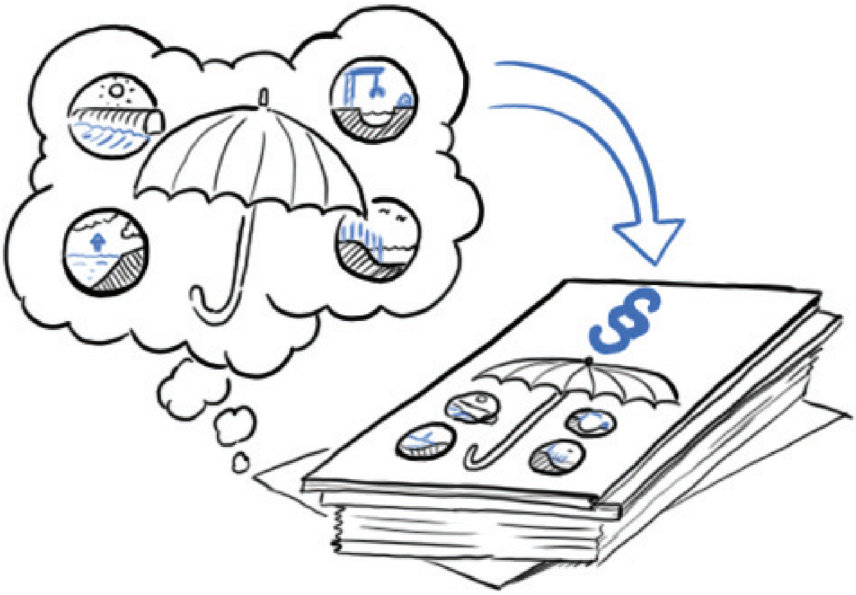
Competence Center for Climate Change



Economic approaches for assessing climate change adaptation options under uncertainty

Excel tools for Cost-Benefit and Multi-Criteria Analysis

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

AdaptationCommunity.net

Published by
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Competence Center for Climate Change

T +49 6196 79-1903
F +49 6196 79-801903
E info@giz.de
I www.giz.de

Authors
Steffen Noleppa,
agripol – network for policy advice GbR

Contributions by
Timo Leiter and Nele Bünner

Responsible
Timo Leiter

Design elements
Climate Media Factory, info@climatemedia.de

Layout & Design
Ira Olaleye, Eschborn

Eschborn, December 2013

Content

List of figures

List of tables

List of abbreviations

BCR	Benefit-Cost-Ratio
CBA	Cost-Benefit-Analysis
CBR	Cost-Benefit-Ratio
CEA	Cost-Effectiveness-Analysis
ci:grasp	Climate impacts: global and regional adaptation support platform
ECA	Economics of Climate Adaptation Working Group
GE	General Equilibrium
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GSF	Global Climate Change Alliance Support Facility
IMACC	Inventory of Methods for Adaptation to Climate Change
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
MCA	Multi-Criteria-Analysis
NPV	Net Present Value
PE	Partial Equilibrium
PIK	Potsdam Institute for Climate Impact Research
SDR	Social Discount Rate
ToR	Terms of Reference
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction: tasks of the study and structure of the report

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) together with the Potsdam Institute for Climate Impact Research (PIK) – is currently implementing the project '**Inventory of methods for adaptation to climate change' (IMACC).** The project is focusing on user-driven application and advancement of existing tools and methods in the field of adaptation to climate change while developing capacities for adaptation planning of involved actors in partner countries.

This study was commissioned as part of IMACC to look at approaches for the economic assessment of climate change adaptation options. Special emphasis is being placed on the issue of including uncertainty in the economic assessment and respective approaches. The study's terms of reference (ToRs), define three main tasks:

1. **Discussing existing needs and experience gained** with respect to the use of economic approaches for the assessment of climate change adaptation options;
2. **Reviewing the most common and promising methodological approaches** for the economic assessment of climate change adaptation options using evaluation criteria such as data requirements and availability, scaling, required skills and ci:grasp compatibility; and
3. **Providing two prototypes of Microsoft Excel-based software/** programming solutions and demonstrating the usefulness of these prototypes for assessing climate change adaptation options with real or fictive data.

The report is structured as follows:

- Chapter 2 defines **important terminology** used in the report for evaluating economic approaches and **clarifies the overall perspective** for the analysis that follows.
- Chapter 3 discusses **experience gained while using economic methods** for assessing climate change adaptation.
- Chapter 4 identifies **available economic approaches** for assessing climate change adaptation. A distinction will be made between major and supportive approaches.
- Chapter 5 **describes in more detail the major economic assessment approaches**, including the cost-benefit analysis (CBA), the cost-effectiveness analysis (CEA) and the multi-criteria analysis (MCA). It discusses the data requirements and other criteria related to the pros and cons of the three techniques.
- Chapter 6 briefly presents the supportive economic assessment approaches, namely partial and general equilibrium models as well as Ricardian and physical models.
- Chapter 7 highlights **specific challenges** with respect to the data needed for a sound economic assessment of climate change adaptation. The chapter first deals with the need to include **uncertainty** in the assessment approaches and then touches on the **problem of discounting** data over time.
- Chapter 8 discusses and explains the **Microsoft Excel-based prototypes** which are available at AdaptationCommunity.net under Knowledge ➡ Mainstreaming ➡ Tools and Training materials.
- In chapter 9 the report will conclude with some recommendations on what is required to incorporate economic assessment activities in development projects and programmes, as well as recommendations on further ac- ties following this study.

2 Methodological remarks: terminology and coverage of the study

Methods and tools for making decisions on climate change adaptation are discussed in this study with a focus on economic approaches under uncertainty. A few terms first need to be defined in order to ensure the following evaluation and analysis is properly interpreted.

The UNFCCC (2008) provides sound definitions for the terms 'methodology', 'method' and 'tool'. For the purpose of this study, i.e. with respect to climate change adaptation options and their assessment, they are defined as follows:

- A **methodology** is a complete framework that describes the entire process for the assessment of climate change adaptation. In this sense it is a rather broad strategic framework assembling certain methods and tools to support this process.
- A **method** is a set or sequence of steps that should be followed in order to accomplish a specific task within the larger strategic framework. Such a task might be the economic assessment of climate change adaptation options.
- A **tool** is used to implement a method, i.e. tools are considered as means or instruments by which a specific task will be accomplished. This usually refers to replicable devices (Hammill and Tanner, 2011) such as a computer programme, an arithmetic procedure, a questionnaire, etc.

According to this terminology a method needs a tool in order to function within the context of an entire methodology. Both are interlinked and thus belong together. The symbiosis between a method and a tool is referred to as an approach in this report.

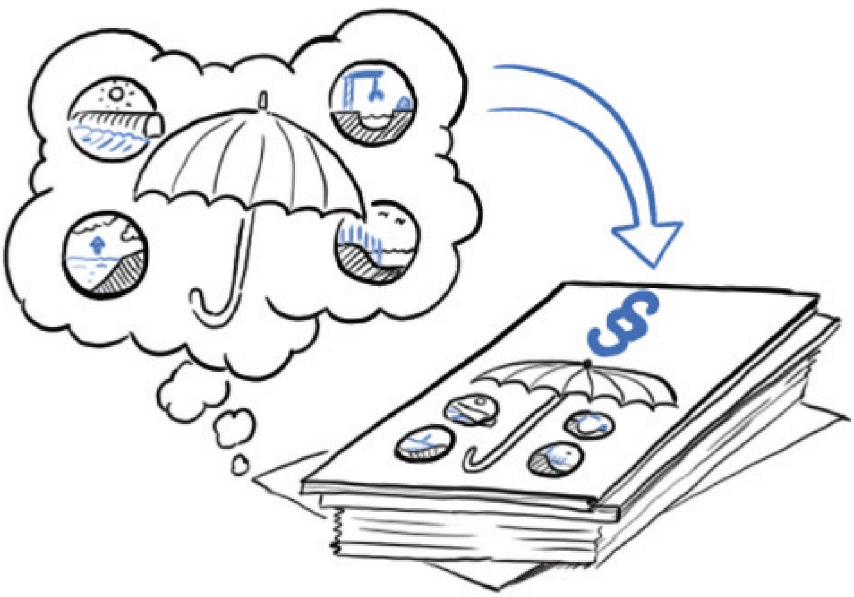
- This study focusses specifically on methods and tools for the analysis of **already defined** adaptation options and their evaluation prior to implementation (see table 1). Such methods and tools may originate in various fields and sciences: applied climate research, climate impact research, politics, physics, biology and/or economics. The sole focus here is on the **economic perspective**: i.e. on an economic appraisal of adaptation options. [1] This limits the scope of this study with respect to the tasks displayed in table 1. Indeed, prioritising climate change adaptation requires both economic and technical analysis (Künkel, 2011), but the technical element is not discussed here.

[1] Methods to monitor and evaluate adaptation projects once they are being implemented are presented in the GIZ publication „Adaptation made to measure. A guidebook to the design and results-based monitoring of climate change adaptation projects" (GIZ, 2013).

Table 1: Locating this study in the tasks of the climate change adaptation process

Main tasks defined in accordance with Hammill and Tanner (2011)	Tasks covered in this study
Awareness raising for adaptation	
Screening of possible adaptation options	
Definition of suitable adaptation options	
Analysis of defined adaptation options	
Appraisal and selection of adaptation options	
Implementation of selected adaptation options	
Monitoring and evaluation	Covered e.g. by GIZ (2013)

One final methodological remark: in this study, we view **adaptation as an economic investment** made to avoid or limit damages due to climate change as defined by Wright (2003). In other words: we focus on negative impacts although climate change may also create opportunities. The economic methods and tools discussed are principally able to assess both positive and negative impacts of climate change and climate change adaptation.



3 Experience with economic assessments of climate change adaptation: achievements and needs

The aim of this chapter is to identify major needs with respect to further promoting economic assessment of climate change adaptation. While analysing experience gained in applying respective approaches, various needs were recognised. They can be grouped into more general needs that focus on the entire approach, as well as more specific needs that address individual shortcomings.

Four basic needs have been identified and can be summarised as follows:

1 Climate change differs from other stress factors as the severity and frequency of its effects are uncertain. The extent of uncertainty increases the further into the future and the more local projections are. **Determining and using information on climate change impacts** is therefore a **fundamental need** for the entire climate change adaptation process (see also Chambwera and Stage, 2010; Hammill and Tanner, 2011), and it is especially important in a comprehensive economic assessment of climate change adaptation.
2 Information on potential climate change impacts is not only weak; it is also uncertain. Uncertainty may always play a role in weak information, but in the case of climate change and climate change adaptation, the level of uncertainty is so profound and widespread that it should be considered a very important issue by itself. **Dealing with uncertainty is another**, and perhaps *the* **major need** (see also chapter 7).
3 This uncertainty in information may be the reasons why there is still no **comprehensive and systematic overview on the usefulness of economic assessments** for climate change adaptation. This study intends to offer a starting point for the basic need of systematisation, too.
4 This paper also aims at contributing to **another basic need**, which **is the de-mystification of economic assessments**. Many who would like to carry out an economic assessment still believe that such an assessment is resource-intensive and requires very sophisticated technical skills (see also Chadburn et al., 2010). This is not necessarily the case, although it should be noted that scientists, economists in particular, tend to use more or less sophisticated models and non-transparent methods to analyse outcomes of climate change and climate change adaptation. The **need for 'ready-to-use' tools** to support decision-making has to be fulfilled noting that a provision of such tools does still require formal training before the tools can be used (see also Hammill and Tanner, 2011).

Furthermore, the paper will try to address other more specific needs, which have been identified while summarising experiences made in development projects and programmes. They are as follows:

- **Scientific findings** and a plethora of other information on climate change and adaptation options are available on larger scales – country, regional and global – but they **have to be interpreted and adjusted for local or more small-scale particularities**. Bottom-up experiences and local perceptions on assessments need to be linked with science-based, top-down approaches that look at climate change adaptation and related impacts.
- The development community poses specific needs. Donors are increasingly looking through a 'climate lens' and trying to combine climate change adaptation activities with overall development activities (Paris, 2011) through climate-proofing (see, e.g., GTZ, 2010). **Trade-offs and synergies between adaptation activities and development activities** (at all levels of intervention) need to be identified.

4 Suitable economic approaches in adaptation planning: main vs. supportive approaches

The entry point for an economic assessment of climate change adaptation options is defined in this report as follows (see also Table 1): After the vulnerability of a country or sector to climate change has been analysed and potential adaptation options have been identified these options have to be appraised and prioritised. Hence, economic assessment is the process of evaluating and prioritising well-defined adaptation options using economic criteria or criteria that can be included in economic analyses.

Adaptation to climate change is seen as an investment. Assuming limited resources, it leads directly to the following question: How much should be invested in which adaptation option(s) and at what time in order to create the highest benefit at reasonable costs and within the available budget? Decision-makers therefore face a basic economic problem: optimising the allocation of resources. By and large, the Intergovernmental Panel on Climate Change (IPCC) also defines this as adaptation assessment, namely to identify options for adapting to climate change and evaluate them in terms of criteria such as availability, benefits and costs, effectiveness, and efficiency (McCarthy et al., 2001).

An economic assessment basically deals with the following: benefits and costs, usually measured in monetary terms, and with efficiency and effectiveness serving as a sort of a quotient or ratio of both cost and benefits. Against this background, it is not surprising that the UNFCCC (2002), along with GSF (2011) and Niang-Diop and Bosch (2011) suggest **three main techniques** to be applied in the economic assessment of climate change adaptation options:

- Cost-benefit analysis (CBA);
- Cost-effectiveness analysis (CEA); and
- Multi-criteria analysis (MCA).

All three approaches are able to (1) analyse and (2) prioritise adaptation options and will be considered as main economic assessment approaches in the following (see chapter 5).

In addition to CBA, CEA and MCA, **more complex techniques** are used as economic methods, tools or approaches with respect to climate change adaptation. The objective often is to model climate change impacts and their associated costs and benefits. Such economic assessments are classified according to the type of model used. There are **two main typologies**:

The first typology classifies models with respect to their economic (i.e. market and/or sector) coverage. Model inputs and outputs are mainly monetary values such as prices, revenues, rents, costs, etc. Frontier Economics Network (2008), Gambarelli and Goria (2004), and Robinson (2011) make use of this perspective and distinguish between **partial equilibrium (PE)** and **general equilibrium (GE)** models. Both types of models are principally able to analyse costs and utilities (benefits) based on the standard concept of **welfare economics**.

The second typology does not use a pure economic concept, but **combines economics with physics and other sciences**. Models first provide information on **physical indicator**s (such as yields, occurrence of health problems, number of damages, etc.), which – endogenously or exogenously depending on the model – can often be **related to monetary values**. Important approaches are very specific physical models (such as a crop model) and so-called Ricardian models (see UNFCCC, 2008; World Bank, 2011).

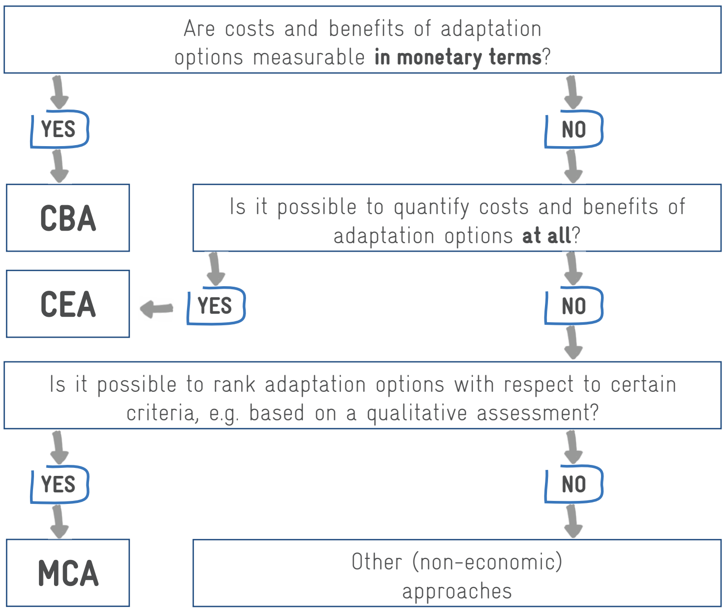
In the following, PE and GE models as well as physical and Ricardian models are not considered main economic approaches for the assessment of climate change adaptation options because they are not specifically designed to prioritise among alternative options. They will therefore be considered as **supportive assessment approache**s in the following (see chapter 6).

The report will now focus on the above-mentioned economic approaches for an assessment of climate change adaptation options. While the following does not provide detailed descriptions of the various techniques, it aims to provide potential analysts and decision-makers with guidance on properly identifying the most suitable approach by describing what is needed to apply it. These needs must be met so that reliable and comprehensible evidence to support decision-making can be generated.

5 Main economic approaches: CBA, CEA and MCA

Before the three main tools are described in greater detail, one important question needs to be answered: What method should be used when? Figure 1 illustrates the decision-making process with regard to that question.

Figure 1: Selecting the suitable economic approach for assessing climate change adaptation options



Source: Author's own figure based on UNFCCC (2002) and Niang-Diop and Bosch (2011).

If costs and benefits of alternative adaptation options can be measured in or translated into monetary terms, a CBA would be preferred. If benefits of adaptation options can be quantified but not expressed in monetary terms (e.g. human lives) whilst costs can be quantified in monetary terms, a CEA would be preferred. If both costs and benefits cannot be expressed in monetary terms, an MCA is recommended. In all other cases, an economic approach is very difficult to be applied and other approaches have to be taken into consideration, e. g. using an expert panel to conduct an assessment.

5.1 Cost-benefit analysis (CBA)

From a purely economic perspective, a CBA is preferred whenever possible with respect to the assessment of climate change adaptation options (ECA, 2009; UNFCCC, 2002). And indeed, a CBA is commonly used for this purpose (Chadburn et al., 2010; Chambwera and Stage, 2010; Hallegatte et al., 2011b). A CBA is basically comparing costs and benefits of an intervention over time (GSF, 2011). The major limitation of a CBA, however, is that all the costs and benefits must be measurable in monetary terms.

A CBA is able to help decision-makers decide which adaptation option is preferred if there is more than one option that makes economic sense to be implemented. Using a CBA often requires just a few training sessions. With regard to the steps involved in a CBA, **data gathering** must be distinguished from (mathematical) **data processing** and the **analysis of results**.

Data gathering is probably the most time-consuming and definitely the most crucial step in a sound CBA (this also applies to a CEA and MCA). Basically, data gathering means to quantify all costs and all benefits, which have to be expressed in monetary values (Policy Research Corporation, 2009). This has to happen not only with regard to their **amounts**, but also their **timing**. The following data and information need to be obtained when assessing climate change adaptation in order to fully cover costs and benefits:

- A 'base case' (UNFCCC, 2002), 'baseline' (Watkiss et al., 2010) or 'business-as-usual' (Sova, 2011) scenario must first be established. This scenario will have to illustrate what will happen without any adaptation. To do this, the present situation has to be projected along a time horizon. This can be 20, 30 or even more years. The focus should be the total costs due to climate change in the absence of adaptation (Policy Research Corporation, 2009).
- Such a 'baseline' scenario has to be distinguished from one or more scenarios that include adaptation. In principle, each adaptation option considered could lead to a particular adaptation scenario.
- Costs and benefits have to be determined for any single point in time (usually a year) along the considered time horizon. Depending on the definition, both costs and benefits can become positive or negative.
- Costs and benefits to be included have to be carefully defined in order to assure that all impacts of adaptation options are properly assessed (see also Sova, 2011; GSF, 2011). This has to be done with such care because the inclusion/non-inclusion of the one and/or other cost and benefit aspect may considerably influence the outcome of an economic assessment such as a CBA.
- **Direct costs** are mainly fixed costs (e.g. initial investment costs occurring at the outset of an adaptation measure) or variable/operating costs occurring on a more or less regular basis throughout the adaptation measure (e.g. repair and maintenance costs). Externality, **indirect** and/or co-costs also need to be taken into consideration. They are usually much more difficult to measure and indicate spillover effects. Costs of adaptation often have to be estimated, especially with respect to future costs since adaptation is mainly a long-term process. In most cases, obtaining reliable cost data is a complex area and requires several sources of evidence ranging from project case studies to global scale assessments (Watkiss et al., 2010).
- Damages that can be avoided through the adaptation option in question count as benefits. Co-benefits of adaptation compared with the 'baseline' also need to be incorporated into a CBA (GSF, 2011). Again, direct and indirect benefits need to be distinguished. Consider the case of improved water management for maintaining agricultural production when climate change will cause more heavy rainfall. In such a case, more or even higher yields due to proper channels or other irrigation devices would be considered a direct benefit, whereas fewer health problems due to more unsuitable environments for carriers of pathogens such as insects would be considered an indirect benefit. Chambwera (2010) provides a more detailed explanation on observing and evaluating benefits in a CBA.
- One important aspect to be thoroughly considered is what to do if not all of the benefits and costs are accountable in monetary terms per se. In such a case, a CBA is still possible if achievements towards an objective can indirectly be translated into monetary units. Examples of valuation techniques to include environmental and social objectives in a CBA can be found in Chambwera and Stage, 2010; World Bank, 2010; or – to take an example from natural disaster impact evaluations – McKenzie et al., 2005. These types of CBA are called **social CBA** (UNFCCC, 2002), sometimes also referred to as an inclusive CBA (Sova, 2011).

Data gathering is followed by data processing and results generation. From a mathematical point of view, a CBA is simply a comparison of costs and benefits, which is reflected in its **output parameters**:

- The **net present value (NPV)** is a first main output of any CBA. The NPV is simply benefits minus costs calculated at their present value, i.e. using a discount rate for future benefits and costs. If the calculation leads to a positive NPV, then an adaptation measure makes sense from an economic point of view. The better the economic value of an adaptation measure is the larger the NPV becomes. However, a larger NPV does not necessarily indicate higher efficiency. This is illustrated using in a simple example shown in table 2 (for simplicity, this example assumes that all costs and benefits occur at the same time, i.e. no discounting is necessary).

Table 2: Example of output parameters of a very simple CBA.

Adaptation option	Costs	Benefits	NPV (= Benefits - Costs)	BCR (= Benefits/Costs)
A	1	3	2	3
B	2	5	3	2,5

One might come to the conclusion that B is the better option, because it leads to higher benefits. In absolute terms this is true and if the objective is to create the highest benefit from a single activity, this option should be prioritised. But if the objective is efficiency, i.e. the highest benefit per unit spent, another output indicator needs to be calculated, namely the ratio of benefits and costs.

- The **benefit-cost ratio (BCR)** is the ratio of benefits to costs. (Note: the inverse can also be used instead: the cost-benefit ratio (CBR) as promoted, e.g. by ECA (2009)). Any BCR above 1 makes sense from an economic point of view as this indicates that benefits are higher than the costs. The larger the BCR becomes, the better the adaptation option is judged to be. Taking the example from above, A would result in a BCR of 3/1 = 3, whereas B would have a BCR of only 5/2 = 2.5 and should therefore not be prioritised over A.
- A third output indicator is the **internal rate of return (IRR)**, which can basically be considered the interest rate an adaptation option would generate for society. Technically speaking, the IRR is the discount rate at which the NPV becomes zero. Hence, a resulting IRR higher than the discount rate to be chosen is a good sign. However, no distinct value can be provided at which an IRR could be considered economically reasonable; instead an IRR should exceed the opportunity costs of capital, i.e. the interest rate one might generate through alternative investments, or be higher than an applicable social discount rate (compare section 7.2 on discount rates).

The basic structure of a CBA is displayed in table 3.

Table 3:
Example structure of a CBA for the economic assessment of two climate change adaptation options

Time period	Costs		Benefits		Difference of benefits minus costs	
	Option 1	Option 2	Option 1	Option 2	Option 1	Option 2
0	100,000	120,000	5,000	10,000	-95,000	-110,000
1	20,000	25,000	6,000	12,000	-14,000	-13,000
2	15,000	18,000	8,000	12,000	-7,000	-6,000
3	8,000	12,000	10,000	20,000	2,000	8,000
4	8,000	12,000	18,000	25,000	10,000	13,000
5	.	.	.	.	.	.
⋮	.	.	.	.	.	.
20	.	.	.	.	.	.

Discounting the annual differences with the **discount rate** to make them comparable

Sum of the discounted differences over all time periods provides the **Net present value (NPV)**

Source: Author's own figure.

Altogether, the CBA provides a powerful instrument for the economic assessment of climate change adaptation options. From the author's point of view, there are no limitations to its application as long as costs and benefits can be properly measured in monetary terms.

5.2 Cost-effectiveness analysis (CEA)

As in the case of a CBA, a CEA can rank and thus prioritise climate change adaptation options. A CEA can be considered a costing analysis of alternatives. Simply speaking, it determines how a well-defined objective can be achieved in the most cost-efficient way. There are two data necessities which must be fulfilled in order to properly conduct a CEA:

- Just as in a CBA, costs need to be quantified in monetary terms to conduct a CEA. The procedure is identical to the cost assessment used in a CBA.
- The difference to a CBA is that a CEAs is used only if it is impossible to assign a monetary value to *benefits* of adaptation options (if both costs and benefits could be measured in monetary values a CBA would be used). For a CEA, the unit in which benefits are measured has to be carefully defined (GSF, 2011). Examples are the number of animals preserved in a biodiversity programme or the area of pristine forest protected in a conservation programme.
- Quantifying (monetary) costs and (non-monetary) benefits means that the unit costs can be calculated as the ratio of total (discounted) costs to total benefits if – as in the case of a CBA – incremental costs and benefits (attainable by comparing a baseline scenario and one or more adaptation scenario(s)) rather than absolute costs and benefits are taken into consideration (GSF, 2011). The output indicator of a CEA is therefore also a Cost-Benefit-Ratio (CBR). The most cost-efficient option is the one with the lowest CBR, i.e. the lowest costs per unit of benefit. Note that the inverse, a Benefit-Cost-Ration (BCR), can also be taken as an indicator; in such a case, the highest BCR directly indicates the most economically promising adaptation option.

If more than one type of benefit results from an adaptation option a CEA can still be conducted as long as benefits can be expressed in the same unit. For example, consider an adaptation option in the health sector resulting in multiple adaptation benefits such as better sanitation, lower risk of diseases and healthier nutrition. If these benefits can all be measured in the same unit, e.g. an improved health status of the local population, then these benefit can be added to form an overall benefit indicator of the adaptation option. If on the other han, an adaptation option would result in diverse benefits that could not be measured in the same unit (e.g. better human health and protected habitat for wildlife) then these benefits could not be accounted for in one CEA calculation because the outcomes could not be numerically compared. Thus, a prerequisite of using a CEA to compare different adaptation options is that their benefits can be expressed in the same unit.

5.3 Multi-criteria analysis (MCA)

When benefits cannot be measured quantitatively or when multiple diverse benefits cannot be aggregated a Multi-Criteria Analysis (MCA) can be used. Similar to a CBA and CEA, an MCA is able to rank and thus prioritise among multiple adaptation options. However, contrary to a CBA, ranks resulting from an MCA are not based purely on economic calculations but on a (qualitative) assessment of criteria such as feasibility, cost effectiveness, co-benefits, ease of implementation, acceptability to local population and resources required. The MCA differs from CBA and CEA in that rules for the assessment of options according to a set of criteria have to be agreed upon in order to rank options. Since reliable quantitative information on this may be difficult to attain, a qualitative expert judgment is the typical way to fill the information gap. This makes an MCA more subjective and may lead to a lack of transparency, especially if calculations are computerised. The UNFCCC (2002) therefore suggests favouring MCA techniques based on simple scoring methods instead of sophisticated programming. In the simplest case, scores from '1' to '10' can be defined and attributed to each criterion. Criteria may be given different weights according to their relative importance. For example, effectiveness may be given a higher weight than resources required (or vice versa). Obviously weights should add up to '1.00' (i.e. 100 per cent).

Chapter 8 explains how to conduct an MCA or CBA using programmed Microsoft Excel tools study which are available at AdaptationCommunity.net.

6 Supportive tools: economic model approaches

In chapter 4, major economic approaches for the assessment of climate change adaptation (i.e. CBA, CEA and MCA) have been distinguished from supportive economic approaches which are more complex but not able to prioritise among different adaptation options. These **supportive approaches**, namely partial equilibrium (PE) and general equilibrium (GE) models as well as physical and Ricardian models, are discussed below. Applying these economic and physical models requires experts and may not be suitable for all circumstances. Simple appraisals of alternative adaptation options can often be dealt with using the main economic approaches presented in chapter 5. The following is meant to provide an overview of more sophisticated economic modelling approaches that may be relevant for complex economic analysis of adaptation decisions. Knowledge in economic theory is advantageous to understand the following details.

6.1 Partial equilibrium and general equilibrium models

Climate change affects many economic variables and actors. For example, rising temperatures and varying water availability may cause production losses, which can results in supply shortages. The demand for energy, water, land, etc. may change as well. Among other things, international trade may react and compensate for shifting geographic patterns of supply and demand. Economic theory offers a way to analyse these market variables simultaneously via so-called **market equilibrium models**.

There are basically **two types of market equilibrium models**: **partial equilibrium (PE)** and **general equilibrium (GE) models**. Both types basically project future market changes based on assumptions of market mechanisms and driving forces observed in the past. In the case of climate change adaptation, these models can provide a sound empirical structure/framework for allowing the user to look at potential interactions between climate change adaptation options and the economic structures or system. This can be done at the global and/or national level, depending on the specific question, model philosophy and data availability. A market equilibrium model only seldom works for the local level, however. If combined with a welfare analysis (see Feldman, 2008; Mas-Colell et al., 1995; Samuelson, 1983), PE and GE models may also provide economic information on the feasibility and effectiveness of adaptation options, which could help to rank and prioritises them. However, the model approach in itself is not able to do so.

The following specifics with respect to the PE and GE modelling approaches should be taken into consideration when considering such models for economically assessing climate change adaptation:

- A PE model can be a very flexible means if the focus of climate change adaptation is on a specific sector of a particular economy. The 'markets' of interest can be specified relatively easily since, in many cases, extensive data sets are available (Robinson, 2011). In addition, PE models are relatively easy for experts to program and solve with standard spreadsheet software. Nevertheless, it should be taken into serious consideration that PE (as well as GE) models depend heavily on historical estimates about market behaviour, which may cause considerable (additional) uncertainty to the assessment of adaptation options if strong behavioural changes are expected over time (see also chapter 7).
- Although it is possible to link sectors within a PE model in principle, e.g. input and output markets, GE modelling provides a much better methodological framework for doing so (see Sova, 2011; Frontier Economics Network, 2008). GE models may cover the entire economy, but they require much more data and programming efforts. The challenging data and programming requirements of the approach – access to relevant data systems and software packages provided by the scientific community is usually necessary – may make GE models a 'black box' for practitioners (Sova, 2011), especially if the user has no or limited options to validate the model due to the many parameters and complex relationships involved. The development and application of a GE model for the economic assessment of climate change adaptation definitely requires sophisticated expert knowledge and the most substantial training in comparison with all other approaches described above.

- As a compromise, tailor-made, multi-region/multi-market models have become popular and have been intensively developed over recent years. According to Robinson (2011), such models should be favoured when assessing climate change adaptation in a country or sub-region. These models are by nature PE models, but they allow for the linking of regions and markets, and sometimes also the crossing of sectors (via modelling of input-output markets; see Liapis, 1990). A good, but rather sophisticated example is the IMPACT model designed to examine alternative futures for the global food supply, demand, trade, prices, and food security (see Rosegrant et al., 2008). Less sophisticated but still powerful multi-region/multi-market models have been developed, especially with respect to climate change issues, by von Witzke and Noleppa (2011) and Moeller and Grethe (2010), or they can be developed for one's own purposes by using already available spreadsheet templates, such as those provided by Jechlitschka et al. (2007).

6.2 Ricardian and physical (or crop) models

A Ricardian analysis is a rather pragmatic approach for assessing certain aspects of climate change adaptation at the local or sub-regional level (Sova, 2011). It is argued that if used wisely, this method could probably provide the best way to assess adaptation at the farm level (Chambwera and Stage, 2010) and enterprise level. It uses patterns of already observed behaviour or changes elsewhere and transfers this experience to the region under consideration. A major obstacle in this analysis is that it does not take into account local particularities and relies on the assumption that climate change impacts and adaptation outcomes observed (or expected) elsewhere can be copied and pasted 1:1 from one location to another. Many examples of Ricardian analyses are available; the World Bank (2010) gives an overview on recent applications in the agricultural sector.

A limitation of Ricardian models is that economic variables in the model hold true only for the region where the data originates. This economic setting cannot be copied without substantial assumptions. Hence, Ricardian models always need to be linked to economic conditions in the location under investigation. Nevertheless, Ricardian models may be able to provide some information, for example on certain expected economic effects caused by climate change which may prove useful for a CBA or CEA. Another shortcoming of the Ricardian approach is that it provides insight with respect to a 'what if' situation, but not to a 'baseline' scenario, which would be required for proper comparisons and hence economic judgments on potential adaptation results. This limits its usefulness for a meaningful economic assessment. Kurukulasuriya (2006) provides a more detailed discussion on the Ricardian model approach, including the pros and cons with respect to its application in climate change adaptation.

Physical models, for example a crop or agronomic model (see, e.g., World Bank, 2010), offer another partial solution to the problem of generating sound information for an economic assessment of climate change adaptation. Physical models display nature-borne or technology-borne relationships between input factors such climate change adaptation interventions or an external shock due to e.g. climate change, and output indicators such as yield or income. Such models do not create any sound monetary indicator, but if combined with economic measurement, e.g. the cost of a hazardous situation, they could provide valuable insight into the cost of climate change or the benefits of adaptation options in the form of avoided losses. A combination of such physical models with economic assessment tools is thus a promising approach, but is not yet standard; nevertheless, initial applications have been made (see CEGIS, 2008; Finger, 2009; Kaul, 2011).

7 Specific challenges: uncertainty and discounting

7.1 Taking uncertainty into consideration

Uncertainty poses a significant challenge in assessing climate change impacts and adaptation to these impacts. The explicit consideration of the uncertainty of climate change and its specific impacts in adaptation assessments is therefore essential (World Bank, 2010). Important causes of uncertainty include the following:

- Information on the impacts of climate change is still often weak since uncertainty in climate change projections is still high (see Watkiss et al., 2010). Uncertainty is increasing the more local projections become and the further into the future they reach.
- Even if the general climatic trend in a particular place can be projected the magnitude and timing of particular climatic extremes remains uncertain. Thus, there is uncertainty about the probability and extent of climatic risk (ECA, 2009).
- As a consequence of the uncertainty with respect to both the magnitude and timing of climate change impacts, the question 'What are the expected losses?' is often not easy to answer. Many assessment studies thus try to avoid including too many impacts and use a narrow scope instead (Policy Research Corporation, 2009). This narrowing of the analysis may result in even more uncertainty if only parts of an interlinked system are modelled.
- Another aspect of uncertainty is the vagueness of socio-economic developments in the long run (see Watkiss et al., 2010). Against this background, it is important to note that most assessment studies also try to avoid including such developments which again contributes to uncertainty of climate impact assessments (Policy Research Corporation, 2009).
- Uncertainty may also exist with respect to the adaptive capacities of a region and its inhabitants. While uncertainty may be low with respect to available resources for adaptation in the short run, uncertainties may be high with respect to the (long-term) resources. In addition, there may be incomplete knowledge on the extent, frequency and speed with which knowledge on adaptation can be transferred.
- The use of tools such as a CBA, MCA, PE and/or GE model results in additional uncertainty, since different input parameters and assessment options lead to different cost and benefit estimates. The more complex the model, the higher the respective uncertainty because assumptions play a more pronounced role in determining the outcome of modelling and analyses.

These uncertainties regarding future developments of so many structural determinants make an assessment of climate change impacts very complex (Hallegatte et al., 2011). Consequently, questions to the effectiveness of adaptation are often not easy to answer. However, there are various approaches available to deal with uncertainty in the assessment of climate change adaptation. The main approaches are as follows (see ECA, 2009; GSF, 2011; Hallegatte et al., 2011a; b; Jotzo, 2011):

- One way to deal with this complexity/uncertainty is to use a **scenario analysis**. The challenge is to identify the dimensions along which structures, be they economic, social or environmental, evolve over time. This conceptual effort is critical for the development of informative scenarios (Hallegatte et al., 2011a). A scenario analysis is often also considered a **sensitivity analysis** (UNFCCC, 2002).
- The simplest scenario technique is to apply a 'maximum-minimum' approach. If the final outcome with respect to an impact is not known, but the probable range in which the final outcome is expected, the resulting interval marks upper and lower boundaries that can be used. Similarly an 'optimistic' and a 'pessimistic' scenario can sometimes be described and applied to an economic assessment approach, be it a CBA, CEA or MCA.
- In addition to the upper and lower boundary scenarios, multiple scenarios in between these boundaries should be defined, e.g. by varying the degree of climate change impacts and adaptation outcomes. The application of multiple scenarios can provide input to a sensitivity analysis of the outcome parameters in an economic assessment such as the BCR, NPV or IRR within a CBA. This may also be considered a stress test of its results.

- A more complex approach is to directly include a **probabilistic function** in an assessment. Assuming that probabilities are known – what is probably seldom the case – the probability of occurrence of various cost and benefit outcomes can be included in the analysis and may lead to a probabilistic function of the NPV and IRR values in a CBA.

A further refinement of the scenario technique is to analyse a large quantity of scenarios (e.g. more than 10,000) in a so called **Monte Carlo simulation**. In this sensitivity analysis technique random numbers in a predefined range of parameters (e.g. costs, benefits, interest rate, and probabilities) generate a multitude of scenarios. The results of these scenarios are summarized and visualized in a distribution function. Various software programmes are available to assist in conducting Monte Carlo simulations.[2]

The incorporation of uncertainty adds complexity to the economic approach as well as to the interpretation and use of its results. However, speaking in terms of the approaches described above, uncertainty should be incorporated even given the danger that the results of using the approaches will be less concrete and not necessarily straightforward. In other words, it would be inappropriate to design adaptation around a single future climate projection (Watkiss et al., 2010). If uncertainty is not taken into account, decision-making based on such analyses may not be robust enough.

7.2 Taking discounting into consideration

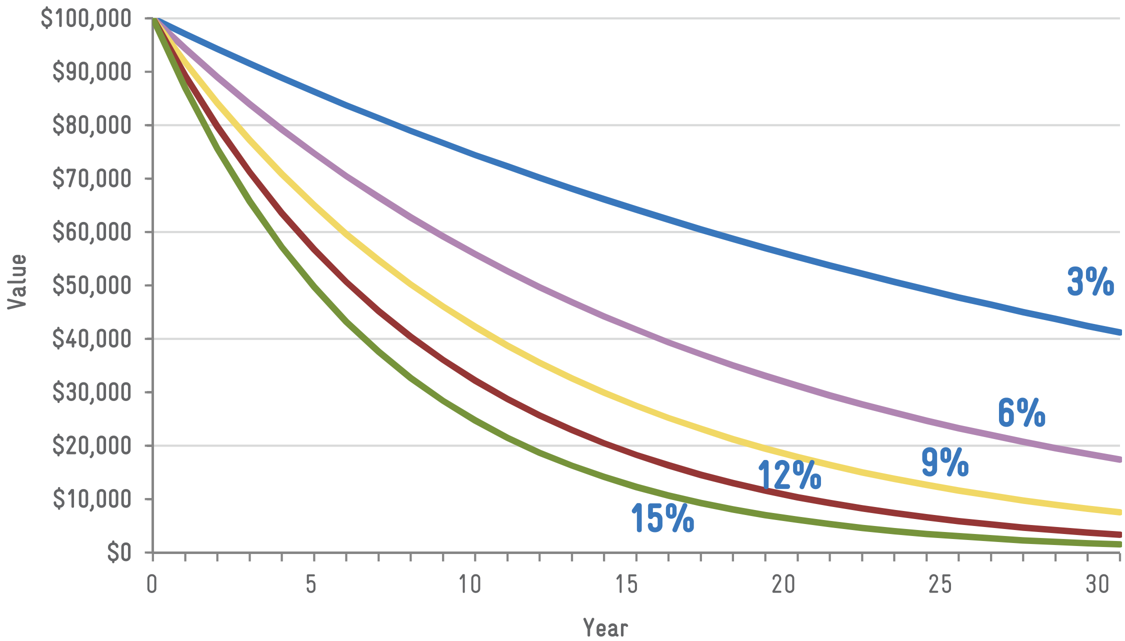
In economic assessments like a CBA, future costs and benefits are usually **discounted**. This is because an alternative to making the investment would be to put the money into the capital market and earn interest.[3] By converting all future costs and benefits that occur at different points in time into their **present value**, discounting makes them comparable. For example, receiving 100 Euros ten years from now would be the same as receiving 74.41 Euro today and putting it in a bank account with an interest rate of 3% which over ten years would earn 25.59 Euros in interest.[4] In this example, 74.41 Euro is the present value. Next to the quantification of costs and benefits, discounting can significantly affect the results of a CBA.

When using CBA for investment decisions that address medium or long-term climate change impacts, discounting plays a significant role. Both the time period considered and the discount rate itself have an effect on the result, because discounting makes the future value of costs and benefits worth less in their present value. For instance, at an interest rate of 6% costs or benefits of 100,000 Euros occurring 15 years from now would have a present value of 41,727 and 100,000 Euros occurring 30 years from now would have a present value of just 17,411 Euros (see figure 2). The higher the discount rate and the longer the time frame, the lower the present value of costs and benefits occurring in the future. This effect is illustrated in figure 2 for different interest rates over a time period of up to 30 years.

When selecting a discount rate, an important difference must be made between private sector investments (which seek a profit above the prevailing market interest rate) and investments in public goods such as coastal protection or emergency services. Indeed, public adaptation investments are typically meant to maximise not just economic but also the social and environmental benefits and therefore may not be comparable to for-profit investments. Therefore, a **social discount rate (SDR)** may be appropriate for investments which are concerned with adaptation to climate change. Social discount rates are typically lower than financial discount rates as the purpose of these investments is not to compete with stock-market or other market based rates of return. Social discount rates for climate change have been suggested in the range of 1 to 6 percent (Mathew et al., 2012; see ADB 2013 for a detailed discussion on different approaches of calculating the SDR). For instance, the "Stern Report" proposes a SDR of 1.4 per cent for assessing the costs of climate change for present and future generations. Other economists like Nordhaus (2007) recommend using a SDR of 5.5 per cent.

[2] Easy to use are so called 'Add-ins' for Microsoft Excel, such as Crystal Ball from Oracle.
[3] The interest rate also offsets for inflation, i.e. for the devaluation of money over time.
[4] Present value = future value * $(1+i)^{-n}$ where i = interest rate (e.g. 0.03) and n = number of years.

Figure 2: The impact of a discount rate on present value estimates



Social discount rates used in adaptation to climate change projects span over a larger range than those recommended by Stern and Nordhaus, especially in developing countries where higher inflation rates prevail. For instance, an adaptation project in Nepal used a social discount rate of 10 per cent for a CBA supplemented by a sensitivity assessment with rates of 5 and 15 per cent. In Gambia, a project assessing adaptation options in agriculture used a CBA to analyse the net benefits of irrigation. A discount rate of 9 per cent was chosen supplemented by a sensitivity analysis using rates of 3 and 14 per cent.

National governments and supranational organizations like the European Commission (EC) also suggest social discount rates. The EC CBA guide from 2008 recommends a 3.5 or 5.5 per cent social discount rate (the higher rate applies to countries with a very low Gross National Income compared to the EU-average). Before 2003, France and UK discounted with 8 and 6 per cent respectively. The tendency after 2005 however, shows a reduction towards 3.5 per cent in UK and 4 per cent in France (Evans et al., 2006; HM Treasury 2008). In Mexico the Secretary of Finance recommends a 10 per cent discount rate for evaluating public projects (GIZ 2013b), while in Peru, the National Public Investment System uses a discount rate of 11 per cent (GIZ 2011, GIZ 2013a).

For any CBA and CEA it is advisable to test how different interest rates affect their outcome parameters.

Table 4: Social discount rates in adaptation to climate change

Suggested by / applied in	Suggested SDR	Source
Stern Report for discounting damages of global warming	1,4 %	Stern 2006
William Nordhaus' review of the Stern Report	5.5 %	Nordhaus 2007
European Commission: Public investments	3.5 % (5.5 % for EU members with Gross National Income below average)	EC 2008
French Government: Public investments	4 %	Evans et al. 2006
British Government: Public investments	3,5 % and lower SDR for long-term project ›30 years	HM Treasury 2008
México: Public investments	10 %	GIZ 2013b
Peru: Public investments	11 %	GIZ 2011, GIZ 2013a
Nepal: Adaptation to climate change project	10 % (5 % - 15 % sensitivity test)	UNFCCC 2012
Gambia: Adaptation to climate change project	9 % (3 % - 14 % sensitivity test)	UNFCCC 2012

8 Programmed prototypes of economic approaches: Excel tools for CBA and MCA

In the following, ready-to-apply 'tools' programmed within the framework of this project will be discussed. Two prototypes of spreadsheet applications are provided: a CBA spreadsheet and an MCA spreadsheet. They can be downloaded at AdaptationCommunity.net under Knowledge ➡ Mainstreaming ➡ Tools and Training material Both applications are able to handle uncertainty, as shown below. Before the basic structure of each 'tool' is explained, some additional reflections on data are provided to demonstrate the usefulness of the CBA and MCA spreadsheet solutions.

8.1 Prototype of a CBA spreadsheet tool

The CBA excel tool consists of a total of eleven sheets. The first sheet is an introductory sheet which consists of basic instructions on how to use the entire file. A CBA of one adaptation measure requires three sheets: one sheet to specify the costs, one to specify the benefits and one for calculating the CBA more or less autonomously. Since three adaptation measures are able to be analysed with the 'tool', three cost sheets, three benefit sheets and three summary sheets are provided. The cost and benefit sheets allow entering up to five different components within a time frame of 30 years (what seems appropriate in the majority of cases given the author's own experiences in the realm of climate change adaptation at the project and/or /programme scale). To compare the CBA outcome parameters of the three adaptation options an overview sheet is provided at the end. In the following a simple case study will demonstrate the use of the tool in practice.

The example is taken from a former GIZ project in Indonesia targeting water availability in spite of climate change (see also Kirschke and Noleppa, 2008). Two alternative adaptation options are compared: changing of cropping patterns and intensification of agricultural production.

Let us first look at the CBA for **adaptation option 1, changing cropping patterns**. Only one cost position – annual maintenance costs of IDR 227,496 – and two benefits – additional agricultural production income in the wet (IDR 1,095) and in dry season (IDR 755,912) – were identified by the project. Benefits are assumed to occur annually starting one year after first costs (first slight investments) are undertaken.

The 'summary-cropping pattern' sheet then shows the results of the CBA taking into account a discount rate of 5 % (Table I-1). An IRR of 233 % and a corresponding NPV of IDR 7,798,869 were calculated for the entire time horizon of 30 years. The results show that the option is beneficial according to economic criteria since the NPV is positive and the IRR is well above any other interest rate obtainable on financial markets.

Secondly, the CBA for **adaptation option 2, intensifying agricultural production** instead of changing cropping patterns, is conducted. This is done using the next three sheets: 'Costs-Agricultural intensification', 'Benefits-Agricultural intensification' and 'Summary-Agricultural intensification'. Again, annual maintenance costs of IDR 54,000 are the only cost component and now only one benefit (in wet season, but not in dry season) of IDR 436,097 was identified leading to an IRR of an astonishing 708 % (Summary: Table II-1).

Results of the CBA of both adaptation options can be compared on the overall results sheet (Results-Overview: Sensitivity analysis 1 for Alternative I and II). Both options have a positive Net Present value and therefore make sense economically as the benefits outweigh the costs. Since the option of intensifying agricultural production has a higher Internal Rate of Return the CBA would suggest preferring this option if all inputs are well-defined and incorporated into the model.

However, doubts may exist due to uncertainty which prompts the use of different scenarios. For instance, the question could be: Do we really know that intensified crop production leads to a benefit each year? What if the benefit can only be obtained every other year due to volatile weather conditions? To account for this case, a second scenario can be constructed within the same excel tool (Sensitivity analysis 2). If costs remain unchanged whilst benefits occur only every second year this results in an IRR of 'only' 139 %, which is still quite high, but lower than the IRR for the adaptation option 'cropping patterns' (which was left unchanged). Hence, following this scenario the option 'cropping patterns' should be prioritised (Results-Overview: Sensitivity analysis 2 for Alternative I and II). This example shows how different scenarios can lead to different results.

An IRR of well over 200 or 300 % should be considered unusual (although not unrealistic since some exceptions to the rule exist). The data background should at least be checked in such a case. Indeed, for the neutral investigator – like the author of this paper – it seems that an important cost factor was simply forgotten in the CBA: initial investment costs (in addition to the already considered maintenance costs). Constructing a third scenario, an initial investment of IDR 1,000,000 in both cases ('changing cropping patterns' and 'intensifying crop production') for new machinery and technology, knowledge transfer, etc., is added as second cost component (Cost tables I-3 and II-3). This has a profound effect on results: the 'cropping pattern' adaptation option would then yield an IRR of 43 %, and the 'intensification' adaptation options would yield an IRR of 36 % (Results-Overview: Sensitivity analysis 3 for Alternative I and II). Now the IRRs are much smaller, but still positive. This example shows the effect on CBA parameters if substantial costs are left out.

Similar to this example, up to five different scenarios (sensitivity analyses) can be performed for all three options using the five tables provided in every sheet. The tables are numbered accordingly in Roman numbers to distinguish the three adaptation options (I, II, III) followed by an Arabic number for scenarios 1-5. For example, 'Table II-3' denotes the third scenario of adaptation option 2.

8.2 Prototype of an MCA spreadsheet tool

The MCA spreadsheet tool as a prototype is rather simple in its structure and with respect to the underlying programming efforts. It allows **comparing up to ten adaptation options on up to ten criteria**. To account for uncertainty, three identical sheets are provided where scores or criteria weights can be changed to compare the effects on total scores and ranking. Detailed instructions are provided on each sheet.

The use of the tool is demonstrated with a hypothetical example of dealing with sea-level rise (modified from Niang-Diop and Bosch, 2011). **Four adaptation options** – installing pumps, improving drainage infrastructure, organising manual labour, and bearing the losses (doing nothing) – are analysed according to **four criteria**: costs of adaptation, effectiveness in safeguarding agricultural production, health benefits and environmental effects. For each of these criteria context-specific rules need to be developed on how to score them. These rules are the most crucial part of an MCA. The tool provided here does not assist in this tasks – all it does is calculating the results once the scores have been determined.

In a **first scenario**, weights are chosen as follows: costs of adaptation (20 %), effectiveness in safeguarding agricultural production (40 %), health benefits (20 %) and environmental effects (20 %). Scoring has occurred on a scale from 1-10 (how this scoring takes place is context specific and not the subject of this study – hypothetical scores are used here). Results of the first scenario show that improving drainage infrastructure would be most beneficial (total score: 6.4) followed by installing pumps (6.2), then organising manual labour (4.4). Doing nothing – no wonder – comes last (2.4).

To compare these results, a **second scenario** is constructed in which costs are weighted the highest with 40 % followed by effectiveness with 30 % and health and environmental benefits with 15 % each. Now, installing pumps would be the most beneficial option (5.65) followed by drainage infrastructure (5.05), manual labour (4.8) and no adaptation (4.3). This example shows how the ranking of options can change if different importance is attached to the criteria.

In a **third scenario**, the change of one particular score is examined. Assuming pumps have higher environmental benefits, the respective score is increased from 7 to 9 whilst the weighting of the first scenario (20 %, 40 %, 20 %, 20 %) is adopted. In contrast to the first scenario, pumps are now ranked as top option with a total score of 6.6 compared to 6.4 for drainage infrastructure. This shows that even small differences in scoring can change the ranking order. The take away is that instead of taking resulting ratings for granted it should be examined what made a particular option score high, particularly if two or more options rank close to each other (as is the case for pumps and drainage infrastructure). The tool can help doing this by constructing different scenarios just as done in this example. To examine more than three scenarios more sheets can be copied and pasted.

8.3 Final remarks

Three remarks are worth mentioning with respect to both spreadsheet tools:

- The provided 'tools' should be considered as prototypes only. They have been developed desk-based and still need project feedback, i.e. real life stress tests. Tailor-made versions of the prototypes will probably be the most suitable. The author of the paper would appreciate the opportunity to support potential users in this.
- Those users who would like to self-adjust the sheets in accordance to their needs are requested to unprotect the files using the **password 'sanzinia'**. However, this should only be done with great care because many cells are programmed with more or less complex algebra. Potential typing errors in those cells will lead to unusable spreadsheet applications, and it is difficult to re-type them.
- The prototypes should not be considered substitutes for well-structured data generation. In fact, **only the 'right' data will lead to the 'right' decisions**. The prototype 'tools' are only an aid in this decision-making process; they are not the solution.

9 Recommendations

This report should only be considered as a starting point for the discussion on a comprehensive economic assessment of climate change adaptation options at development programme/project level. A dozen recommendations shall be given with respect to future developments and discussions on the issue:

1 Given the evolution of a rather broad spectrum of (semi-)scientific methods, models and tools targeting the economic assessment of climate change adaptation (as listed in UNFCCC, 2008) and their often unique algorithms and settings, it makes sense to **carefully reflect upon their real usefulness** before an adaptation project or programme is assessed. Especially when data availability is low and/or uncertainty is very high, the costs and time involved in applying too sophisticated methods must be assessed.

2 A non-transparent CBA, CEA and/or MCA tool is often behind the various models and methods offered by science and private/public bodies. In addition, some of the tools are basically PE or GE models, which have been considered in this paper only as supportive in the context of an economic assessment. In most cases, it makes more sense to use a **more simplified and transparent approach** to prioritise adaptation options.

3 Climate change adaptation focuses on decision-making under uncertainty. Hence, assessment results need to be robust in order to be usable. Against this background, it is suggested to use not only various future projections (scenarios), but to additionally **make use of more than one economic assessment approach**, e. g. a CBA and an MCA. Indeed, **there is no 'one size fits all' approach** (Chadburn et al., 2010).

4 Historically, CBAs, MCAs and, PE and GE models have been used extensively at the national and international decision-making level. Meanwhile the approaches are being applied more and more also to regional and even local particularities. Economic assessment approaches should be **applied across scales**, i.e. combining different levels whenever possible.

5 An extensive amount of data and information on climate change and adaptation impacts is required in order to conduct meaningful economic assessments of climate change adaptation (Basher, 1999). These data relate to biological, physical, economic and social systems. While there might be an attainable data set for one or another input factor with regard to the assessment, in many cases data availability is weak or inadequate and sound data generation is a must. Decision-makers and their advisors should **make use of top-down** (e.g. available case studies and data sets/databases within ci:grasp) **and bottom-up** (local and regional knowledge and expectations) **approaches in generating data** (see also Gebhardt et al., 2011).

6 A particular sub-task specified in the ToR of this study was an evaluation of the usability of ci:grasp in the available economic assessment approaches. All approaches discussed fit ci:grasp and may **use ci:grasp for proper decision-making**, especially with respect to partly overcoming data uncertainty. The suggestion is to always link ideas with ci:grasp, as it is a climate information service providing sound knowledge on current and projected climate stimuli, climate impacts and adaptation options at national, sub-national and regional level.

7 Top-down and bottom-up approaches should not only be combined with respect to data generation, but also with respect to prioritisation. Economic assessments will certainly provide best guesses on rankings of economic feasibility and effectiveness, etc., of climate change adaptation options. However, they will not or will only seldom look at the distributional effects of costs and benefits. **Participation of stakeholders** will certainly **help in making broadly accepted decisions** on adaptation options so they can be prioritised and ultimately implemented.

8 Economic assessments like CBA, CEA or MCA are no substitutes for bottom-up approaches. Since the assessment of climate change adaptation should normally be demand-driven, **a participatory approach involving all potential key stakeholders** of the future adaptation process is a must. This has been made clear by Sova (2011) and is also a basic principle of the GIZ 'Climate proofing for development' methodology (GIZ, 2010). Economic analysts and participants in the process may benefit from each other. Analysts may gain data and information, e. g. expectations based on real-life experiences, from stakeholders, enabling them to better perform under uncertainty; stakeholders may compare their own judgments with the calculated results of economic assessments, ensuring that resulting adaptation measures are more appropriately prioritised than if there were no economic analysis. Indeed, a **proper mix of quantitative and qualitative assessment tools** should be used prior to the implementation of climate change adaptation (see also Sova, 2011).

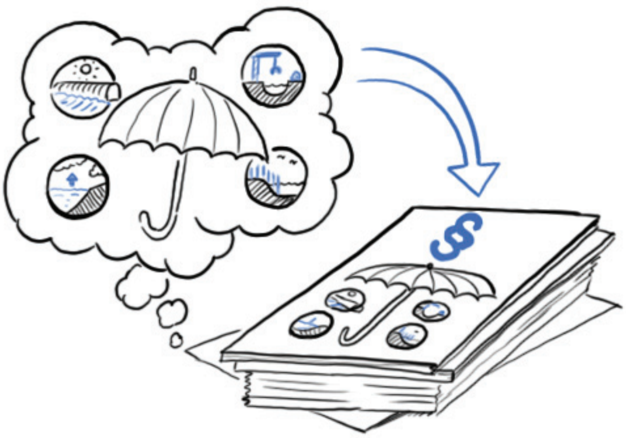
9 Even when top-down modelling is properly combined with bottom-up stakeholder participation, not all uncertainties will be overcome. In other words, in order to be applicable, **economic assessment approaches** will – in the vast majority of cases – still involve (some or many) **assumptions and simplifications**. **While interpreting results, this should always be considered** and clearly marked. Over time, assumptions and simplifications may be revisited in light of new information. Therefore, regular updates to an economic assessment may be undertaken.

10 Scientists around the world increasingly investigate climate change and adaptation-related issues and communicate the results of their research. Unfortunately, their findings are often not easy to understand for non-experts. The synthesis and transformation of scientific information into 'ready to go' messages are thus important in order to meet the needs of stakeholders in adapting to climate change. It is strongly recommended to use expert knowledge for such syntheses and to incorporate new findings into ongoing and future adaptation planning.

11 Finally, two very specific recommendations should be given with respect to the GIZ project 'Inventory of Methods for Adaptation to Climate Change' (IMACC):

12 This study can only be considered a starting point for the (perhaps broad-based) application of economic assessment approaches to climate change adaptation. **At least some training is necessary** to impart the 'right' handling of the approaches so they can be effective in development programmes and projects. The training should deal with the mathematical algorithms behind an analysis, but probably even more importantly with the gathering of the best available data.

13 The spreadsheet-based prototypes are nothing more than simple generalised tools. Anything else was beyond the scope of the study and they need to be further developed. The IMACC project, with its seven partner countries and their diverse adaptation needs, provides an **ideal platform to apply and trial CBAs, MCAs**, etc. in order to support decision-making and to improve their usefulness for development programmes and projects in the future.



References

ADB (2013): Cost-Benefit Analysis for Development – A Practical Guide. Asian Development Bank, Mandaluyong City, Philippines.

Basher, R.E. (1999): Data requirements for developing adaptations to climate variability and change. In: Mitigation and Adaptation Strategies for Global Change (4), p. 227-237.

CEGIS (Center for Environmental and Geographic Information Services) (2008): Economic modeling of climate change adaptation needs for physical infrastructure in Bangladesh. Dhaka: Climate Change Cell.

Chadburn, O.; Ocharan, J.; Kenst, K., Venton, C.C. (2010): Cost benefit analysis for community based climate and disaster risk management: synthesis report. Eddington: Tearfund.

Chambwera, M.; Stage, J. (2010): Climate change adaptation in developing countries: issues and perspectives for economic analysis. London: IIED.

Chambwera, M. (2010): Beyond cost-benefit: developing a complete toolkit for adaptation decisions. In: IIED briefing, June 2010.

ECA (Economics of Climate Adaptation Working Group) (2009): Shaping climate-resilient development: a framework for decision-making.

European Commission (2008): Guide to Cost-Benefit Analysis of Investment Projects, DG Regional Policy.

Evans, J. D. (2006): Social discount rates for the European Union. In: Milan European Economy Workshops. Working Papers no. 2006-20.

Finger, R. (2009): Climate change impacts and adaptation in Swiss cereal production: integrating biophysical and economic models. Zurich: ETH.

Feldman, A.M. (2008): Welfare economics. In: Durlauf, S.N.; Blume, L.E. (eds.): The New Palgrave: A Dictionary of Economics. Volume 4, p. 889–95. New York: Palgrave MacMillan.

Frontier Economics Network (2008): Modeling climate change impacts using CGE models: a literature review. Melbourne: Frontier Economics Network.

Füssel, H.M. (2007): Adaptation planning for climate change: concepts, assessment approaches, and key lessons. In: Sustainability Sciences (2007/2). P. 265-275.

Gambarelli, G.; Goria, A. (2004): Economic evaluation of climate change impacts and adaptation in Italy. Milan: Fondazione Eni Enrico Mattei.

Gebhardt, O.; Kumke, S.; Hansjürgens, B. (2011): Kosten der Anpassung an den Klimawandel: Eine ökonomische Analyse ausgewählter Sektoren in Sachsen-Anhalt.UFZ-Bericht 05/2011. Leipzig: UFZ.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2013): Adaptation made to measure. A guidebook to the design and results-based monitoring of climate change adaptation projects. Second edition. Available at: https://gc21.giz.de/ibt/var/app/wp342deP/1443/wp-content/uploads/filebase/me/me-guides-manuals-reports/GIZ-2013_Adaptation_made_to_measure_second_edition.pdf

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2013a): WEBINAR CBA Peru – A Contribution to the Discussion Series on Cost-Benefit Analysis. Available at AdaptationCommunity.net ¢ Exchange ¢ Webinars or at: https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/exchange/webinare

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2013b): WEBINAR CBA Mexico – A Contribution to the Discussion Series on Cost-Benefit Analysis. Available at AdaptationCommunity.net ¢ Exchange ¢ Webinars or at: https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/exchange/webinare

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (2011): Costos y beneficios de la adaptación al cambio climático en América Latina. Lima, Peru.

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) (2010): Climate proofing for development: adapting to climate change, reducing risk. Eschborn: GTZ.

GSF (Global Climate Chance Alliance Support Facility) (2011): Costing, assessing and selecting, adaptation and mitigation, options and measures. Training workshop on mainstreaming climate change: module 6. Broomfield, CO: MWH.

Hallegatte, S.; Przyluski, V.; Vogt-Schilb, A. (2011a): Building world narratives for climate change impact, adaptation and vulnerability analyses. In: Nature Climate Change 1, p. 151-155.

Hallegatte, S.; Lecocq, F.; de Perthuis, C. (2011b): Designing climate change adaptation policies: an economic framework. Washington, DC: The World Bank.

Hammill, A.; Tanner, T. (2011): Harmonizing climate risk management: adaptation screening and assessment tools for development cooperation. OECD Environment Working Papers No. 36. Paris:OECD.

HM Treasury (2008): The Green Book: Appraisal and Evaluation in Central Government. HM Treasury. London.

Jechlitschka, K.; Kirschke, D.; Schwarz, G. (2007): Microeconomics using Excel: integrating economic theory, policy analysis and spreadsheet modeling. London and New York: Routledge.

Kaul, S. (2011): Bio-economic modeling of climate change on crop production in India. New Delhi: Indian Agricultural Statistics Research Institute.

Kirschke, D.; Noleppa, S. (2008): Economic assessment and prioritization of climate change adaptation options: methodological approach and case study for Indramayu (Indonesia). Berlin: Humboldt University of Berlin.

Künkel, N. (2011): Being prepared: the experts' view. In: GIZ (ed.): Adaptation to climate change: new findings, methods and solutions, p. 14-15. Eschborn: GIZ.

Kurukulasuriya, P. (2006): Estimating impacts of climate change on agriculture. New Haven, CT: Yale University.

Liapis, P.S. (1990): Incorporating inputs in the Static World Policy Simulation Model (SWOPSIM). Technical bulletin no. 1780. Washington, DC: USDA.

Mas-Colell, A.; Whinston, M.D.; Green, J.R. (1995): Microeconomic theory. New York: Oxford University Press.

Mathew, S.; Trück, S.; Henderson-Sellers, A. (2012): Kochi, India case study of climate adaptation to floods: Ranking local government investment options. Global Environmental Change, 22: 308-319.

McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S. (eds.) (2001): Climate change 2001: impacts, adaptation and vulnerability. Cambridge: Cambridge University Press.

McKenzie, E.; Prasad, B.; Kaloumaira, A. (2005): Economic impact of natural disasters on development in the Pacific. Canberra: AusAID.

Moeller, T.; Grethe, H. (2010): Climate change and European agriculture in 2050: outlook for cereal and oilseed markets. Paper presented at the 13th annual Conference on Global Economics Analysis: 'Trade for Sustainable and Inclusive Growth and Development', 9-11 June 2010, Penang/Malaysia.

Niang-Diop, I.; Bosch, H. (2011): Formulating an adaptation strategy. Dakar: University Cheikh Anta Diop.

Nordhaus, W. D. (2007): A review of the Stern review on the economics of climate change, Journal of Economic Literature, 45(3): 686-702.

Paris, R. (2011): Setting the course. In: GIZ (ed.): Adaptation to climate change: new findings, methods and solutions. Eschborn: GIZ.

Policy Research Corporation (2009): The economics of climate change adaptation in EU coastal areas. Final report. Brussels: European Commission.

Robinson, S. (2011): The economics of climate change: appropriateness of partial and general equilibrium approaches. Paper presented at the OECD expert meeting on climate change, agriculture and land use, 9 February 2011.

Rosegrant, M.W.; Ringler, C.; Msangi, S.; Sulser, T.B.; Zhu, T.; Cline, S.A. (2008): The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): model description. Wasington, DC: IFPRI.

Samuelson, P.A. (1983): Welfare Economics. In: Samualson, P.A. (ed.): Foundations of Economic Analysis. Cambridge, MA: Harvard University Press, p. 203–253.

Sova, C.A. (2011): Economics of agricultural adaptation to climate change: tools for informed decision-making. CIAT policy brief no. 5. Cali: CIAT.

Stern, N. (2006): The Economics of Climate Change: The Stern Review.Cambridge, UK: Cambridge University Press.

UNFCCC (United Nations Framework Convention on Climate Change) (2012): Assessing the costs and benefits of adaptation options. The Nairobi work programme on impacts, vulnerability and adaptation to climate change.

UNFCCC (United Nations Framework Convention on Climate Change) (2008): Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change. Bonn: UNFCCC.

UNFCCC (United Nations Framework Convention on Climate Change) (2002): Annotated guidelines for the preparation of national adaptation programs of action. Bonn: UNFCCC.

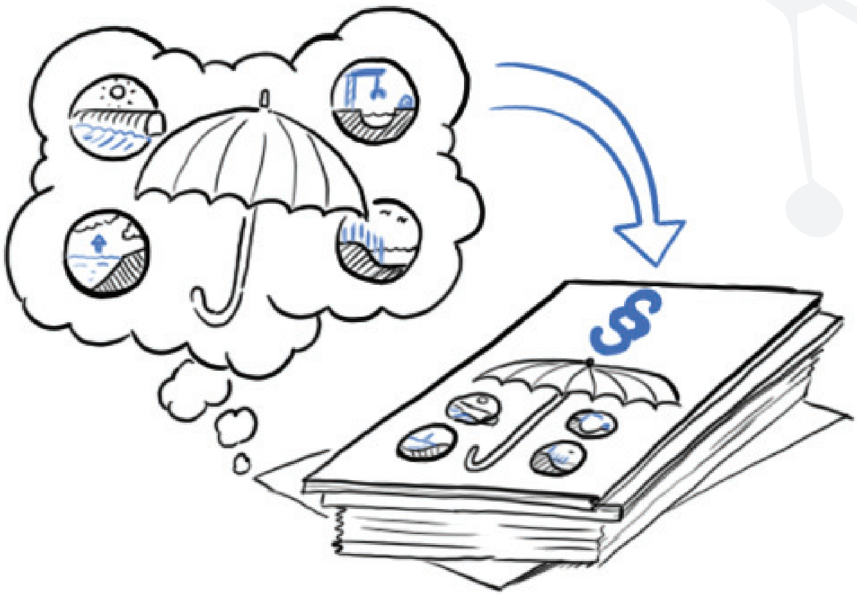
von Witzke, H.; Noleppa, S. (2011): Zur Bedeutung der Pflanzenzüchtung in Deutschland für soziale Wohlfahrt, Klimaschutz und Ernährungssicherung. Berlin: Humboldt University of Berlin. (forthcoming).

Watkiss, P.; Downing, T.; Dyszynski, J. (2010): 2010 AdaptCost project: Analysis of the economic costs of climate change adaptation in Africa. Nairobi: UNEP.

Worldbank (2011): Mainstreaming adaptation to climate change in agriculture and natural resources management projects: guidance notes. Washington, DC: The World Bank.

Worldbank (2010): Economic evaluation of climate change adaptation projects: approaches for the agricultural sector and beyond. Washington, DC: The World Bank.

Wright, E.L. (2003): Climate variability, economic adaptation, and investment timing. In: International Journal for Global Environmental Issues (3), p. 357-368.



Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de