelsohn (2008b) developed the so called ***Structural Ricardian Model***, which explicitly models the underlying endogenous decisions by farmers. This approach compares, through a cross section analysis, the choices of farmers who face different conditions, thus uncovering *how* farmers adapt. Conditional incomes, using a Ricardian approach, are then estimated for each choice made by each farmer.

		related effects (Quiggin and Horowitz, 1999). Does not provide any insight into *how* farmers adapt (Seo and Mendelsohn, 2008b).	Schlenker and Roberts, 2009 combine historical crop production and weather data in SSA into a panel analysis. This approach can take care of the omitted variable problem by using Fixed Effects capturing all time-invariant effects for which data are not available. Massetti and Mendelshon, 2011 argue that if panel data is available for the Ricardian method, one should use panel data methods that properly specify which coefficients should vary over time and which should remain stable. The authors claim that repeated cross sections are the wrong estimation method.

Integrated Assessment Models (IAMs)			
Seminal Paper	Main features & benefits	Critiques	New Developments
Several of the current IAMs grew out of the energy models of the 1970s and 1980s DICE & RICE: Nordhaus (1992, 1994a) Nordhaus and Yang (1996) MERGE: Manne, et. al. (1993) WITCH: Bosetti et al. (2006) PAGE: CEC (1992)	IAMs are models combining scientific and socio-economic aspects of climate change primarily for the purpose of assessing policy options for climate change control (Kelly and Kolstad, 1999). IAMs include the full range of cause and effect in climate change (Nordhaus, 2013). These models try to take into account the complex interactions between natural and social sciences, linking knowledge different domains into a single framework. The major goals of these models are to (1) project trends in consistent manner, (2) assess costs and benefits of climate policies and (3) estimate the carbon price and efficient emissions reductions (Nordhaus, 2013).	Most IAMs have a relatively high degree of computational complexity. Results may vary depending on the underlying assumptions, rising scope for results' uncertainty. IAMs are weak in representing policies and decentralized decision-making, which is particularly relevant within the context of adaptation. Some economists criticize IAMs' limited ability to simulate all of the adaptations that could occur in response to climate change.	Adaptation was not explicitly incorporated in IAMs. Recently examples overcoming this issue: RICE-2010 and DICE-2010 model PAGE model developed by Hope et al. (1993, 2006, 2009). AD-WITCH: an adaptation variant of the WITCH model which is made to distinguish between investments in building adaptive capacity and for adaptation actions that directly reduce the net climate damage. FUND model developed by Tol (2008).

The Structural Approach			
Seminal Paper	Main features & benefits	Critiques	New Developments
The Structural Approach grew out of the stochastic production function approach developed by Just and Pope (1978, 1979). This method has anticipated the moment based specification of the stochastic production function (Antle, 1983 and 1987; Antle and Goodger, 1984; Chavas, 2004), which is at the core of the Structural Approach.	This approach can be used to study the risk implications of adaptation to climate change. It shows the importance to consider higher moments, in particular skewness, in the analysis of climate related risk in agricultural production. Notably, skewness approximate downside risk exposure. Several contributions use a flexible estimation approach where uncertainty is considered by using moments of the profit distribution as determinant of farmers' decision regarding the input mix. Through the moment based approach the researcher avoids making strong assumptions on technology parameters, farmers' preferences, and the distribution of the error term.	The estimation of production equation such as [*] $y_1=f(y_2,y_3,\ldots,x,\beta)+e$, poses at least two econometric challenges: (i) collinearity problems when a large number of parameters ids needed, for example in case of a flexible representation of output effects with a large number of outputs. (ii) endogeneity issues the choice of (y, x), when applied to a production function that involves netputs that are subject to direct management. If the netput decisions for (y, x) depend on information that is not available to the econometrician, then they would become correlated with the error term e in [*], implying the presence of endogeneity bias. This bias means that standard estimation methods (e.g., least squares) will provide biased and inconsistent parameter estimates. (Di Falco and Chavas, 2009)	The empirical estimates is increasingly done by using instrumental variable estimation methods that provide consistent parameter estimate in the presence of endogeneity. Panel data techniques are increasingly adopted.

Annex 4 Literature findings: summary of selected papers

Main Findings: Summary			
AUTHORS	LOCATION	MODEL & CONTROLS	FINDINGS / CONCLUSIONS
Di Falco and Veronesi (2013)	Ethiopia Nile Basin	Combine households' data with spatial climate data. Analyse the impact of different adaptation strategies on crop net revenues. Disentangle the economic implications of different climate change adaptation strategies within a Structural Ricardian framework. Estimate a multinomial endogenous switching regression model of climate change adaptation and crop net revenues and implement a counterfactual analysis to identify the most successful strategies.	Adaptation to climate change based upon a portfolio of strategies significantly increases farm net revenues. Changing crop varieties has a positive and significant impact on net revenues when is coupled with water conservation strategies or soil conservation strategies but not when implemented in isolation.
Cervigni, et al. (World Bank). (2013)	Nigeria	**IAM** a high-resolution regional climate model (RCM) was used to simulate and project climate changes from 1971 through 2065 under an A1B emission scenario, which represents a median between the most extreme (optimistic and pessimistic) storylines developed in the Intergovernmental Panel on Climate Change (IPCC)	Average temperatures +1°C to 2°C, with the already arid north more affected than the wetter south. Projected rainfall: Not particularly evident changes in the amount of Agriculture will mainly be affected by increasing loss of yields for the main crops (cassava, millet, yam, maize, sorghum, and rice). Effects are more uncertain in the shorter term (2020).

			Half of Nigeria's agro-ecological zones will be food insecure by 2020 and 75% by 2050 unless their dwindling local food production is complemented by improved in-country trade. Decline in crop yields will reduce GDP (compared to the no-CC scenario) by up to 4.5%. by 2050 By 2050, in about half of the country wet risk is expected be dominant, 10% of the country to be exposed to drier conditions, and 23% to be stable but 33% of total land area is subject to uncertainty. Robust sustainable land management practices for 14–18 million (ha) of rain-fed areas and 1.5–1.7 million additional irrigated ha might fully offset long-term climate change impacts on agriculture. The regrets for not including CC in policies design can be as high as 40% of investment costs, which can be reduced by 30–50% on average (up to 90% in some locations). Designing the dam without taking into account CC exposes the project to a regret (the cost of failing to deliver power) of 25% of capital costs; Reducing energy storage in anticipation of a possibly drier climate reduces the regrets to 5% of capital costs.
Chavas and Di Falco (2012)	Ethiopia Tigray region, in the highlands of the country	**Structural Approach** Investigated agroecosystem productivity empirically, using farm-level data. Estimation procedure: 2-step GMM with Arellano-Bond Instruments. Evaluate the productive value of diversity as the productivity difference between an	The value of biodiversity is positive. Complementarity is the main source of biodiversity value in this agroecosystem (the complementarity component is large and statistically significant) Neither the scale effect nor the catalytic effect is important.

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<td>integrated system and a less diverse system, holding aggregate resources constant.
Estimate a multi-output production function.
Rely on instrumental variable estimation to address endogeneity issues
The estimated coefficients are then used to investigate the magnitude and determinants of
biodiversity value.
The authors does not rely on a specific biodiversity index.</td>
<td>The convexity component is negative. This shows that nonconvexity contributes to reducing the value of biodiversity at the farm level.</td>
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<tr>
<td>Di Falco, Veronesi and Yesuf (2011)</td>
<td></td>
<td>Examine the driving forces behind farm households’ decisions to adapt to climate change, and the impact of adaptation on farm households’ food productivity.
Estimate a simultaneous equations model with endogenous switching.</td>
<td>Main drivers behind adaptation choices:
Access to credit, extension (both formal agricultural extension
through government extension officers and farmer-to-farmer extension) and information (particularly relevant
in this setting is that farmers received information on climate).
Adaptation increases food productivity and farm households that did not adapt would benefit the most from adaptation.
Average Expected Production per Hectare
<table>
<tr><td></td><td colspan="2">Decision Stage</td></tr>
<tr><td>Season</td><td>To Adapt</td><td>Not to adapt</td></tr>
<tr><td>Farm households that adapted</td><td>1,133.9</td><td>952.7</td></tr>
<tr><td>Farm households that did not adapt</td><td>1,161.8</td><td>862.8</td></tr>
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<tr>
<td>Deressa and Hassan (2009)</td>
<td>Ehiopia</td>
<td>Ricardian Approach
Analyze the impact of climate change on crop farming. Use data from 1,000 farm households in different agro-ecological zones of the county and regress net crop revenue per hectare on climate, household and soil variables.
Calculate the net crop revenue impact of predicted climate scenarios from 3models (CGM2, HaDCM3 and PCM) for the years 2050 and 2100. the damage that climate change would pose increases with time unless this</td>
<td>Marginal Impacts of Climate on Net Revenue per Hectare (US$):
<table>
<tr><td>Season</td><td>Winter</td><td>Spring</td><td>Summer</td><td>Fall</td><td>Annual</td></tr>
<tr><td>Temperature</td><td>-2998*</td><td>376</td><td>-21277*</td><td>1878*</td><td>-222</td></tr>
<tr><td>Precipitation</td><td>-2465*</td><td>225*</td><td>-219</td><td>-264</td><td>-2323*</td></tr>
</table>
* Indicates coefficients are significant at 5 or 1%
Net revenue impact of climate change is not uniformly distributed across the different agro-ecological zones of Ethiopia.
There would be a reduction in crop net revenue per hectare by the years 2050 and 2100. The reduction in net revenue per hectare by the year 2100 would be more than the reduction by the year 2050 indicating negative impact is abated through adaptation.</td>
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<td>Deressa et al., (2009)</td>
<td>Ethiopia Nile Basin</td>
<td>Use cross-sectional household survey data from 1000 households during 2004/2005 production season. Uses the multinomial logit model (MNL). Dependent variables include different adaptation methods and the explanatory variables include different household, institutional, and social factors. Look at marginal effects from the MNL to measure the expected change in probability of a particular choice being made.</td>
<td><u>Farmers' perceptions</u>: 51% of the surveyed farmers observed increasing temperature. 53% observed decreasing rainfall over the past 20 years
Main <u>methods used by farmers</u> to adapt to climate change: use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation.
Main <u>factors influencing farmers' choices</u>:
education (+1 year→ +1% probability of soil conservation and+ 0.6% prob. to change planting dates)
gender (Male-headed households are 9% more likely to conserve soil, 12% more likely to change crop varieties 10% more likely to plant trees) age (+1 year → 0.5% more likely to plant trees 0.06% increase in irrigation) wealth of the head</td>
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			of household (+1 unit → 0.01% more likely to change crop varieties, conserving soil and changing plant dates) access to extension (+11% likelihood to use different crop varieties and +12% prob. to plant trees) and credit; information on climate(+18 % likelihood to use different crop varieties), social capital, agroecological settings, and temperature (+1degree w.r.t. mean→ change crop varieties +5.5%, conserving soil +3% changing planting dates +1.2%, irrigation +0.6%) Main barriers: lack of information on adaptation methods and financial constraints.
Boko et al. (2007) *Contribution of Working Group II to the 4th Assessment Report of the IPCC, 2007*	Africa	Contribution of Working Group II to the 4th Assessment Report of the IPCC, 2007 The report includes analysis of existing Studies.	Yield reduction: in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers being the most affected. The population at risk of increased water stress in Africa is projected to be between 75-250 million and 350-600 million people by the 2020s and 2050s, respectively. The proportion of arid and semi-arid lands in Africa is likely to increase by 5-8%. by the 2080s. Between 25 and 40% of mammal species in national parks in sub-Saharan Africa will become endangered. The cost of adaptation to sea-level rise could amount to at least 5-10% of gross domestic product Human health, could be further negatively impacted by climate change and climate variability, e.g., malaria in southern Africa and the East African highlands

[i] It is conventional in this body of literature to use quadratic terms for the climatic variables. This in order to capture non linearities and threshold effects in the relationship between revenues and climate (Mendelsohn *et al.* 1994). Increasing temperature may have a positive impact on the growth of crops, however, up to a threshold level after which increased warming of the production environment may have detrimental effects on yields.

[ii] Holden and Yohannes (2002) noted, however, that the direction of causality ma be reversed. Farmers with more tenure security may plant more perennials.