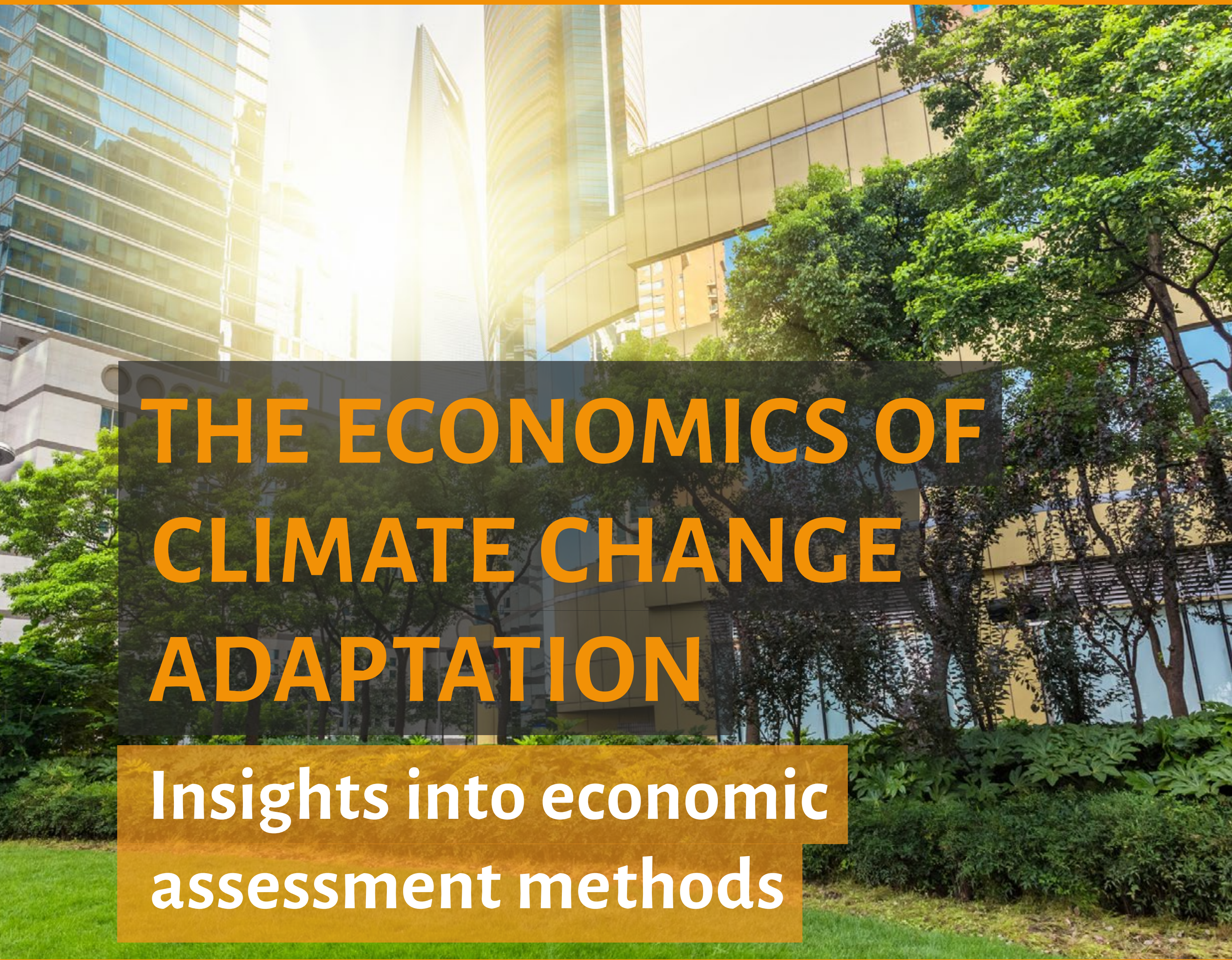
ECONADAPT / THE ECONOMICS OF ADAPTATION



THE ECONOMICS OF CLIMATE CHANGE ADAPTATION

Insights into economic assessment methods

Authors

Tröltzsch, J., Rouillard, J., Tarpey, J., Lago, M., Watkiss, P., Hunt, A.

Contributors

Biewald, A., Bosello, F., Chiabai, A., Christensen, O., Eaton, E., Ermolieva, T., Galarraga, I, Goodess, C., Kaprová, K., Khabarov, K., Kontogianni, A., Kuik, O., Mechler, R., Melichar, J., Mochizuki, J., Pardy, J., Parrado, R., Sainz de Murieta, E., Scussolini, P., Skourtos, M., Szewczyk, W., van Ierland, E., Wellman, J.

Layout

Vargová, B.

Citation

Tröltzsch, J., Rouillard, J., Tarpey, J., Lago, M., Watkiss, P., Hunt, A. (2016). The economics of climate change adaptation: Insights into economic assessment methods. ECONADAPT Deliverable 10.2

To find out more about the ECONADAPT project, please visit the web-site: **www.econadapt.eu**

For further information on the ECONADAPT project, please contact Alistair Hunt at: **ecsasph@bath.ac.uk**

The ECONADAPT project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No. 603906.

WHAT WILL YOU FIND IN THIS DOCUMENT?

HOW CAN THIS DOCUMENT HELP YOU?

With climate change impacts increasing and becoming widespread, decision makers face the need to take informed decisions on the long term costs and benefits of investing in different infrastructure projects or policy programmes. The use of **economic analysis can provide valuable information on the value, efficiency and feasibility** of adaptation projects and strategies.

This guide has been developed as part of the **ECONADAPT project**, funded by the European Commission under the Seventh Framework Programme. The objectives of the project are to build the knowledge base on the economics of adaptation to climate change and to convert this into practical information for decision makers, in order to help support adaptation planning.

This guide aims to:

- Inform **the application of economic assessment tools to adaptation**. In particular, it provides information on methodologies, data and evidence for practitioners with a more technical background.
- Target **interested economists and policy makers**, some of whom may use or develop the methods further, others who may simply gather information on how to interpret results or methodological approaches. Furthermore, it can be of interest to a wider group of experts, stakeholders, and students carrying out case studies.
- Provide **linkages to the more detailed information** available online through the **ECONADAPT toolbox** and **ECONADAPT library**.

What was the FP7 ECONADAPT (2013–2016) project about?

The aim of the ECONADAPT project was to **provide user-orientated methodologies and evidence relating to economic appraisal criteria** to inform the choice of climate change adaptation actions using analysis that incorporates cross-scale governance under conditions of uncertainty. A critical theme was to support the application of adaptation economics in the period following the publication of the **EU's 2013 Adaptation Strategy**, focusing on key decision areas that need enhanced economic information, and on the key users of such information. The project has received funding from the EU's Seventh Framework Programme for research and technological development under grant agreement No. 603906.

HOW TO NAVIGATE THIS DOCUMENT?

This guidance document is organised in a manner that corresponds with the approach that might be taken by economists in the context of adaptation decision-making.

- The concept of **economic appraisal of adaptation** is first introduced, in order to provide background for the subsequent, more detailed, methodologies.
- An important factor in climate change adaptation relates to **the problem of uncertainty**. The importance and treatment of uncertainty is outlined next in order to understand how it plays into the economic appraisal methods.
- The document then provides an overview of **several economic appraisal methods**, highlighting their strengths and weaknesses, as well as their applicability and treatment of uncertainties. Each individual method is then described in detail, including what it does, when it should be used and how it treats uncertainty. Additionally, each appraisal method is accompanied by practical examples.
- **Further project information** is provided at the end of the document which may be useful.

What you will not find in this document!

This document aims to present guidance on the application of economic appraisal in the context of climate change adaptation. However:

- It does not offer a **one-size-fits-all approach** to economic appraisal of climate change adaptation options. An important conclusion to be drawn from this guidance is that each adaptation situation is unique, and so must be treated as such.
- It does not provide **compulsory steps** to be followed when undertaking economic appraisal of adaptation options. Again, adaptation situations must be treated independently in order for any economic appraisal to be valid.
- It does **not repeat the basics** of climate change adaptation or explain the fundamental of economic appraisal. It is expected that the target audience will have a basic understanding of these issues.
- Nor does it go into **great detail** on each economic method. Many involve complex modelling and calculations. The role of this document is thus not to describe the actual implementation of these economic tools, rather to shed light on when they can be useful while offering a basic overview of each method's application.

HOW CAN ECONOMICS SUPPORT DECISION MAKING IN CLIMATE CHANGE ADAPTATION?

Why should I use economics?

Adaptation is increasingly recognized as an important part of many policies, as unavoidable climate change will affect almost every part of our society. The progressive adoption of adaptation strategies and plans has been accompanied by greater consideration of the costs and benefits of alternative courses of action. Economic analysis for adaptation however is not only a question of costs or financial return of climate proofing projects.

There is wide recognition that economic analysis currently used in adaptation can provide valuable information for decision-makers and stakeholders, for example by:

- Bringing clarity on trade-offs associated with different development paths in the medium to long term, and providing an indication of **the net value of different options under different possible futures**;
- Highlighting, in a more transparent way, **the value of future benefits**, including the importance that current generations place on the future. This can ultimately enhance **the consideration of sustainability principles** in decision-making;
- Strengthening the capacity of society to envision and plan strategically **in face of high uncertainty** and supporting the identification of robust solutions capable of high performance against a large number of futures, thereby **enhancing the resilience of society against future risks**;
- Presenting a **structured approach** to design, implement and evaluate projects, measures and policy programmes, and enabling the comparison of trade-offs between wait-and-see strategies and immediate action. This can ultimately support the application of the precautionary principle and **enhance the capacity of society to adapt** to non-linear dynamics in the climate and natural system.

What does it involve?

The economic assessment of adaptation measures is different from a normal economic appraisal, in that **the focus of analysis is on managing uncertainties and risks**. It must take into account different time-scales, complex systemic relationships and dynamics, multiple sources of uncertainties, etc.

Furthermore, mainstreaming adaptation involves **embedding adaptation decisions within multiple sectors and decision contexts**, which vary in relation to the nature of the intervention, its spatial and temporal scales and its institutional context.

A number of principles structure the economic analysis of adaptation:

- Investments are seen **as dynamic processes** which should respond to new climatic and socio-economic conditions. There is thus a strong focus on iterative risk management and learning.
- There is a focus on **strategic scoping, phasing** and **prioritisation** of adaptation, considering responses adapted to current climate variability and future climate change over longer periods of time.
- There is a **much greater attention on early steps** to adequately characterise current policy objectives, wider non-climatic drivers, baselines and interventions, as well as the context for decisions.
- Practical adaptations are seen as **portfolios of measures**, taken in front of uncertainties about climate changes, which allow future society to deal with unforeseen events in a robust and flexible way. Investments may involve a more broad set of response types than an optimisation approach would allow.

A policy-led framework to adaptation economics

The ECONADAPT project has supported the development of a "policy led framework", characterised by the following:

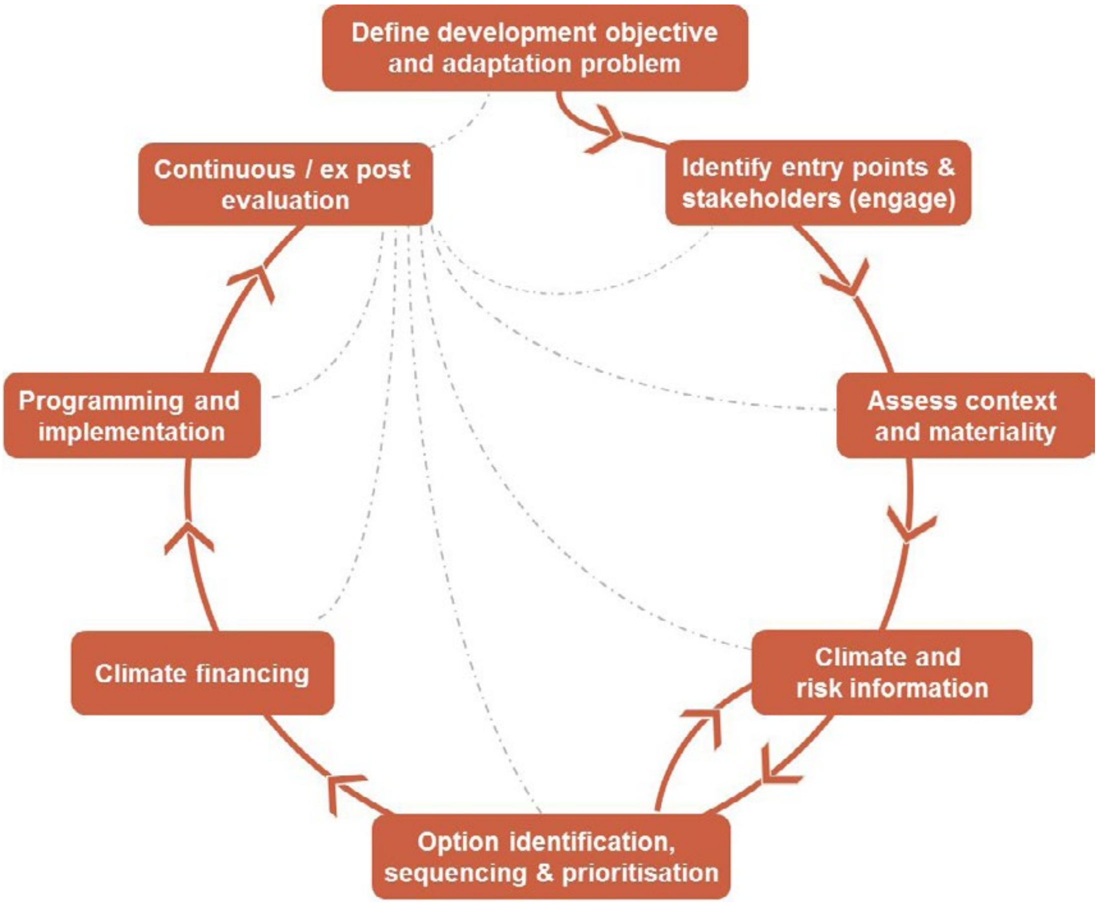
- There has been a **move towards a policy-orientated approach** framed around adaptation, coupled with a greater emphasis on integrating (mainstreaming) adaptation into current policy and development.
- There has been a shift to look at **the phasing and timing of adaptation**, with an increasing recognition of uncertainty and the use of iterative risk management approaches.

More information on the policy-led framework canbe found **here.**

The application of the framework can help frame the **overall consideration and early prioritisation of adaptation** and aligns it with a typical policy or appraisal cycle. It has particular relevance for: 1) short listing options and 2) for prioritising the shortlisted options. The framework can be applied to help in the **identification, timing and sequencing of adaptation** and the short-listing of options. This can help identify focus areas for a sector plan or strategy or identifying a list of options for individual projects.

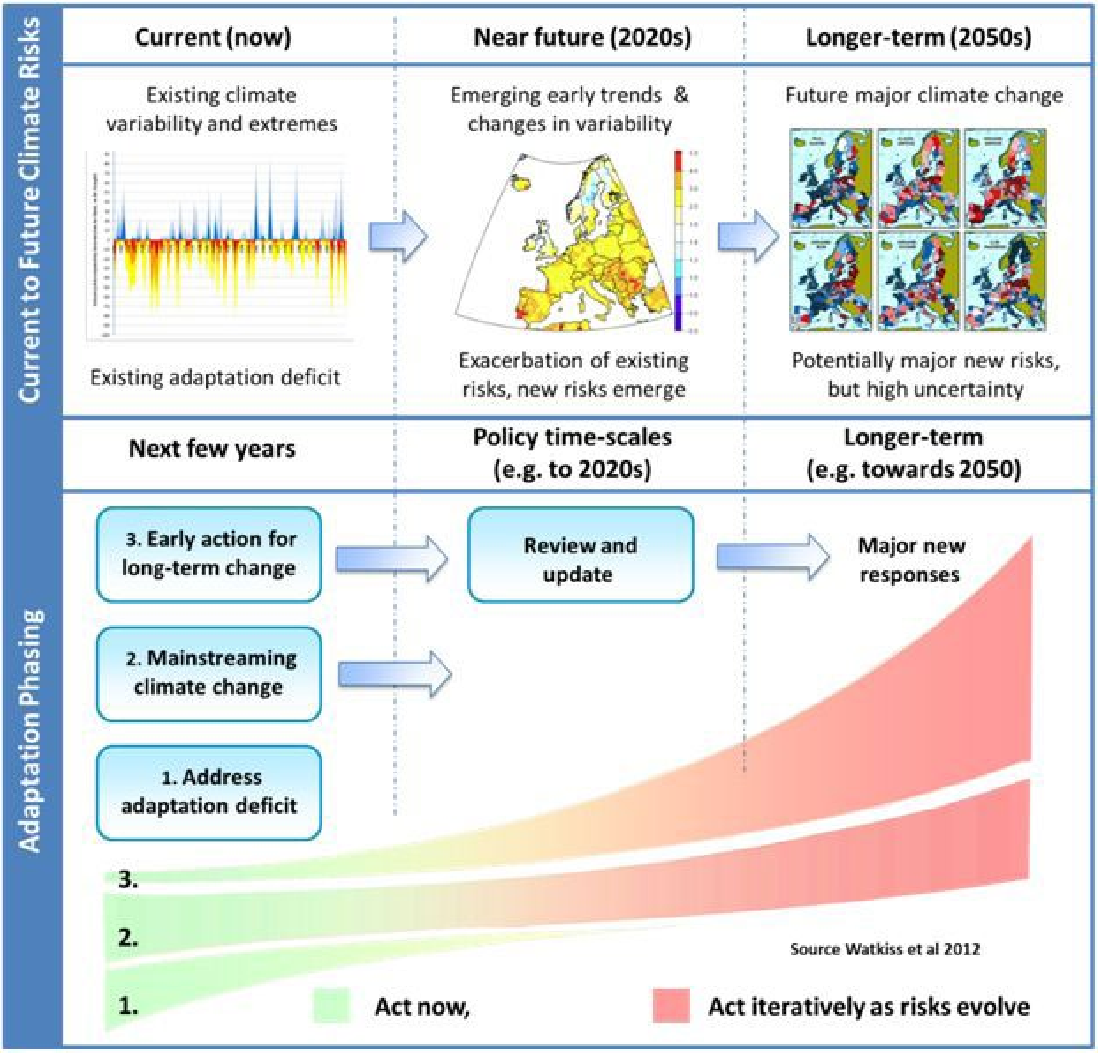
The framework starts with current climate variability and then assesses future climate change, considering uncertainty and analysing inherent risks. It then investigates how adaptation decisions map out against these risks, and recommends categorising actions into three types of early policy decisions and associated interventions, i.e. actions that could be undertaken in the next decade for addressing the impacts of short, medium and long-term climate change, under conditions of uncertainty. These are:

- Immediate actions that address the current risks of weather and climate extremes (the adaptation deficit) and also build resilience to future climate change. This includes early capacity-building and the introduction of low- and no-regret actions, which provide immediate economic benefits as well as future benefits under a changing climate.



- The integration of adaptation into immediate decisions or activities with long life-times, such as infrastructure or planning (climate smart development). This involves different options (to 1 above) because of future climate change uncertainty. It involves a greater focus on climate risk screening and the identification of flexible or robust options that perform well under uncertainty.
- Early monitoring, research and learning to start planning for the future impacts of climate change. This includes a focus on adaptive management, the value of information and future option values and learning so that appropriate decisions can be brought forward or delayed as the evidence and knowledge emerges. The three categories can be considered together in an integrated adaptation strategy, often termed a portfolio or adaptation pathway.

An illustration of the framework is shown in the figure on the next page. The framework starts with climate change (top), which is split into a number of linked risks, each related to different policy problems and time-scales. This starts with current climate variability and extremes (top left), i.e. the adaptation deficit. Over time, climate change will affect these existing impacts, and lead to major new risks (top right), though often with high uncertainty. In response, an adaptive management framework has been recommended for adaptation (bottom).



Linking climate services and adaptation economics

Sourcing and using climate information is something that should be taken collaboratively between climate experts and adaptation economists. Building relationships, trust and understanding between these different communities is essential. It should also not be seen as a one way process, from climate information providers, but as an iterative and integrated process, in which information and discussion will flow back and forth. The adaptation community has different needs to the impact community. There is a much greater focus on the current climate (including observations and recent trends) and also on capturing uncertainty of future climate projections: the latter includes a move beyond multi-model ensembles to include more comprehensive scenario uncertainty, as well as specific metrics to allow the application of decision making under uncertainty methods. Climate experts working with the adaptation community need to be flexible particularly in response to ad hoc requests and bespoke applications.

*More information on the using and sourcing climate information can be found **here**.*

HOW ARE UNCERTAINTIES TAKEN INTO ACCOUNT IN ADAPTATION ECONOMIC APPRAISALS?

Why should you worry about uncertainties?

Uncertainty is a state of having limited knowledge where it is impossible to precisely describe existing state or future outcomes. It applies to predictions of future events, to physical measurements already made, or to the unknown.

When designing climate-sensitive investments, decision-makers use weather and climate data. Attempts to model the future climate in terms of temperature face problems associated with many causes of uncertainty e.g. lack of knowledge about the climate system, measurement errors, and/or subjectivity of analyst opinion. As a result, no single climate model is able to produce reliable and global climate statistics for the future. In this way climate change represents a dramatic increase in deep uncertainty for decision-makers.

Three types of uncertainties are typically considered:

- Epistemic uncertainty: lack of information or knowledge for characterizing phenomena;
- Normative uncertainty: the absence of prior agreement on framing of problems and ways to scientifically investigate them;
- Translational uncertainty: incomplete or conflicting scientific findings.

It is important to take into account that an overabundance of information or contradicting information also can lead to uncertainty; thus, gathering more data and information to reduce epistemic uncertainties may not always be successful in reducing uncertainty.

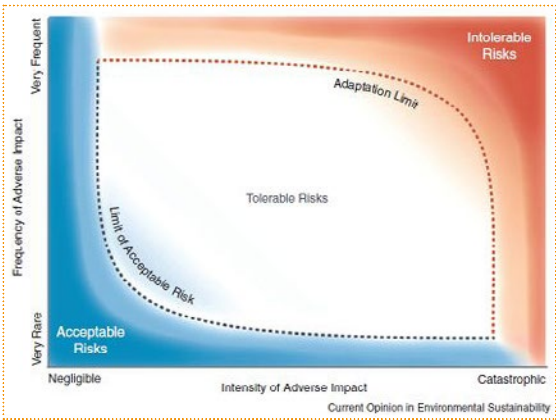
There are various sources of uncertainties in adaptation. A more detailed discussion can be found **here.**

How can you consider uncertainties in decision-making?

Adequate consideration of uncertainties – and their interaction – is necessary when designing an adaptation project. However, reducing all uncertainties is an impossible task. Whilst reducing epistemic uncertainty by acquiring knowledge or reducing normative uncertainties through participatory processes is possible, translational uncertainty cannot necessarily quickly be reduced.

A risk framework can represent a good strategy to deal with uncertainties. Distinct from the traditional economic understanding of, in this context risk can be defined as the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems, economic, social and cultural assets, services, and infrastructure. In climate change, major risks lie in the failure to adapt to changes in the environment, leading to instability and insecurity of economic system(s) threatening adequate level of societal welfare.

Three broad risk categories can be used to guide decision-making: acceptable risks, tolerable risks, and intolerable risks (which exceed a socially negotiated norm). The figure on the right[1] maps these categories of risk on a two dimensional space. One can see that the type of risk depends on the degree of the potential impact and also its probability (frequency). The low probability catastrophic events can be of the same high degree of risk as very probable events with a moderate impact. The boundaries have a fuzzy structure due to the qualitative definition of acceptable, tolerable, and intolerable risks (e.g. different opinions of stakeholders). The shading around the limits indicates those actors' views of what is acceptable, tolerable or intolerable risk may vary. Adaptation may be seen as action aimed at maintaining the position of a given valued objective (such as a technical norm of flood protection) within a tolerable area relative.



Assessing and managing risks involves a number of steps: describing and modelling the systems to be managed; identifying hazards related to the system functioning; selecting the events that may initiate accident(s); quantitatively analysing the accident(s); evaluating risk and carrying out the decision making (or deliberative) process. Several economic methods are available to quantitatively of qualitatively analyse the economic risk of alternative investment options (see below).

It is important to highlight that in order to reduce uncertainties from different subjective opinions, a clear way of communication and the use of a well-founded vocabulary can help avoid linguistic ambiguity. Transparency generally helps; however, particular care should be given to the way information on scientific methods, statistics and the like are communicated, including ranges and so on. Communication on uncertainty should be different for different types of audiences.

Dealing with uncertainties through social learning

One of the ways to cope with multiple perspectives and interpretations of governments, organizations, private enterprises and individuals lies in social learning. We can consider two types of uncertainties which are connected with social learning: informational uncertainty (due to the lack of knowledge) and normative uncertainty, which is linked to perception of acceptable risk. Planning processes can take a dynamic learning approach to climate modelling based on the availability of more robust information; estimates are regularly updated with advances in knowledge and understanding of the risks posed to society by any given climate disaster. In order to address the issue of uncertainty over time in climate policy paths, the dynamic learning approach can be employed by creating decision points along policy paths to incorporate improved information and models.

1) Renn, O., Klinke, A., 2013. A Framework of Adaptive Risk Governance for Urban Planning. Sustainability 5, 2036–2059. doi:10.3390/su5052036

Which methods are available?

The two following tables summarise the main groups of economic tools and their potential use, as well as their key strength and weaknesses. There are no hard-and-fast rules on which tool to use in which application, though, certain techniques do align with various elements of the policy-led framework. There is no "one-size-fits-all" approach to economic appraisal; each method presents a unique set of strengths and challenges. It is important to carefully select the most appropriate approach for each individual adaptation scenario.

In overall terms, it is worth highlighting that:

- For analysis that is focused on current climate variability (the adaptation deficit), existing decision support tools can be used, including **Cost-Benefit Analysis (CBA)** and **Cost-Effectiveness Analysis (CEA)**;
- As adaptation interventions are often in areas that are difficult for valuation, and usually involve a lack of quantitative information, **Multi-Criteria Analysis (MCA)** is often used;
- For long-term applications in conditions of a low current adaptation deficit, **Iterative Risk Management (IRM)** may be more applicable.
- When investments are nearer term (especially high upfront capital irreversible investments), there is potential for learning as new climate risk information available becomes available, and where there is an existing adaptation deficit, **Real Options Analysis (ROA)** is a potentially useful tool;
- For the analysis of adaptation in the face of uncertainty, when risk of maladaptation is high, **Robust Decision Making (RDM)** can be employed. RDM has broad application for current and future time periods and focuses on robustness rather than optimality as a decision criterion;
- For the analysis under high uncertainty of combinations of adaptation projects which are potentially complementary, **Portfolio Analysis (PA)** can be a useful approach.

A light touch approach to the application of economic instruments

While the tools are presented individually, it should be noted that they are not mutually exclusive. Many of these methods are resource intensive and technically complex, and this is likely to constrain their formal application to large investment decisions or major risks. Given this, a critical question is whether their concepts can be used in 'light-touch' approaches that capture their conceptual aspects, while maintaining a degree of economic rigour. This would allow a wider application in qualitative or semi-quantitative analysis. This could include the broad use of decision tree structures from Real Options Analysis, the concepts of robustness testing from Robust Decision Making, the shift towards portfolios of options considered in Portfolio Analysis and the focus on evaluation and learning from Iterative Risk Management for long-term strategies.

Main groups of methods in adaptation economics and their potential use

	APPROACH	SUMMARY	POTENTIAL USE
Traditional economic decision support	Cost-Benefit Analysis	Values all costs and benefits to society of all options, and estimates the net benefits/costs in monetary options	To identify low- and no-regret options in the near future. As a decision support tool within iterative climate risk management
	Cost-effectiveness analysis	Compares costs against effectiveness (monetary/non-monetary) to rank, then cost-curves for targets/resources	As above, but for market and non-market sectors where benefits are not monetised
	Multi-criteria analysis	Allows consideration of quantitative data together for ranking alternative options	As above, but for scoping options. Can complement other tools and capture qualitative aspects
Uncertainty framing	Iterative risk management	Uses iterative framework of monitoring, research, evaluation and learning to improve future strategies	For appraisal over medium-longer term. Also applicable as a framework at policy level
Economic decision making under uncertainty	Real-option analysis	Allows economic analysis of future option value and economic benefit of waiting / information / flexibility	Economic analysis of major capital investment decisions over the medium term. Analysis of flexibility within major projects
	Robust decision-making	Identifies strategies which are optimal (robust) against a large number of plausible scenarios	Identifying combination of strategic (long-term scenario-independent) and operational (short-term scenario-dependent) decisions
	Portfolio analysis	Economic analysis of optimal portfolio of options by trade-offs between return (net present value) and uncertainty (variance)	Project based analysis of future combinations. Designing portfolio mixes as part of iterative pathways

Main strengths and limitations of economic tools to support adaptation decision-making

METHOD	STRENGTHS	CHALLENGES	DEALING WITH UNCERTAINTY
Cost-benefit analysis	Most useful when climate risk probabilities are known and sensitivity is small. Also where clear market values can be used	Valuation of non-market sectors / non-technical options. Uncertainty limited to probabilistic risks / sensitivity testing	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modelling
Cost-effectiveness analysis	As above, but for non-monetary sectors and where pre-defined objectives must be achieved	Single headline metric difficult to identify and less suitable for complex or cross-sectoral risks. Low consideration of uncertainty	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modelling
Multi-criteria analysis	When there is a mix of quantitative and qualitative data	Relies on expert judgement or stakeholders, and is subjective, including analysis of uncertainty	Can integrate uncertainty as an assessment criterion, however usually relies on subjective expert judgement or stakeholder opinion
Iterative risk management	Useful where long-term and uncertain challenges, especially when clear risk thresholds	Challenging when multiple risks acting together and thresholds are not always easy to identify	Deals explicitly with uncertainty by promoting iterative analysis, monitoring, evaluation and learning
Real-option analysis	Large irreversible decisions, where information is available on climate risk probabilities	Requires economic valuation (see CBA), probabilities and clear decision points	Deals explicitly with uncertainty by analysing the performance of adaptation for different potential futures
Robust decision-making	When uncertainty and risk are large. Can use a mix of quantitative and qualitative information	Requires high computational analysis and large number of runs	Explicitly incorporates uncertainties and risks, in particular, systemic dependent risks, to derive robust solutions
Portfolio analysis	When number of complementary adaptation actions and good information	Requires economic data and probabilities. Issues of inter-dependence	Deals explicitly with uncertainty by examining the complementarity of adaptation options for dealing with future climates

COST-BENEFIT ANALYSIS

Cost-Benefit Analysis (CBA) **determines the economic efficiency of a project or policy** by comparing the net present value of the costs of planning, preparing and implementing the adaptation intervention to its benefits. Benefits are related to the avoided damage costs or the accrued benefits following adoption and implementation. In using a common metric to compare the costs of undertaking a project with the benefits it will provide, it highlights trade-offs and offers a methodology which promotes rational and systematic adaptation policy making.

When to use it?

More information on the application of cost-benefit analysis in adaptation can be found **here**.

- The methodology behind cost-benefit analysis **can be applied to virtually any project** or policy which offers costs and benefits in quantitative economic terms.
- Cost-benefit analysis requires a **good understanding and quantified information** on the variety of positive and negative impacts of adaptation options.
- It is most appropriate **for assessing low and no regret options** in market sectors and when uncertainties related to climate risk probabilities are known or small.

What are its key strengths and weaknesses?

CBA does not select options that can perform well against a range of potential futures, but rather optimises adaptation options against the most likely set of impacts.

- The most important strength comes from its structured and thorough consideration of costs and benefits which can be economically quantified to make adaptation related decisions more transparent.
- One major drawback is the need for quantitative and monetized data regarding adaptation costs and benefits, as this information is often limited in adaptation contexts.

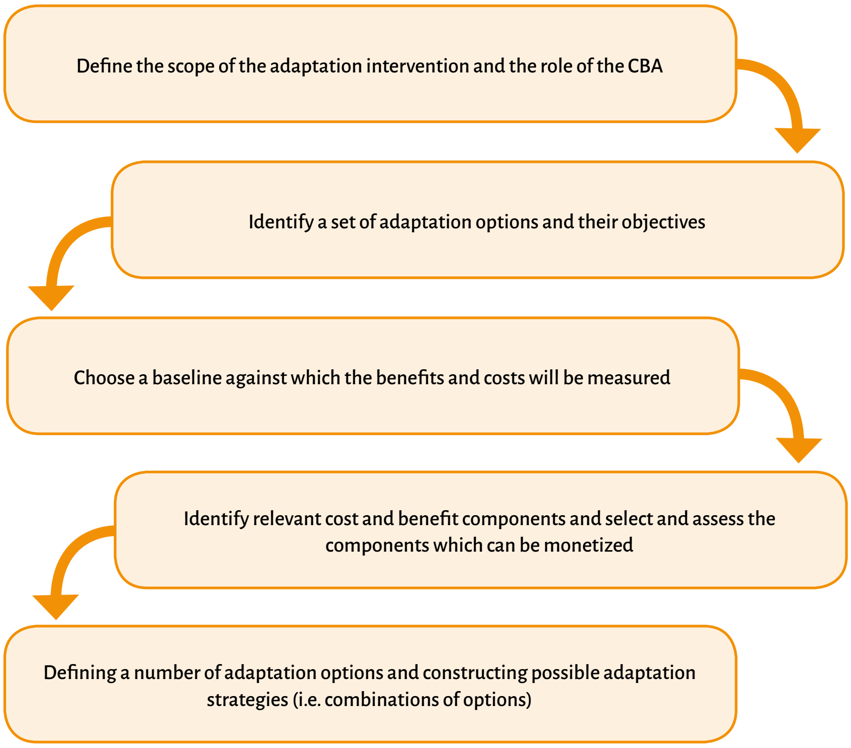
The choice of discount rates in adaptation!

One long-standing issue in the adaptation field is the choice of the discount rate. Discount rates are factors used to increase the weight of costs and benefits occurring in the shorter term, hence **they are a representation of how society values the future**. Many governments and businesses tend to use discount rates that put a substantially lower value on the future. It may therefore provide a bias to established, engineering measures that have well-defined, short-term benefits, over soft and green measures that have more diverse, less clear, longer term benefits and costs. Good practice is to use the official rates adopted by the implementing private or public agency, supplemented with sensitivity analysis based around different configurations of the Social Time Preference Rate (STPR).

*More information on the use of discount rates in adaptation can be found **here**.*

What does it involve?

The figure shows the main steps when applying cost-benefit analysis in adaptation.



Source: adapted from **Mediation**

Good practice when applying cost-benefit analysis to adaptation

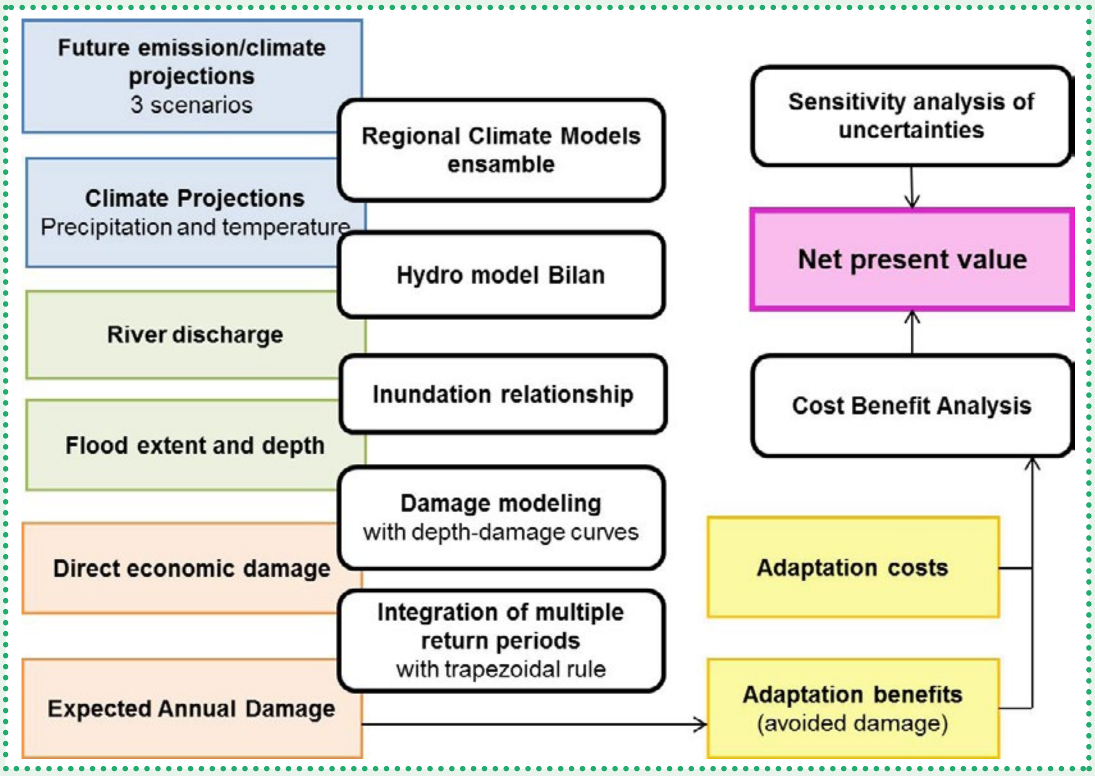
Reviews on the costs and benefits of adaptation in different sectors are available **here**.

- It is important to think of cost-benefit analysis as a decision-making guide **providing an approximation of societal preferences**, and not an expression of the exact economic value of a project or policy. The final decision on adaptation options is however a societal choice involving political discussions at different levels.
- As such, it is best used **as a part of a broader assessment process** along with other decision support tools, for example those which are able to consider other cultural and social factors such as multi-criteria analysis, or those that frame adaptation in a broader iterative risk framework.
- The **impact of uncertainties on cost-benefit results** can be considered via specific techniques, with standard approaches being for example sensitivity analysis and probabilistic modelling.

ILLUSTRATION

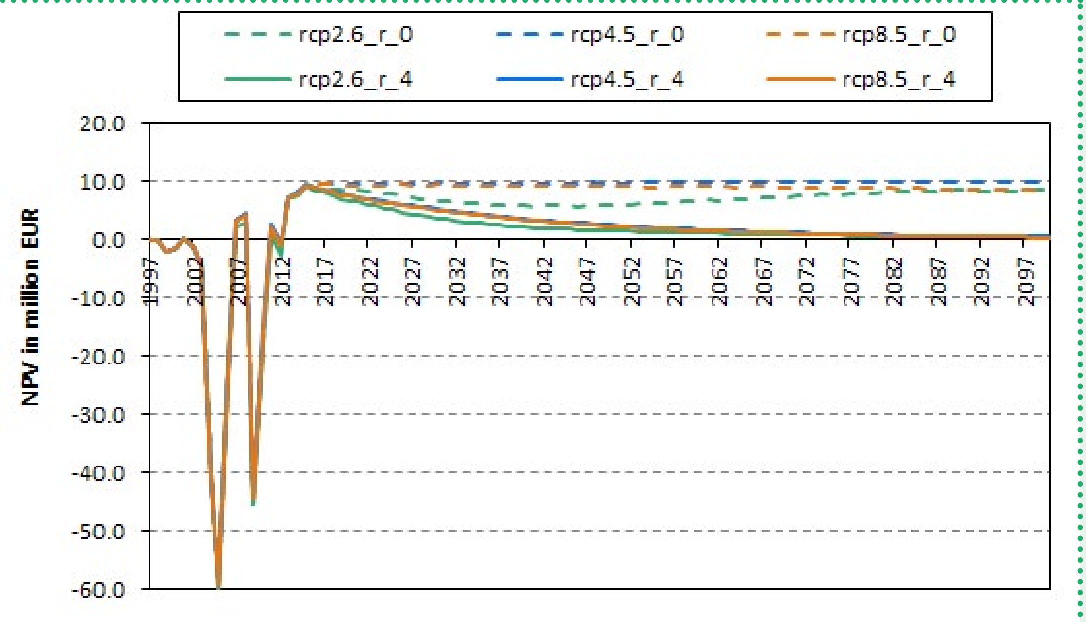
Appraisal of adaptation options to river flood at the Vltava River, Prague

The study aimed to carry out an ex-post appraisal of adaptation options to flood risks in the city of Prague. The flood protection project consisted of several types of measures built between 1999 and 2014: fixed anti-flood earth dikes, reinforced concrete walls, mobile barriers and back-flow control. The costs were understood as the investments into flood protection and operating costs. These were calculated at 256 million EUR from data provided by the city authorities of Prague. Benefits were calculated as avoided Expected Annual Damage (average until year 2100) following the steps presented in the diagram. Benefits represented the differences between the status-quo situation (with a 10-year protection) and the situation with the adaptation investment (a 500-year protection realized in the period of 1999–2014).



The study then estimated economic efficiency through the expected net present value (ENPV). The graph below displays the annual ENPV of flood protection measures in Prague according to different RCP scenarios. The dashed lines represent a discount rate of 0%, while the solid lines are discounted at 4%. The average value of ENPV for all RCP scenarios is € 626 million, if we assume 0% discount rate. The differentiation between RCPs will have a moderate impact on ENPV, the RCP2.6 scenario will decrease the value by 30%, RCP4.5 will increase ENPV by 6% and RCP8.5 decreases by 4%. When considering 4% discount rate, then the effect of RCPs on ENPV is larger, the change is -107%, 14% and -7% for RCP2.6, RCP4.5 and RCP8.5, respectively.

Next, the study incorporated a sensitivity analysis measuring the influence of changes in key input parameters when other parameters are held constant. This demonstrated that the ENPV varies significantly with the use of different discount rates and return periods while the choice of infrastructure cost variables, depth-damage functions are less significant. Results of the sensitivity analysis indicate that the choice of the pure rate of time preference and consumption elasticity in the discount rate dramatically influences results, whereas the intertemporal risk aversion RIRA coefficient had a negligible effect. While computation-intensive, running damage simulations for a very high number of return periods may be necessary to provide adequate information for adaptation decision-making in flood risk management.



Overall, results of the study showed that the flood protection measures provide a positive ENPV in the order of millions of Euros, depending on data and assumptions. The investments are thus efficient across scenarios of changing future climate. However, the study also showed that the selection of discount rate is a critical decision in the cost-benefit analysis: up to 3% results in a positive ENPV, while a discount rate above 4% means the project is no longer efficient.

*More information on the application of CBA to adaptation in Prague can be found **here**.*

COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis (CEA) is a methodology used to compare different options aiming to achieve similar outcomes. It is particularly attractive in the adaptation context because it allows for **benefits to be valued in non-monetary terms**, opting for quantification in physical terms instead.

When to use it?

- Cost-effectiveness analysis is generally most useful for **short-term adaptation assessment**, for example when ranking low and no regret options. This is because CEA does not explicitly deal with uncertainty and optimises the selection of adaptation interventions against a single objective usually under one climate scenario.
- Cost-effectiveness analysis is also a helpful tool when dealing with sectors which include **significant non-market dimensions** such as biodiversity protection.

More information on the application of cost-effectiveness analysis in adaptation can be found **here**.

What are its key strengths and weaknesses?

CEA is useful at the project level for comparing and ranking alternative options in terms of cost per unit of benefit delivered. At the policy or programme level, where combinations of measures are needed, CEA is useful in determining the most cost-effective order of implementation.

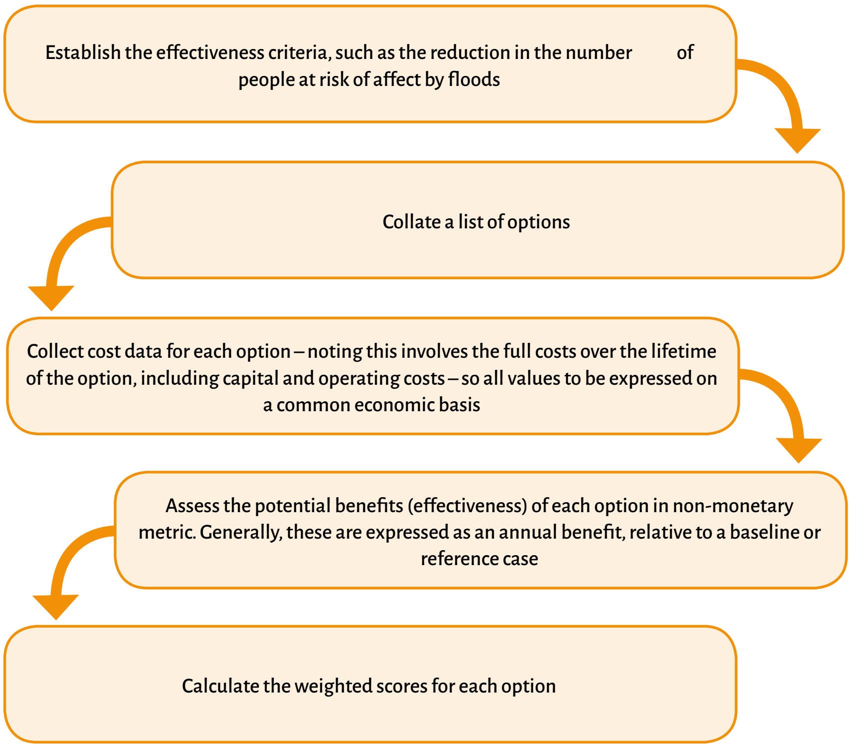
- The biggest advantage of CEA is that it **does not require the economic valuation of benefits**. This is hugely important in the adaptation context, where it can often be difficult to assign monetised values of benefits
- One major weakness is that it **optimises to a single metric**, which can often be difficult to choose. This focus on a single metric may omit important risks and may not capture all costs and benefits.

What does it involve?

The figure on the next page shows the main steps when applying cost-effectiveness analysis in adaptation.

Good practice when applying cost-effectiveness analysis to adaptation

- Cost-effectiveness analysis is most applicable in sectors where there is a clear headline indicator and where climate uncertainty is low. CEA helps avoid the challenge of estimating controversial values such as the monetary value of reduced health and morbidity. In addition, indicators are simple and transparent and outcomes are easy to communicate.



Source: adapted from **Mediation**

Applying alternative discounting rates: the Equivalency Principle

The choice of discount rate has been heavily debated in adaptation. Recent discussions support the use of lower discount rates to justify acting on climate change now, rather than delaying action. There is also growing consensus on the use of social discount rates which decrease in the long term. The application of the Equivalency Principle provides a new way of guaranteeing a sustainable reallocation of the land in the long run perspective, taking into account the many dimensions of sustainable development which includes economics, society, institutions and environment.

The Equivalency Principle is based on the premise that the long term value of a piece of undeveloped land ought to be at least the same as the value of an identical piece of land in the vicinity to which permission has been granted for development. This could be the case of making appropriate choices between ecosystem-based adaptation and grey infrastructures, which are affecting in different ways natural and developed land uses.

More information on the use of the Equivalency Principle can be found ***here****.*

- It is also considered good practice to undertake CEA within an iterative plan, to capture enabling steps, portfolios and inter-linkages, rather than using the outputs as a simple technical prioritisation.
- The use of multiple cost curves can help limit the impact of uncertainties, and approaches such as scenario and sensitivity analysis can also be used to better consider the potential of different future climate change impacts.

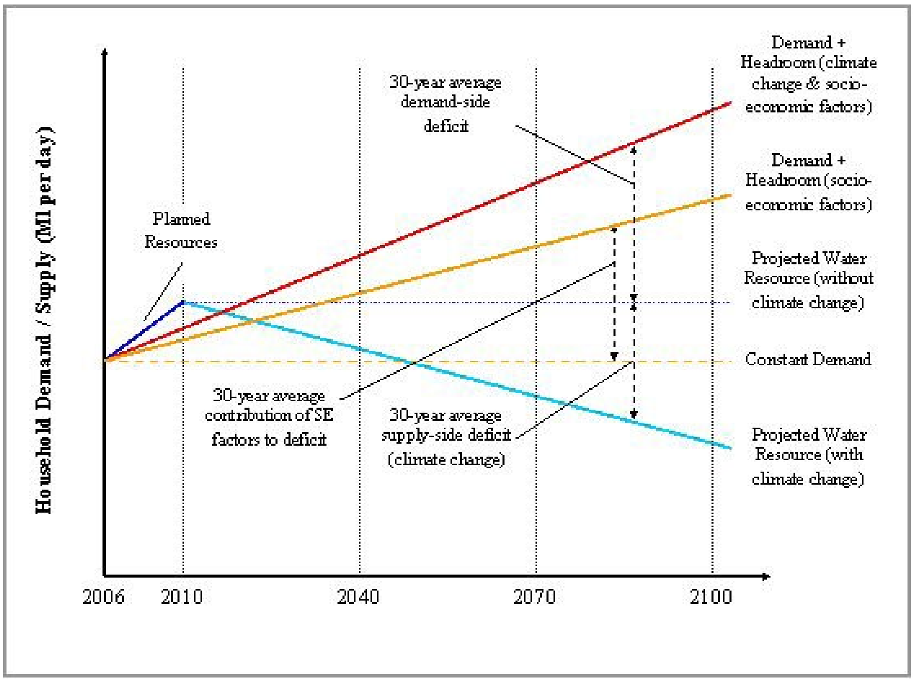
More information on the analysis of the use of non-monetary metrics to assess adaptation actions through CEA were carried out in ECONADAPT can be found **here**.

ILLUSTRATION

Cost-effectiveness analysis of adaptation options for public water supply

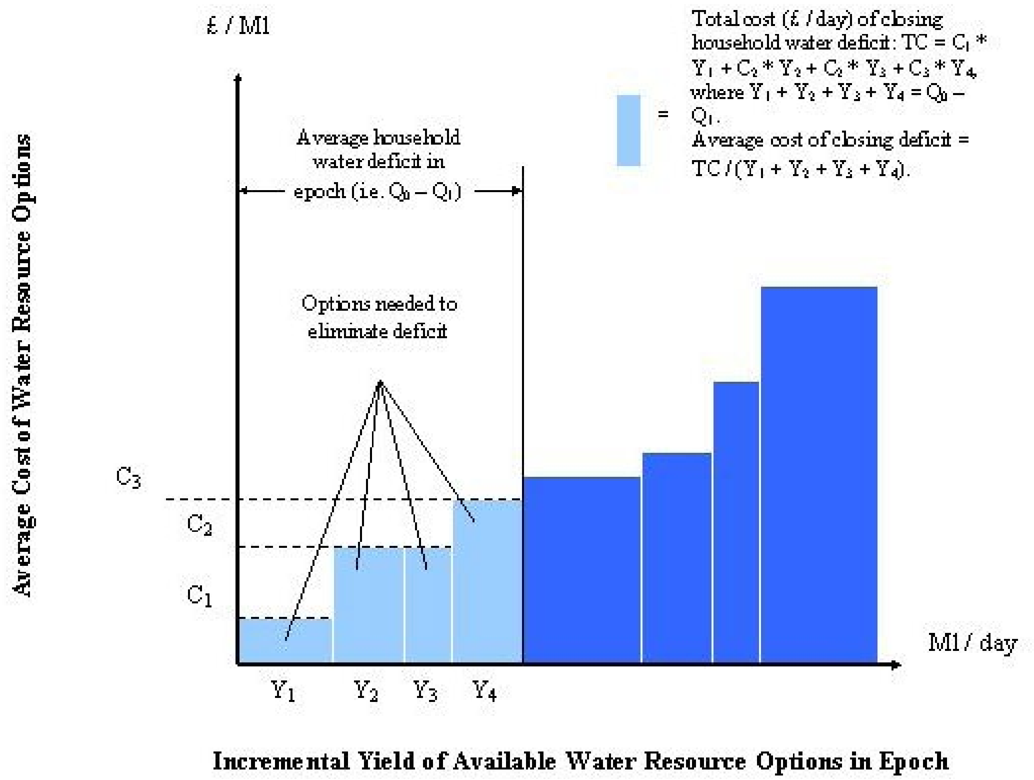
This study carried out a cost-effectiveness analysis of adaptation options against growing water scarcity in SE England and SE Scotland. It estimated the incremental costs of adapting to household water deficits. It is assumed that the objective of the decision-maker is to eliminate household water deficit at minimum cost. The approach involved two principal steps.

Firstly, the 30-year average household water deficit was estimated for three periods (2011–2040, 2041–2070, 2071–2100) under four climate scenarios. The figure below illustrates the process of developing household water deficits. Projected climate change reduces yields from planned resources. Household demand for water over time is affected by socio-economic change, with the assumption that water demand increases. Climate change also increases household demand for water. Rising demand for water combined with decreasing availability lead to increasing deficits over time.



The second step of the methodology involved estimating the cost of addressing the water deficit. The study looked at a variety of water management options which either reduce demand or increase supply. The options were first examined to determine in what timeframe and socio-economic scenario they may or may not be available. Based on the information available for all the options, indicative cost-yield curves were created under the various timeframes, scenarios and assumed costs. These curves show by how much the water deficit can be reduced by each individual measure, and at what cost.

An example of one of these curves is presented in the figure below. The measures are ordered from the lowest cost options on the left to the higher cost options on the right. These cost-yield curves are applied to both the SE England and SE Scotland case studies. It is assumed that the household water deficit is entirely eliminated in each period or epoch. Thus, in this example, implementation of options 1–4 is sufficient to eliminate the household water deficit. These options were likely to include waste-water re-use and retrofit of toilets. Examples of more expensive options included the construction of new reservoirs and water metering in households.



Reference: Metroeconomica (2006) Climate Change Impacts and Adaptation: Quantify the Cost of Impacts and Adaptation. Report to Defra, London.

MULTI-CRITERIA ANALYSIS

Multi-criteria analysis (MCA) provides a systematic approach for **ranking adaptation options** against a range of decision criteria. The various criteria can be weighted to reflect the relative importance of different criteria. The weighted sum of the different chosen criteria is used to rank the options.

When to use it?

- Multi-criteria analysis can be applied to the analysis of alternative adaptation strategies or for individual projects or investment decisions.
- Because MCA is able to consider both **qualitative and quantitative information**, it is especially applicable in scenarios where such a combination of factors must be considered in the ranking of adaptation interventions.
- In addition, the approach is well suited to **encourage engagement with stakeholders** as MCA allows for the consideration of stakeholder preferences in the scoring and weighting of criteria.

More information on the application of multi-criteria analysis in adaptation can be found **here**.

What are its key strengths and weaknesses?

Because MCA allows for the consideration of both quantitative and qualitative data, it is especially useful in situations where many such factors must be considered to reach a ranking of different adaptation options.

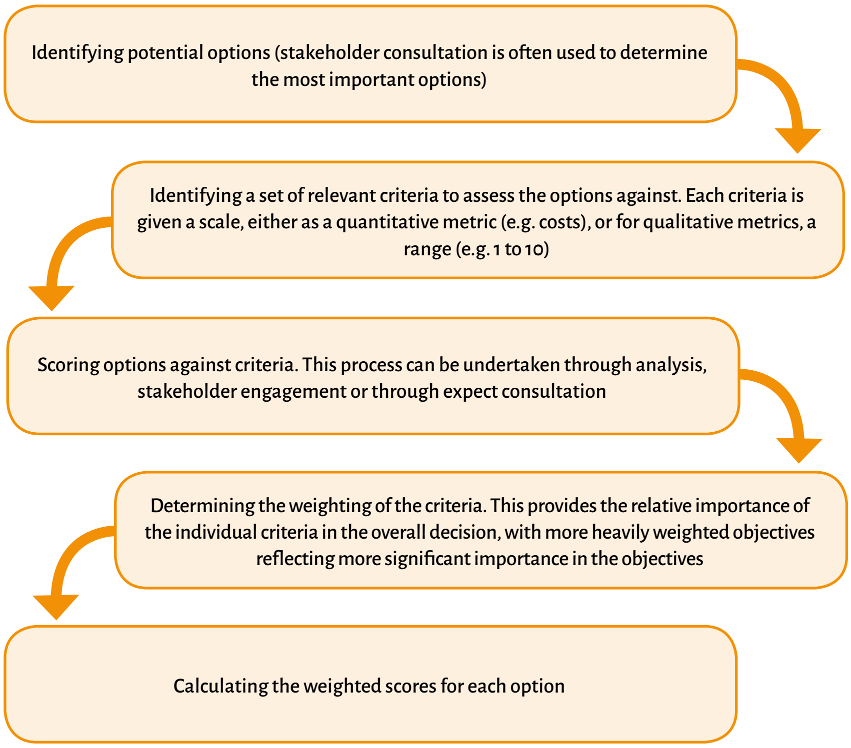
- The methodology can effectively incorporate **important dimensions in adaptation** such as urgency, co-benefits, no-regret and robustness characteristics.

More information on the use of non-monetary metrics to assess adaptation actions through MCA can be found **here**.

- On the other hand, the results can suffer from a **high level of subjectivity** due to the judgement and input from experts and stakeholder, which can also impact the analysis of uncertainty.

What does it involve?

The figure on the next page shows the main steps when applying multi-criteria analysis in adaptation.



Source: adapted from **Mediation**

Good practice when applying cost-effectiveness analysis to adaptation

- The selection of the range and the **scoring of criteria** are crucial, and require careful consideration. It is essential to make sure that the weighted scores can be added, i.e. all criteria should be formulated in either positive terms or negative terms.
- The inclusion of criteria for how options perform against **uncertainty** can be included, but it is important to note that this makes the consideration of uncertainty qualitative.

Distributional impacts and equity in economic analysis

In its conventional form, CBA aggregates costs and benefits accruing to different actors. This is a significant problem in adaptation when climate change impacts disproportionately affect the most vulnerable communities and groups.

More information on methods to account for distributional issues can be found ***here****.*

ILLUSTRATION

Adapting to climate change in The Netherlands

The following example describes the preparation of an inventory of climate adaptation options and ranking of alternatives via an MCA for The Netherlands. The approach combines a qualitative and quantitative assessment and the ranking system of identified potential adaptation options to respond to climate change in the Netherlands in connection to spatial planning. The here described example focuses on the qualitative assessment, but De Bruin et al (2009) describe also the characterization of adaptation options on their feasibility and includes an inventory of the incremental costs and benefits.

The first step of the assessment was the **identification and categorisation of adaptation options**. The adaptation options have been selected and identified on the basis of literature review and stakeholder consultation in a sectoral approach, in order to obtain the best inventory for the various sectors of the economy. Sectors included in the study are: agriculture, forestry, fisheries, water, energy and infrastructure. Some information is included on health, recreation and transport. A database was constructed to summarise the identified adaptation options and the associated effects, and to make an inventory of the institutional aspects related to their implementation. The interconnections between the adaptation options were also identified, including overlap, synergy and competition. 96 adaptation options have been identified and they include a wide variety of policy measures, technological solutions and adjustments in behaviour.

The second assessment step was the **definition of the criteria for the raking of the options and the scoring of these criteria**. The adaptation options have been given scores with respect to the following criteria: (i) the importance of the option in terms of the expected gross benefits that can be obtained, (ii) the urgency of the option, reflecting the need to act soon and not later

Adaptation option	Importance (40%)	Urgency (20%)	No regret (15 %)	Co-benefits (15%)	Mitigation effect (10%)	Weighted summary
Integrated nature and water management	5	5	5	5	4	4.9
Integrated coastal zone management	5	5	5	5	4	4.9
More space for water: a. regional water system, b. improving river capacity	5	5	5	5	4	4.9
Risk based allocation policy	5	5	5	5	4	4.9
Risk management as basic strategy	5	5	5	5	4	4.9
New institutional alliances	5	5	5	4	5	4.9

(iii) the no-regret characteristics of the option (it is good to implement, irrespective of climate change) (iv) the co-benefits to other sectors and domains and (v) the effect on climate change mitigation (for instance through changes in land use that reduce emissions of greenhouse gases as a side effect). The scoring of these criteria for each of the option is based on subjective expert judgement with a broad overview and has been discussed in a workshop with external experts to validate the scores.

The third step includes the **ranking of the adaptation options** based on the importance of the various criteria to make rankings of the options according to the weights attached to the various criteria. The weights for the criteria can be changed interactively by individuals or decision makers. De Bruin et al (2009) have chosen the ranking based on the weighted summation of the scores on the different criteria. The weights are based on expert judgment and a workshop with key stakeholders. The weights defined by the experts and stakeholders are following: (i) importance (weight 40%), (ii) urgency (weight 20%), (iii) no-regret characteristics (weight 15%), (iv) co-benefits (weight 15%) and (v) mitigation effect (weight 10%). From the ranking, the adaptation options in the following table have the **highest priority. Adaptation options with low priority** are Subsoil drainage of peat lands (weighted summary 1.2), Reclamation of (part of) southern North Sea (1.4), Abandoning of the whole of low-lying Netherlands (1.3) and Self sufficiency in production of roughage (1.6).

Reference: De Bruin, K., Dellink, R.B., Ruijs, A., et al. (2009). Adapting to climate change in the Netherlands: An inventory of climate adaptation options and ranking of alternatives, Climatic Change, 2009, Volume 95, Issue 1–2, July 2009, Pages 23–45.

REAL OPTIONS ANALYSIS

Traditionally used in financial markets to mitigate investment risks, Real Options Analysis (ROA) can be used in adaptation to gain **insight into the risks associated with investing in physical (real) assets**. It is particularly useful when considering when to invest into an adaptation intervention or the value of adjusting adaptation interventions over time in response to changing events. ROA provides an **economic analysis of the value of flexibility and future learning**.

When to use it?

More information on the use of real options analysis in adaptation can be found **here**.

- Real options analysis is particularly useful in considering large-scale, long-lived and costly adaptation interventions such as dyke flood protection or dam-based water storage.
- ROA can be used to support the scoping of such adaptation interventions projects and the value of securing investments for future development.
- It can also help explore how to incorporate flexibility into the design of these interventions and how the project value will evolve over stages of development.

What are its key strengths and weaknesses?

Standard economic appraisal normally assesses the performance of a project over its whole lifecycle. ROA recognises that projects are usually more complex than a simple one-off investment, and ROA can add to the understanding of the **value of expanding, contracting, or even stopping an intervention** altogether if it appears unlikely to be successful.

- One of the major strengths of ROA is that it allows for quantitative economic analysis of the value of **flexibility and learning**.
- However, a drawback of ROA is linked to its **complex methodology**, which typically requires high volumes of data and resources.

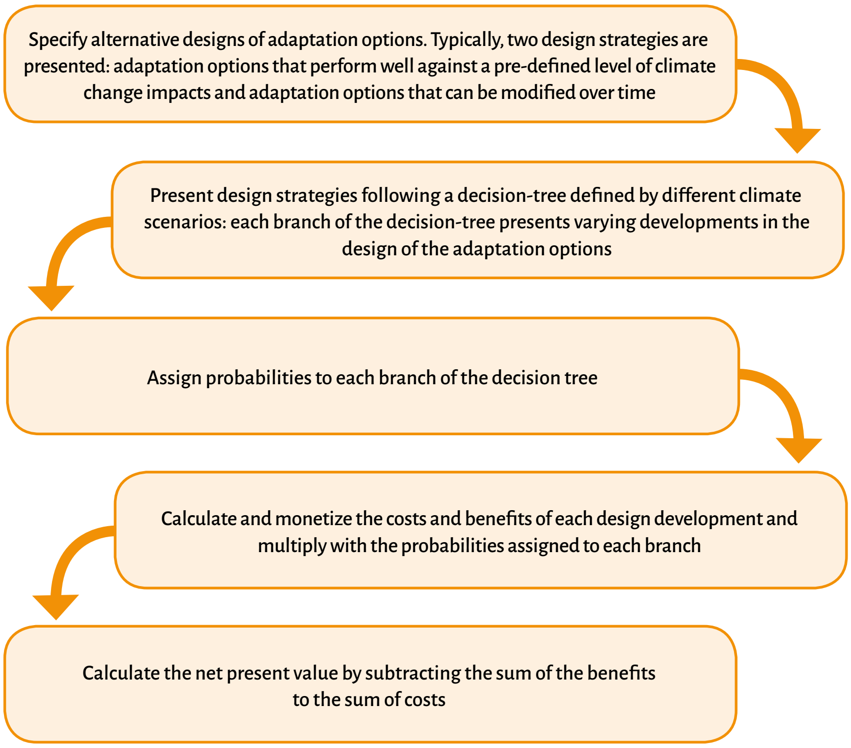
Treatment of future learning: Acceptable Risks Analysis

While approaches considering flexibility and future learning are becoming increasingly recognised as valuable tools to support decision-making, real option analysis can be a relatively complex method to apply and resource intensive. A light-touch method based on the idea of "acceptable risks" can be used to incorporate learning into the economic analysis of adaptation options. After selecting an acceptable level of risk, decision makers can determine what year adaptation actions need to occur to avoid high damage.

*More information into acceptable risks analysis can be found **here**.*

What does it involve?

The figure shows the main steps when applying real options analysis in adaptation.



Source: adapted from **Mediation**

Good practice when applying real options analysis to adaptation

- While the full application of ROA involves a complex methodology, a more qualitative approach combined with the use of decision trees can be taken, which is of benefit when significant amounts of data are unavailable.
- The application requires inputs related to probability or probabilistic assumptions for climate change and the identification of decision points. For situations of (deep) uncertainty, where probabilistic information is low or missing, alternative approaches, such as robust optimisation, may be considered.

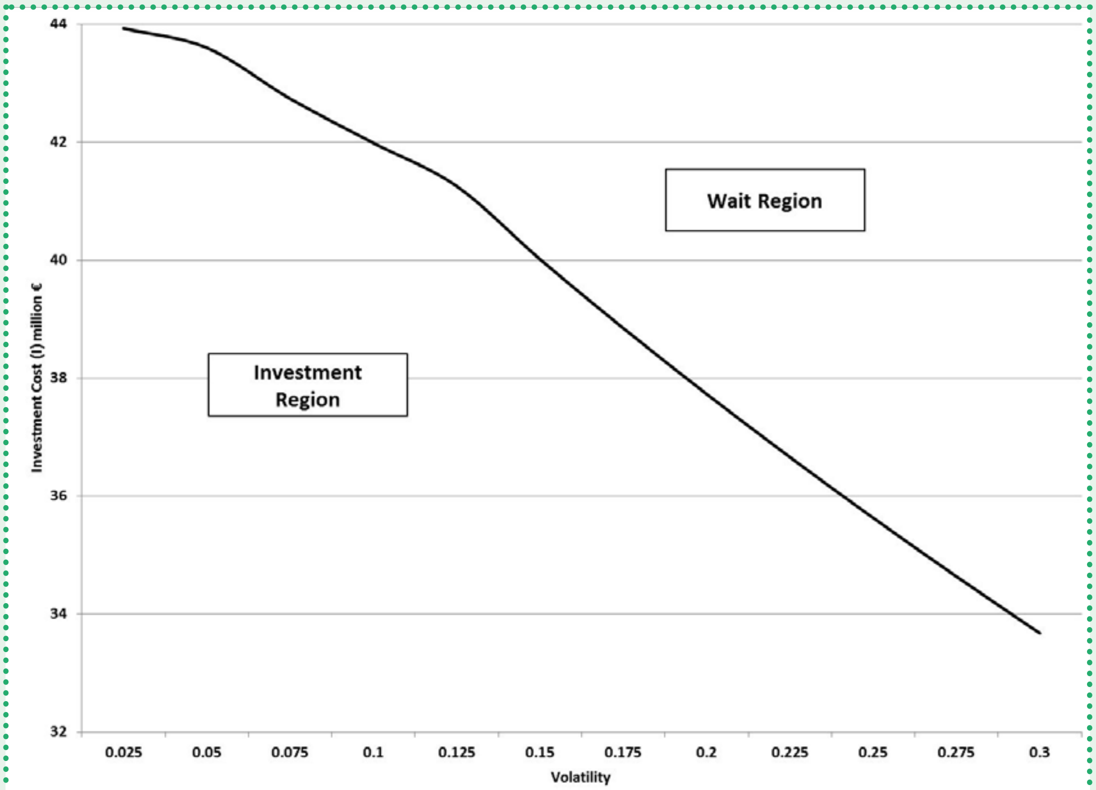
ILLUSTRATION

Application of Real Options Analysis for flood risk protection in Bilbao

This case study uses an application of real options analysis to inform decision-making on a public investment in infrastructure planned to reduce flood-risk in the city of Bilbao (Basque Country, Spain), which involves opening a pre-existing canal that will turn the current peninsula of Zorrotzaurre into an island in the Bilbao Estuary. In 2012 a new important urban development was approved in an old industrial site located on the peninsula of Zorrotzaurre, a flood-prone area in the Bilbao Estuary.

The first step of the study was to estimate expected damages at different points in time. To do this, a stochastic function was developed containing two risk variables: the frequency of extreme flood events and the stochastic growth rate of damage, taking into account climate change impacts and economic growth. Using the function, the expected flood damages of different return periods were calculated and expected benefits (in terms of avoided impacts) were estimated.

The second step was to include uncertainty into damage values. Two main risk measurements were used: Value-at-Risk (VaR) and Expected Shortfall (ES). The VaR expressed the losses that could occur for a time interval of 100 years (with a given confidence level of 95%). The second risk measure, ES, represents the expected damage when VaR is exceeded. It is a better measure



of risk for low probability but high damage events. The study estimated both measures of risk, determining that the opening of the canal is expected to reduce not only the expected damage but also the level of damages that would occur in the worst 5% of the cases.

Subsequently, a risk assessment was performed using Monte-Carlo simulations for both the baseline scenario (keeping the peninsula) and the adaptation scenario (creating the island). This estimated the distribution of damages probabilities for different events in order to calculate the probability of exceeding different levels of damages. The damage distributions generated did not increase deterministically over time but rather behaved stochastically, though with an expected value identical to the case of deterministic growth. As such, a stochastic function could be applied to estimate damage more appropriately. In this instance, the function selected was of the Geometric Brownian Motion (GBM) type.

The final step was to evaluate the economic impact of different investment timing. The chart shows the results that determine the boundary value of investment cost between the "investment region" and the "wait region" for a limited time period. The graph shows that the greater the volatility, and therefore in uncertainty, reduces the investment boundary. In other words, greater volatility makes potential investors more demanding and they invest only when the cost is lower.

More information on the application of real options analysis in Bilbao can be found ***here***.

ROBUST DECISION MAKING

Robust decision making (RDM) is based on the concept of "robustness" with respect to a large number of alternative scenarios rather than "optimality" with respect to a single scenario, which emphasises an option's ability to be **effective over a range of possible future conditions.**

When to use it?

More information on the application of robust decision making in adaptation can be found **here**.

- Robust decision making was developed to help policymakers make more effective decisions on **near-term options which could have long-term consequences**.
- RDM can examine the performance of large infrastructure investments as opposed to capacity-building, considering multiple potential futures.
- The RDM analysis can help identify **trade-offs and synergies** between a variety of strategic (costly, often irreversible) and operational (easily reversible) options and help build the best combination of the options to reducing long-term vulnerability and build resilience.

What are its key strengths and weaknesses?

More information on the application of robust decision making in global-scale modelling can be found **here**.

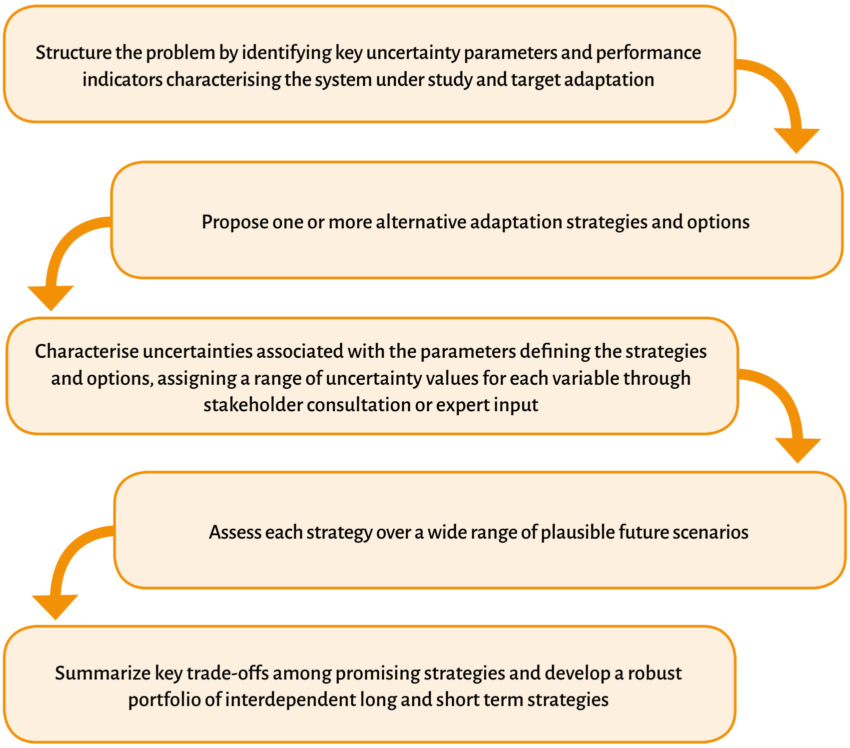
- One of the biggest strengths of RDM is its capacity to help make informed adaptation decisions possible without relying on probabilistic predictions of future climate change.
- Furthermore, RDM is applicable under situations of **high uncertainty**, e.g. climate change, where probabilistic information is low or missing.
- RDM can be used in various practical studies in cases of incomplete or uncertain information, and requires basic knowledge of computational methods.

What does it involve?

The figure on the next page shows the main steps when applying robust decision making in adaptation.

Good practice when applying robust decision making to adaptation

- Ideally, an RDM analysis concludes by identifying a robust combination of adaptation options or strategies that perform well over a very wide range of possible future scenarios.
- Applications of RDM for interdependent systems can require high volumes of data, therefore informal testing of RDM can be done with simplified models.



Source: adapted from **Mediation**

ILLUSTRATION

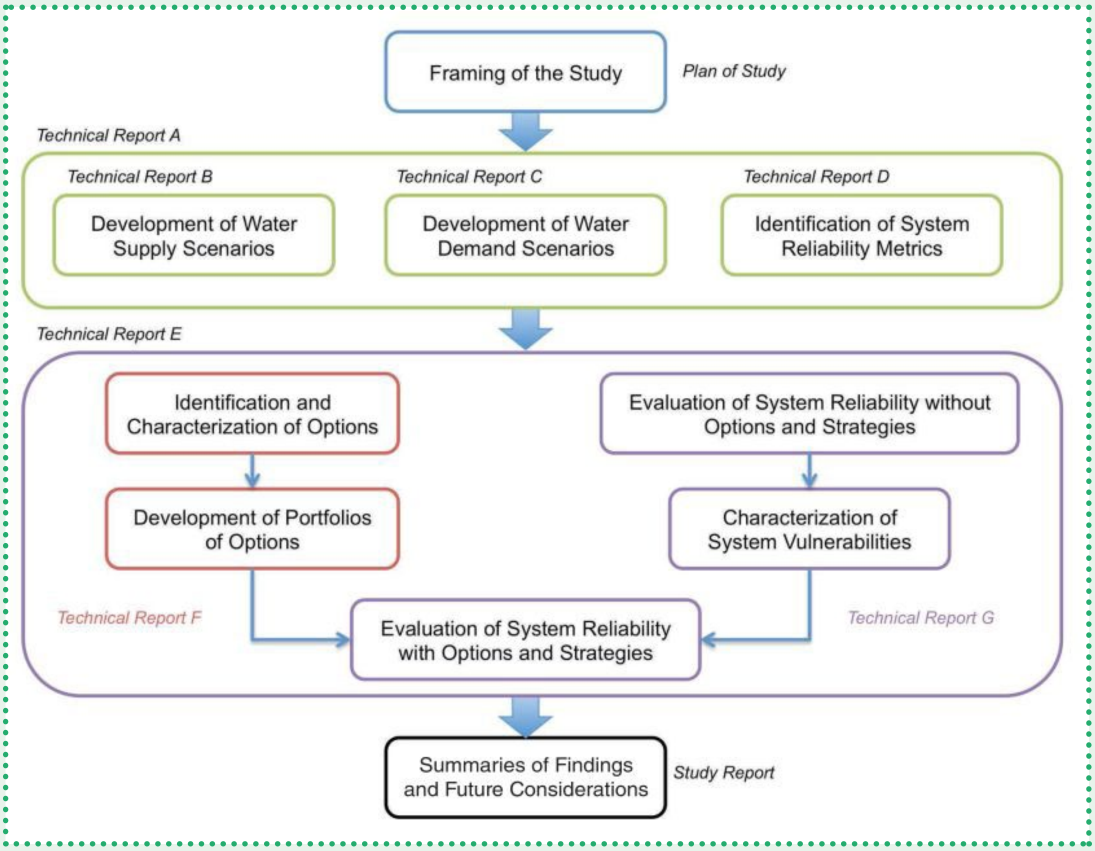
Robust decision making in the Colorado river basin

RDM was applied to water management in the Colorado River Basin (Groves et al, 2013). The approach developed a set of scenarios: four supply scenarios, six demand ones, and two reservoir operations scenarios (timeline: 2012-2060). 80 management options were considered by expert and stakeholders against a range of 19 performance criteria (e.g. cost, yield, availability, technical feasibility, legal risk, energy intensity). As result four portfolio strategies were developed.

Description of the four Portfolio

Portfolio	Portfolio description
Portfolio A (Inclusive)	Includes all options included in the other portfolios
Portfolio B (Reliability Focus)	Emphasizes options with high technical feasibility and high long-term reliability; excludes options with high permitting, legal, or policy risks
Portfolio C (Environmental Performance Focus)	Excludes options with relatively high energy intensity; includes options that result in increased instream flows; excludes options that have low feasibility or high permitting risk
Portfolio D (Common Options)	Includes only those options common to Portfolio B (Reliability Focus) and Portfolio C (Environmental Performance Focus).

Steps followed for the RDM application



The performance of portfolio strategies was evaluated against system performance criteria (e.g. water deliveries, electric power resources, flood control, water quality, ecological resources). The evaluation of each portfolio is dynamic: rules are included in the simulations that only implements specific options when thresholds of river basin conditions are crossed. Based on the simulation environment described above, the study considered the vulnerabilities of the system under different scenarios, which portfolio strategies may reduce those vulnerabilities, and their costs.

Overall, the study found that implementing any of the designed strategies increases the robustness of the river basin, and that, while the environmental strategy was cheaper than the reliability strategy for the upper and lower basin, it was only more effective than the reliability strategy in the upper basin. The method managed to present trade-offs against a large set of criteria and taking into account a large set of internal and external drivers to the river basin. In addition, the dynamic analysis helped to identify low regret options over time. For example, it was estimated that municipal water re-use and agricultural conservation should be implemented in the short term (<5 years) under all the presented scenarios.

Reference: Groves, D.G. Fischbach, J.R. Bloom, E., Knopman, D. Keefe, R. (2013). Adapting to a Changing Colorado River. Making Future Water Deliveries More Reliable Through Robust Management Strategies. ISBN/EAN:9780833081797.

ITERATIVE RISK MANAGEMENT

Iterative risk management (IRM) is a long established approach that uses a monitoring, research, evaluation and learning process to improve future management strategies. IRM is based on the idea that current decisions are essentially constrained by imperfect knowledge and cognitive bias, and cycles of revisions are necessary to improve the performance of strategies and actions. Thus, **IRM incorporates learning at the core of its methodology**.

When to use it?

More information on the application of iterative risk management in adaptation can be found **here**.

- Since IRM encourages flexibility, it is especially useful in helping decision makers to develop plans where **decisions can be made over time**, at the right time, and adjusted appropriately.

- IRM can help policy makers **avoid taking irreversible decisions** which may not be needed down the road depending on the progression of climate change impacts. As a result, it allows for application in adaptation situations of high uncertainty where probabilistic information may be lacking.

What are its key strengths and weaknesses?

IRM has a focus on starting with current climate variability (and the adaptation deficit) and then looking at future climate change within a framework of decision making under uncertainty. Early steps within IRM have a strong focus on **building adaptive capacity, implementing low and no-regret options and identifying areas of long-term concern** that warrant early investigation or action.

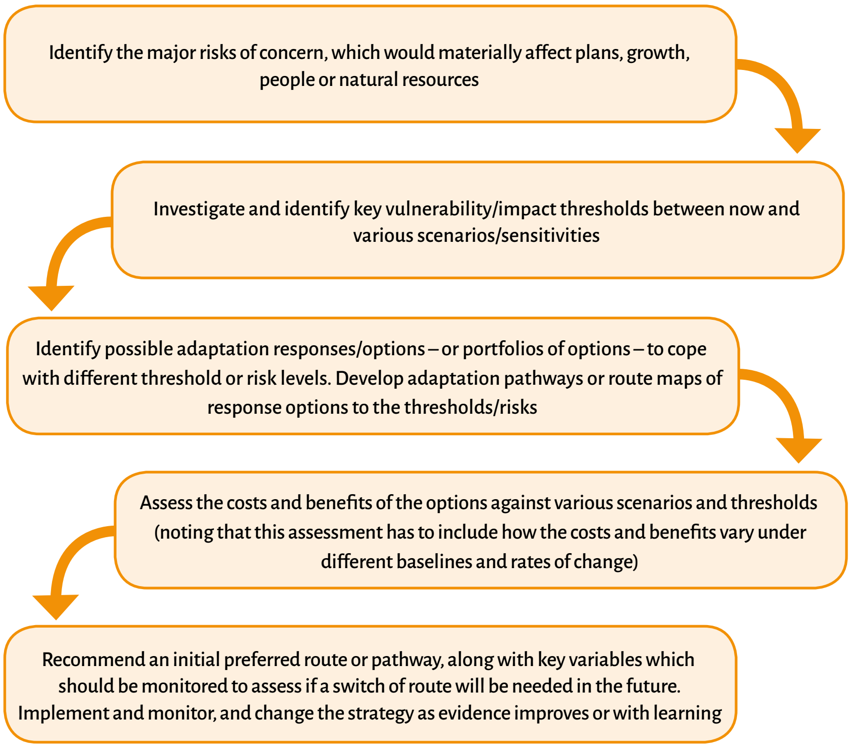
- A major benefit of IRM is that it encourages decision makers to **consider alternative adaptation strategies and options**, as well as phased implementation.
- However, IRM can become complex when **multiple risks must be considered** or when a suitable risk threshold must be identified to trigger future responses.

What does it involve?

The figure on the next page shows the main steps when applying robust decision making in adaptation.

Good practice when applying robust decision making to adaptation

- Because it is not limited by a strict formal methodology, IRM is an approach that fits especially well in **conjunction with other support tools**, such as cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis.
- It is also useful to combine with e.g. CBA to identify low regret measures for the near future, then PA to look at the portfolios of long-term options in an IRM framework.



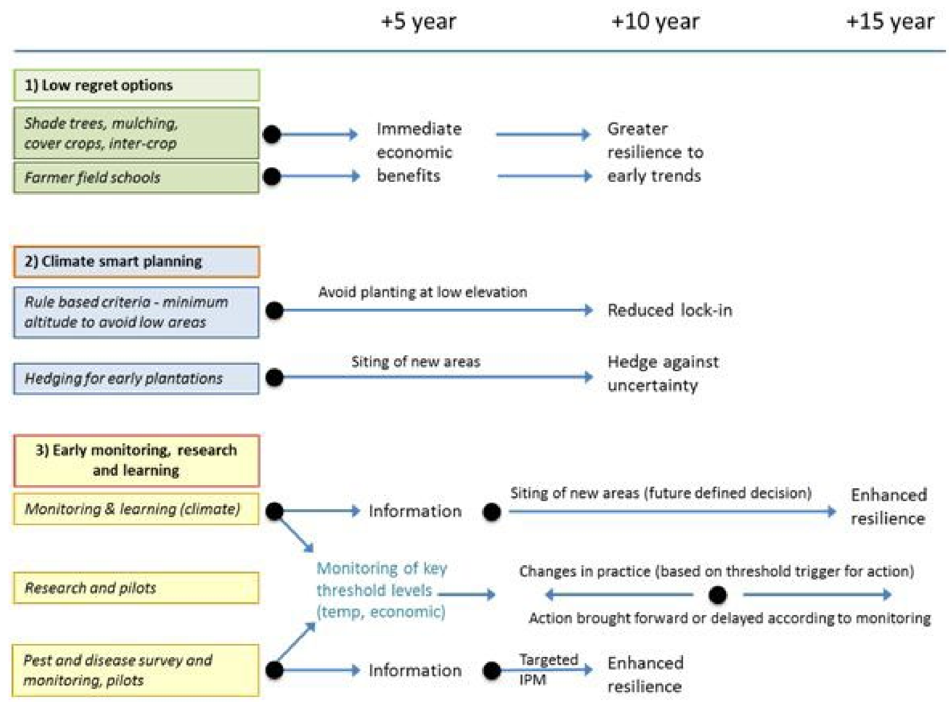
Source: adapted from **Mediation**

ILLUSTRATION

Iterative Risk Management of coffee and tea production

In Rwanda, tea and coffee are grown in certain areas of the country where the soil, temperature and rainfall are suitable. The main production areas (especially for tea) are at higher elevations, where there is a cooler climate. Production and quality of both crops is affected by annual rainfall variability, and the climate also has a role in the incidence and severity of pests and diseases. Future climate change has the potential to have a large impact on these sectors, which are critical for exports. It can affect productivity and quality of existing plantations, the suitability of areas for growing these crops, as well as the range and prevalence of pests and disease. These effects are particularly important because tea and coffee are long-lived crops and new plantations and are managed over decades. Importantly there are current plans to expand the areas of tea and coffee under production, thus there is a need to plan these areas with the future as well as the current climate in mind.

The case study applied a policy-orientated iterative climate risk management (ICRM) approach, with an economic and financial analysis to analyse options. It first identified the current and future climate risks and the types of early policy decisions, and from this identified three areas of adaptation to consider in the overall plan.



The case study showed that the application of a policy-orientated ICRM framework was extremely useful in developing the timing and phasing of adaptation, and translating this through to practical interventions that could form the basis for the adaptation strategy. It showed that a portfolio of interventions is needed, to address the different (temporal) risks and different types of decisions, with a combination of methodological approaches. The portfolio is summarised below.

The study found high economic benefits from investing in early low-regret options that address current weather risks, especially climate-smart options whose benefits increase with climate change. These options had high benefit to cost ratios and high internal rates of return, and are an immediate priority for early adaptation.

In relation to future orientated risks, the study found economic benefits from some options - but importantly not all. A robust finding was that planting new production areas at very low altitudes today (e.g. towards the lower end of current production ranges) would not make economic sense. The analysis also showed that planting at higher altitudes, which will become better suited in the future, involves a more complex trade-off, and the choice of strategy is important.

A further finding is that given the long planting periods, there is time to learn, and investing in early monitoring and risk information to help to improve future siting decisions. This highlights a key finding of the study, i.e. with the application of an adaptive management framework and investments in early monitoring, research and learning.

*More information on the application of Iterative Risk Management can be found **here**.*

PORTFOLIO ANALYSIS

Portfolio Analysis (PA) is a methodology that helps examining the value **of incorporating a diverse set of options in adaptation strategies**, as opposed to relying on a single one. It is based on the idea that diversification is an important risk management response: the benefits of a strategy relying on a portfolio of adaptation options are likely to be higher than for a strategy that relies on a single option. It also aims to minimise the risk of failure on the assumption that lower performance of one option is compensated by the better performance of another.

When to use it?

More information on the application of portfolio analysis in adaptation can be found **here**.

- Portfolio analysis can used to **compare multiple portfolios of options** against the uncertainties of future socio-economic conditions across multiple climate change scenarios and models.
- It can be used for the design and evaluation of adaptation policies and strategies, and has a clear application in cases where **different adaptation actions are likely to be complementary** in reducing climate risks.
- PA can be used for economic analysis, but can also work with **non-monetary metrics** and therefore can be applied in non-market sectors, such as for ecosystem based adaptation.

Assess systemic risks in adaptation

Systemic risk encompasses those impacts from climate change that create changes in welfare that transcend single social-ecological systems. They may result from the possibility of highly uncertain, but catastrophically damaging events, such as tipping points in the melting of large ice sheets or a global food crisis due to extreme weather events. Feedback loops play an important role in systemic risks as they can amplify impacts of single change process or events.

Systemic risks are usually excluded from many economic analyses of climate change due to methodological questions, including those around expressing the uncertainty of when and how these events may occur. Recent improvements of existing methodological tools allow for better consideration of systemic impacts in economic analysis. For example, catastrophic impacts have been included in some Social Cost of Carbon calculations while Integrated Assessment Models and Agent-Based Models can be used to cope with complex dynamics in social-ecological systems.

*More information on how to assess systemic risks in adaptation can be found **here**.*

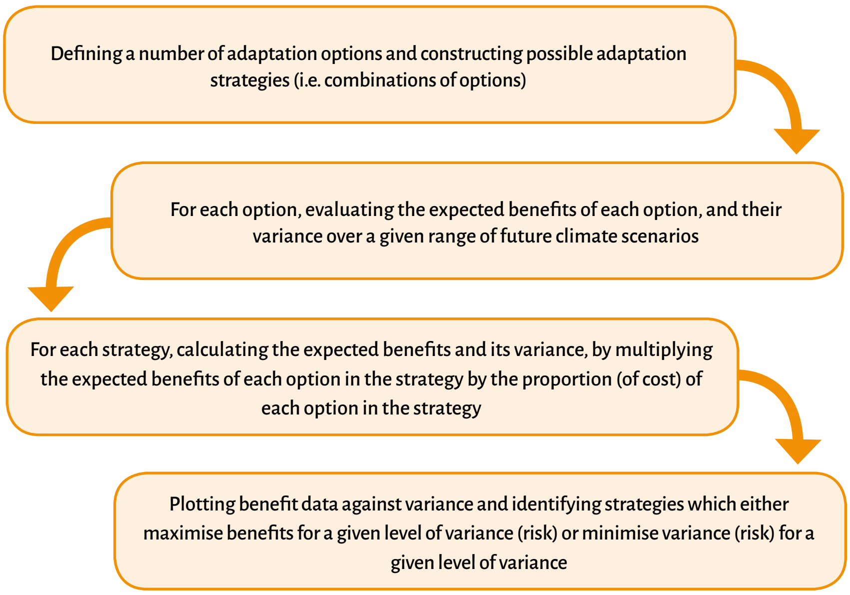
What are its key strengths and weaknesses?

PA emphasises the **trade-offs that can be expected between risks and benefits of various strategies**. In the context of adaptation, risk preferences often relate to the uncertainty of future climate scenarios: it is desirable to select strategies which perform well over a range of plausible futures, and so PA can help to identify a group of strategies which match that preference.

- PA is particularly attractive in the adaption context because it offers a **clear way to handle climate uncertainty** by selecting options which are effective together over a range of possible future scenarios, instead of one best option for one future
- On the other hand, the methodology involved with PA is **resource intensive**, requiring a high degree of expert knowledge.

What does it involve?

The figure shows the main steps when applying robust decision making in adaptation.



Source: adapted from Mediation

Good practice when applying robust decision making to adaptation

- PA requires **benefits to be expressed in quantitative terms**, either as economic values or physical benefits, thus it is more applicable in cases where data availability is reasonable.
- The application of the technique requires probabilities, which makes it more applicable to cases where **climate information is good**, and some information on climate uncertainty exists.

ILLUSTRATION

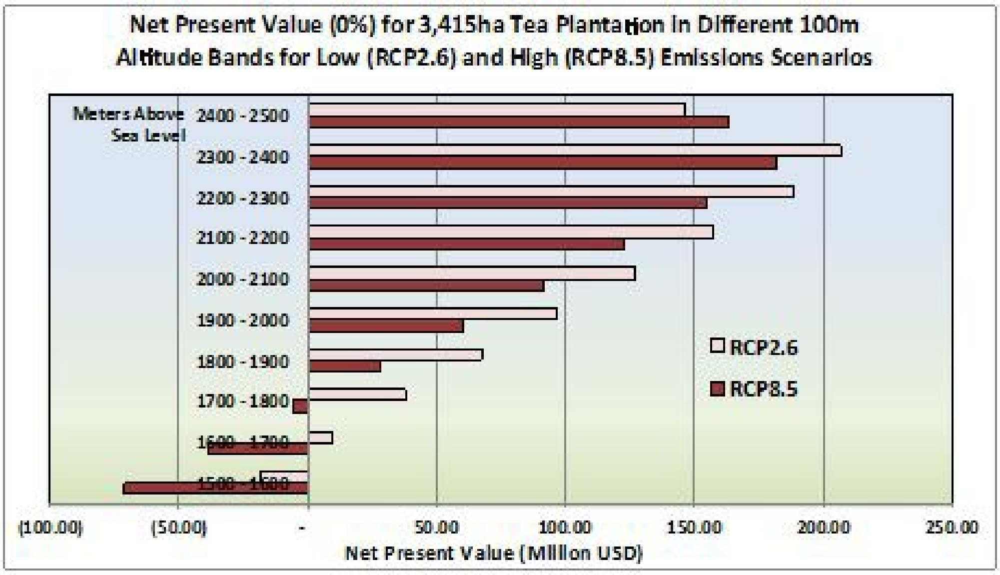
Portfolio analysis for adaptation in Rwanda

Portfolio analysis was used to evaluate investment in tea plantations at different altitude bands. The longevity of the assets in question, in this case tea plants, are similar to infrastructure investments with large sunk costs and can remain economically viable for over 50 years. Decisions about the location of new plantations are therefore well advised to consider the impacts of climate change.

Average temperatures decline with altitude. Combined with the varying tea yield and price at different temperatures, this means that tea plantations in one altitude band may perform differently to tea plantations in another. Without climate change, the relative performance of tea plantations in different altitude bands is likely to remain the same because the yield and price outcomes for tea in different altitude bands are constant. However, with climate change the yield and price of a tea plantation in a given altitude band is likely to change. The optimal altitude band for planting tea in a scenario without climate change may therefore be suboptimal in a future scenario with climate change.

This study evaluates how the information gained from climate risk mapping could change the plantation portfolio chosen by the tea investors. Portfolios are the different combinations of these options (altitude bands) that investors can choose to form their "plantation portfolio". The decision criteria used in this study are the financial internal rate of return and economic efficiency (measure as the Net Present Value and the Benefit-Cost-Ratio). These criteria are tested for multiple investments across different future climate scenarios.

Without climate risk mapping, the investors can only use the Government of Rwanda's current tea expansion maps to decide where to plant tea. This is the business as usual (BAU) case where the optimal plantation portfolio is chosen under the assumption of no climate



change. With climate risk mapping, the investors have additional information about the suitability of planting tea in different altitude bands under different future climate scenarios. This study first assesses the BAU plantation portfolio in climate scenarios 1 and 2, before considering how the climate risk mapping investment may change the investors' planting decision.

The risk assessed in traditional portfolio analysis is represented by the difference in returns between the two scenarios aggregated into one single "expected value". This usually requires assigning a probability weight to each climate scenario. Since there is no reliable data or local scenarios on which these weights could be based, the approach did not aggregate the information; rather, we present results for each of the two climate scenario selected (see figure). This allows the tea investors to see the difference in returns between climate scenarios, rather than aggregating information into one "expected value".

The figure shows that planting tea at an altitude between 2,300 and 2,400 metres above sea level is expected to produce the highest financial and undiscounted economic returns in both climate scenarios. However, at a 0% social discount rate, the absolute difference in returns between the two climate scenarios is lowest for plantations between 2,400 and 2,500 metres above sea level. In addition, the undiscounted economic results show that planting below 1,800 metres above sea level is expected to yield negative returns in the high emission scenario, and below 1,600 metres above sea level is expected to yield negative returns in both scenarios.

This study shows positive returns to climate risk mapping across a wide range of these uncertainties; the worst-case scenario is no climate change and the tea investors choosing a plantation portfolio that is similar to the BAU portfolio. However, even this scenario has positive financial and economic returns (Internal rate of return of 47%, or USD 6.7 m at a 0% discount rate, and USD 0.6 m at 13%). In the "best-case scenario" with climate change, the returns to climate risk mapping are just over 20 times greater.

More information on the application of Portfolio Analysis to tea plantation can be found ***here***.

LOOKING FOR MORE INFORMATION?

Insights into the economics of adaptation

The following methodological information is available at **econadapt-toolbox.eu/insights**.

Framing of adaptation economics

Framing adaptation economics in decision-making: a policy-led framework

Sourcing and using climate information for economic assessments of adaptation

Energy: Cost & benefits of adaptation

Health: Cost & benefits of adaptation

Agriculture: Cost & benefits of adaptation

Infrastructure: cost & benefits of adaptation

Coastal zones: cost & benefits of adaptation

Water and flood management: cost & benefits of adaptation

Biodiversity and ecosystem services: cost & benefits of adaptation

Micro-economic foundations

Framework for the evaluation of system-wide adaptation

Analysing trade-offs between development and adaptation

Evaluating adaptation options through the elicitation of preferences

Dealing with changing preferences over time

Treatment of future learning: Real-Option Analysis

Treatment of future learning: Acceptable Risks Analysis

Scaling, aggregation and transfer

Private adaptation of adaptation goods: potential and policy instruments

Integrating distributional objectives in the cost-benefit analysis of adaptation options

The Use of Non-Monetary Metrics to Assess Adaptation Actions: Multi-Criteria Analysis

The Use of Non-Monetary Metrics to Assess Adaptation Actions: Cost-Effectiveness Analysis

Transferring values between locations in climate change adaptation

Applying alternative discounting rules: the Equivalency Principle

Treatment of uncertainty and risks

Uncertainties and causes of uncertainties in climate change adaptation

Uncertainties and risk analysis in climate change adaptation

Integrated uncertainties and risk management for robust decision making

Methods for expressing risk and ambiguity in economic analysis

Assessing systemic risks in adaptation

Economic project appraisal

Appraisal of adaptation to river flood at the Vltava river, Prague

Appraisal of adaptation to river and coastal flood in Bilbao

Disaster risk management

Assessing flood risk management: The Netherlands

Assessing flood risk management: Czech Republic

Assessing flood risk management: Austria

Assessing flood risk management: United Kingdom

Fiscal consequences of extreme weather risks in Europe

International development support

Prioritisation of adaptation in the development context: Rwanda

Prioritisation of adaptation in the development context: Zanzibar

Policy Impact Assessment

Adaptive management of rural land use systems: the Common Agricultural Policy

Risk attitudes and preferences for adaptation in agriculture

Stochastic modelling for robust decision-making: the Common Agricultural Policy

Macro-economic effects of adaptation

The role of autonomous adaptation in global assessments at global level

Economy-wide implications of planned adaptation: the case of sea level rise

Economy-wide implications of planned adaptation: the case of agriculture

ECONADAPT / THE ECONOMICS OF ADAPTATION

INSIGHTS INTO ECONOMIC ASSESSMENT METHODS

ECONADAPT Toolbox:
econadapt-toolbox.eu

Sources for data on costs and benefits of adaptation
econadapt-toolbox.eu/data-sources

Library of publications related to adaptation economics
econadapt-library.eu

Further policy briefs and Deliverables of the project
econadapt.eu

The FP7 ECONADAPT project was led by the University of Bath and undertaken by the following consortium of European research organisations:

University of Bath
Ecologic
bc3 Basque Centre for Climate Change Klima Aldaketa Ikergai
IIASA
DMI
VU University Amsterdam
PIK Potsdam Institute for Climate Impact Research
UEA University of East Anglia
Agricultural University of Athens
Environment Center Charles University in Prague
Wageningen UR For quality of life
European Commission Joint Research Centre
cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici
Paul Watkiss Associates