Decision Support Methods for Climate Change Adaption

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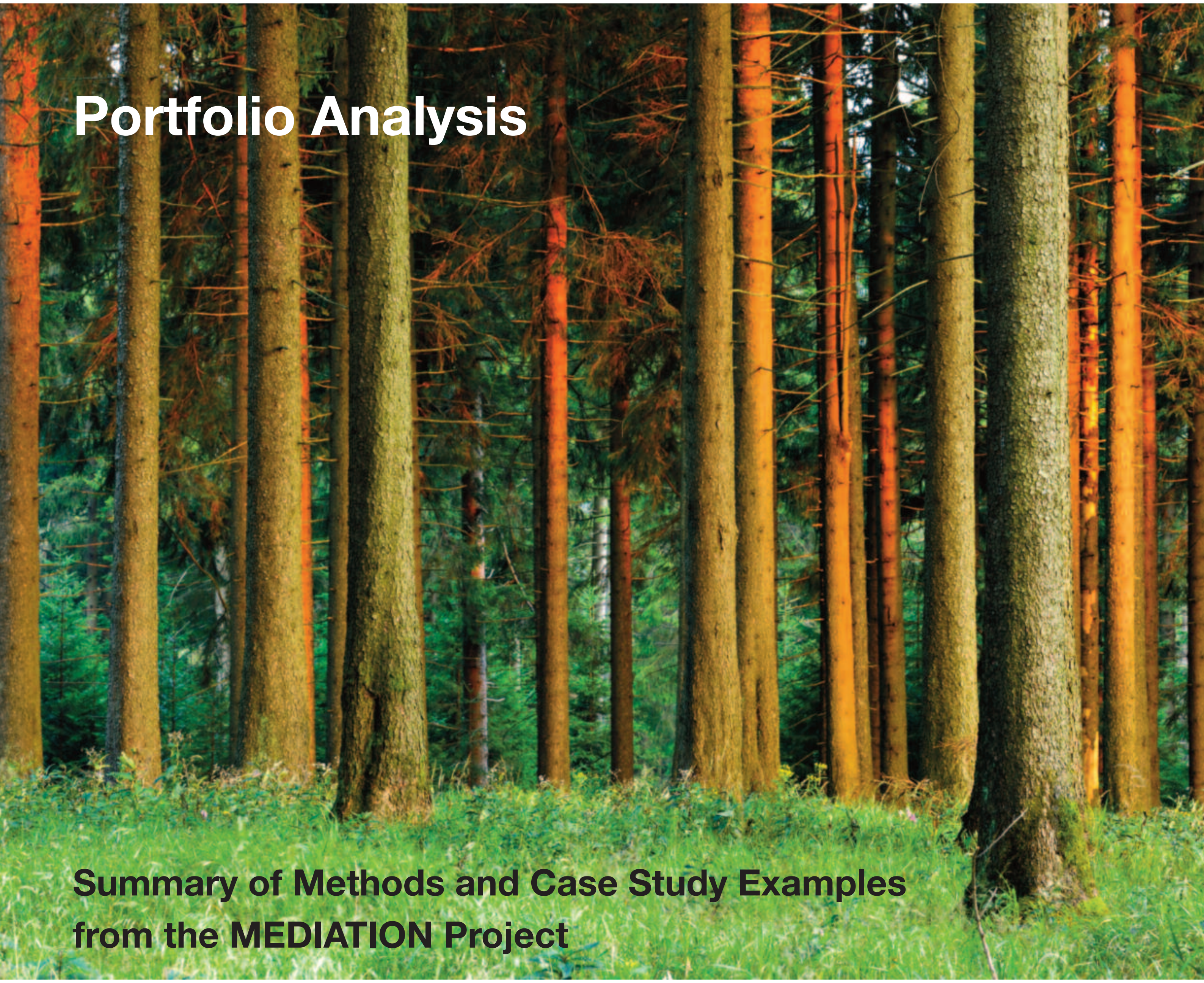


Portfolio Analysis

Summary of Methods and Case Study Examples from the MEDIATION Project

SEVENTH FRAMEWORK PROGRAMME

Mediation

Key Messages

- There is increasing interest in the appraisal of options, as adaptation moves from theory to practice. In response, a number of existing and new decision support tools are being considered, including methods that address uncertainty.
- The FP7 MEDIATION project has undertaken a detailed review of these tools, and has tested them in a series of case studies. It has assessed their applicability for adaptation and analysed how they consider uncertainty. The findings are including on the MEDIATION Adaptation Platform and summarised in a set of policy briefing notes.
- One of the tools recommended for adaptation is **Portfolio Analysis (PA)**.
- PA is a tool that helps in the design and evaluation of portfolios, i.e. in selecting a set of options which (together) are effective over a range of possible future climates, rather than a single option best suited to one possible future.
- The approach allows the identification of efficient portfolios, i.e. those that have the highest possible expected return for a given risk, or the lowest degree of risk for a given rate of return. This then provides the investor or decision maker with a choice of alternative (efficient) portfolios, which they can choose from based on their risk-return preferences.
- The approach has considerable potential for addressing climate change uncertainty, through the use of portfolios of options rather than single solutions. It has a high resonance with the concepts of iterative risk management in its encouragement of diversification (a key part of risk management). The approach can be used within an economic analytical framework and can also assess portfolios in terms of non-monetary (physical) effectiveness.
- The review has considered the strengths and weakness of the approach for adaptation. The main strength of portfolio analysis is that it provides a structured way of addressing (climate change) uncertainty through the identification of suitable combinations of options that – between them – reduce climate impacts over the range of impact uncertainty, expressing the effectiveness of alternative portfolios in quantitative terms.
- This provides a way of managing uncertainty that the analysis of individual adaptation options does not allow. It can also assess benefits in economic or physical terms, allowing application in market and non-market sectors.
- The potential disadvantages are that it is resource intensive, requires a high degree of expert knowledge, and relies on the availability of quantitative data. The approach also requires the use of probabilities, which can prove challenging for the application to climate change. The technique is obviously not relevant when one option addresses the full range of uncertainty in climate impacts.
- Previous applications of PA for adaptation have been reviewed and a number of adaptation case studies are summarised which provide information on practical applications.
- The review and case studies provide useful information on the types of adaptation problem types where PA might be appropriate, as well as data needs, resource requirements and good practice lessons.
- PA is a key tool for helping to identify and analyse alternative portfolios of adaptation options. It has a clear application in cases where adaptation actions are likely to be complementary in reducing climate risks.

Introduction

There is increasing policy interest in the appraisal of options, as adaptation moves from theory to practice. At the same time, it is recognised that the appraisal of climate change adaptation involves a number of major challenges, particularly the consideration of uncertainty in the climate impacts addressed. In response, a number of existing and new decision support tools are being considered for adaptation.

The European Commission FP7 funded MEDIATION project (Methodology for Effective Decision-making on Impacts and AdaptaTION) is looking at adaptation decision support tools, in line with its objectives to advance the analysis of impacts, vulnerability and adaptation, and to promote knowledge sharing through a MEDIATION Adaptation Platform (http://www.mediation-project.eu/platform/). To complement the information on the Platform, a series of Policy Briefing Notes have been produced on *Decision Support Methods for Climate Change Adaptation*.

An overview of all the decision support tools reviewed is provided in *Policy Briefing Note 1: Method Overview*, which summarises each method, discusses the potential relevance for adaptation and provides guidance on their potential applicability. The methods considered include existing appraisal tools (cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis), as well as techniques that more fully address uncertainty (real options analysis, robust decision making, portfolio analysis and iterative risk (adaptive) management). It also includes complementary tools that can assist in adaptation assessment, including analytical hierarchic processes, social network analysis and adaptation turning points. Additional information on each method is presented in a separate *Policy Briefing Notes (2 – 10)*.

This *Policy Brief (Note 5*) provides a summary of **Portfolio Analysis**. It provides a brief synthesis of the approach, its strengths and weaknesses, the relevance for adaptation, how it considers uncertainty, and presents case study examples. It is stressed that this note only provides an overview: more detailed information is available in MEDIATION deliverables, and sources and links on the MEDIATION Adaptation Platform.

Description of the Method

Portfolio Analysis (PA) originated in the financial markets as a way of utilising portfolios of assets to maximise the return on investments, subject to a given level of risk. The principle is that spreading investments over a range of asset types also spreads risks.

Since individual assets are likely to have different and unpredictable rates of return over time, an investor may be better in maximising the expected rate of return and minimising the variance and co-variance of their asset portfolio as a whole, rather than managing assets individually (Markowitz, 1952).

As long as the co-variance of assets is low, then the overall portfolio risk is minimised (for a given rate of overall return). Aggregate returns for an individual investor are therefore likely to be higher when low returns on an individual stock are at least partly offset by higher returns from other stocks during the same period.

PA helps in the design of such portfolios. It highlights the trade-off between the returns on an investment and the riskiness of that investment, measuring risk by estimating the variance (standard deviation) of the portfolio return: thus a portfolio with a relatively high (low) variance is judged to have a higher (lower) risk. The information on returns and risks is used to identify a portfolio that most closely matches (risk) preferences.

The overall concepts of the approach are fairly straightforward, though the actual analysis is quite complex.

An investor first identifies those portfolios that are efficient (from a longer list of all feasible portfolios). The efficient portfolios have the highest possible expected return for a given risk, or the lowest possible degree of risk for a given mean rate of return (Aerts et. al. 2008). The investor is then able to choose a portfolio that best represents their balance of preferences between risks and returns.

A representation of this choice is given below, plotting the expected return against the variance. In this example, the small circles represent portfolios of two technologies combined in varying proportions. The analysis produces an efficiency frontier, which identifies those portfolios which have the highest return for a given level of variance or, equivalently, the lowest variance for a given return. This is the line from portfolios A to C. These represent the key choice for the investor, and reflect a different mix of risk versus return. It also identifies those portfolios that are inefficient and should be avoided, in this case those located to the bottom-right (i.e. D, E and F).

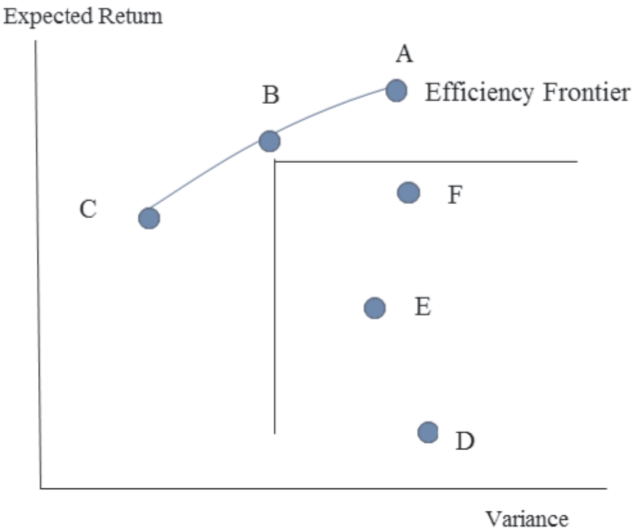


Figure 1. Risk-Return Space and the Efficiency Frontier in Portfolio Analysis

- To derive these values (and figures) a series of analytical steps are taken, set out below.
- First, the objective is established, e.g. to reduce flooding to a 1 in 1000 annual risk.
- The investment possibilities, or adaptation options, are then defined.
- Feasible portfolios are constructed, noting that these may be constrained by the total available budget.
- The returns are defined and measured. These returns can be in economic terms (as in the case of expected values above) but can also be expressed as physical metrics, e.g. the quantity of water conserved.
- The risk is characterised. In portfolio analysis, uncertainty (or more accurately risk) is traditionally characterised in terms of the variance or standard deviation around the mean. This requires probabilities of alternative outcomes since the mean – or expected value – of a distribution is calculated as the sum of all the products of outcomes and their associated probabilities. Probabilities are therefore employed to estimate the Expected NPV (ENPV). The variance of the NPV expresses the risk that the actual (NPV) return will differ from the expected return.
- The expected return of each portfolio is estimated and the efficiency frontier is identified. The risk-return data for each portfolio is estimated by multiplying the ENPV of each asset in the portfolio by the proportion (of cost) of each asset in the portfolio. The risk-return data for each portfolio is combined to create a plot as in Figure 1 above. The efficiency frontier is then defined by the plots of the portfolios whose returns are maximised for a given level of variance.
- The decision-maker defines preferences with respect to returns and risk. The efficiency frontier identifies the optimal risk-return trade-offs that are available to the decision-maker.

The Application to Adaptation

The principles of diversification and the use of portfolios have high relevance for climate change adaptation. PA helps in selecting a set of options which (together) are effective over a range of possible projected future climates, rather than a single option best suited to one possible future.

The approach has a high resonance with iterative risk management and the preference for portfolios of options over single solutions (IPCC SREX, 2012), recognising that diversification is an important risk management response. Importantly, it can be used to compare alternative portfolios of options against the high uncertainty associated with future socio-economic and emission scenarios, and across alternative climate model projections.

The use of portfolio theory in the adaptation context requires identification of a range of possible adaptation options, data on the average effectiveness (or expected return) of each option, the variance of each option over the range of climate scenarios, and the covariance of return of each option over the range of climate scenarios. A minimum level of effectiveness also needs to be defined.

In the climate change context, the trade-off is then between the possibility of a high degree of effectiveness in reducing climate risks, and the risk that the adaptation options will fail to be effective over a certain range of climate change.

The choice that is made will then be determined by the level of risk aversion. As in Figure 1 above, a more risk-averse decision-maker is likely to choose a portfolio located between B and C, whilst a more risk-loving decision-maker is likely to choose a portfolio located between A and B.

Strengths and Weaknesses

A key part of the MEDIATION project has been to identify the strengths and weaknesses of the different approaches for adaptation. A summary is presented below.

The main strength of portfolio analysis is that it provides a structured way of addressing (climate change) uncertainty through the identification of suitable combinations of options, expressing the effectiveness of alternative portfolios, and the risk associated with each, in quantitative terms.

This provides a technique for managing the uncertainty from climate change that the analysis of individual adaptation options does not allow.

A major advantage of the approach is it can work with different metrics for returns, assessing benefits in economic terms, or with the analysis of non-monetary (physical) effectiveness. This allows applications in market sectors but also non-market sectors such as biodiversity and ecosystem services.

The use of the efficiency frontier is an effective way of presenting (and visualising) alternative portfolio options, and the trade-offs between risk and reward involved in alternative choices.

The main disadvantage is that the technique is resource intensive, and requires a relatively high degree of expert knowledge and judgement. It relies primarily on the availability of data on effectiveness (return) and variance / co-variance. In the formal application, it requires probabilities (or other assumptions, such as scenario likelihood equivalence).

Case Studies

The MEDIATION study has reviewed examples in the existing literature that have applied Portfolio Analysis to the adaptation context, though a relatively small number of such applications currently exist.

A number of the recent case studies applications to adaptation are summarised in the box over the page.

Key strengths

Provides a structured way of quantifying portfolios of options to address climate change uncertainty, which analysis of individual adaptation options does not allow.

Measures “returns” using various metrics, including physical effectiveness or economic efficiency, thus broad applicability in market and non-market sectors.

Use of the efficiency frontier is an effective way of visualising results and the risk-return trade-offs.

Potential weaknesses

Resource intensive and requires a high degree of expert knowledge.

Relies on the availability of quantitative data (for effectiveness and variance/co-variance).

Requires probabilistic climate information to be imposed, or an assumption of likelihood equivalence between alternative scenarios.

Case Study 1: Forest Regeneration

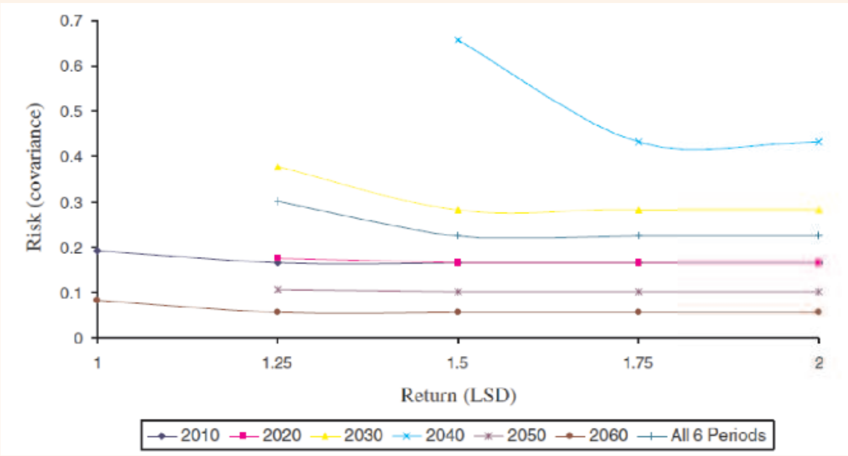
Crowe and Parker (2008) provide an empirical case study of the approach for forest regeneration. The objective of the study was to apply and test the portfolio analysis method for selecting genetic material that could be used for the restoration or regeneration of forests under climate change futures, taking account of the wide range of uncertainty. Data were used to estimate how well different seed populations of White Spruce grew under different climatic conditions. This data, combined with regional climate data under alternative, modelled climate scenarios, allowed a statistical Species-Range Impact Model (SRIM) to estimate how well each population – or seed source – would be adapted to a specific site (under alternative climate futures).

For each seed source, the SRIM estimated the distance over which a seed source was adaptive from any given location, for a given climate future. The estimates of adaptive distances were then utilised in the model to identify the optimal set of seed populations to use in restoring a specific site – optimality being defined as minimising the risk of maladaptation whilst achieving a certain threshold or level of adaptive suitability (the latter defined as the expected adaptive distance of the portfolio). The seed portfolio model aimed to minimise the expected variance and covariance of the adaptive suitability of a portfolio of seed sources subject to a lower bound on the total expected adaptive distance. The weighting of each seed source option within a portfolio was given by the proportion of a portfolio made up by each source, with a minimum proportion specified to avoid the large numbers of sources for regeneration in a given location. A further constraint was introduced for biological thresholds, beyond which species cannot survive. This constraint serves to limit the size of the variance.

A total of 127 white spruce seed sources in Canada were modelled at 6 future time intervals from 2010 to 2060, using temperature and precipitation outputs from five climate scenarios from three climate models. Each scenario was assumed to have an equal probability of occurring. The mean adaptive distances (the number of least significant differences between a baseline reference point and a future point) were estimated for several hundred geographical locations. The portfolio model was run for the six time periods, plus all dates combined.

The study found that current locations of seed populations were poor predictors of optimal future locations, confirming the case for adaptation and for adoption of a broad portfolio of seed sources. Conversely, the best matching seed sources differ drastically according to year and time period;

The efficiency frontier showed that there were only two unique solutions in each time period, and beyond a certain point risk was not reduced as lower returns were specified. The use of the portfolio approach resulted in covariance being minimised across scenarios, such that the optimality of the seed sources varied according to the scenario, suggesting that the approach is successful in producing an outcome robust to climate change uncertainties. The optimal approach was considered to be a range of specialist seed sources.



Time specific efficiency frontiers

(note risk is plotted on the y axis). Source: Crowe and Parker (2008)

Case Study 2: Flood Management

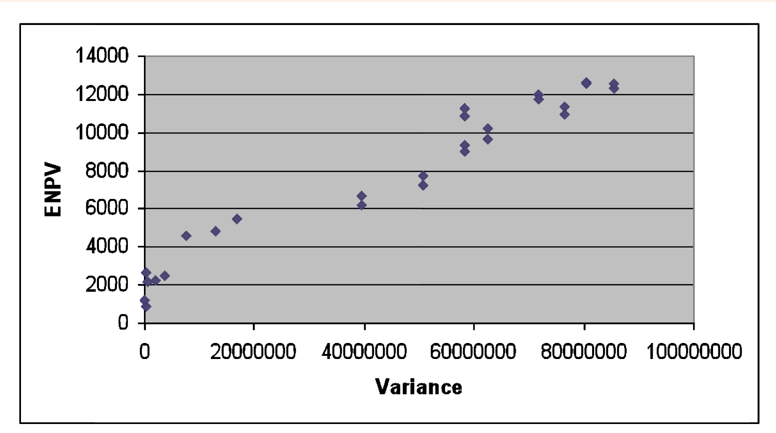
Hunt (2009) applied portfolio analysis to a case of flood management at the local geographical scale, for the River Severn in Shrewsbury in the UK. The application considered climate change and socio-economic change over future decades through to 2050 and changes in flood event frequencies and return periods (up to the 150 year return event).

The application built upon existing decision-support tools used in the UK – primarily cost-benefit analysis – that rely on the monetisation of flood impacts (and the economic benefits of flood protection) to assess investment in flood management. Three alternative and contrasting flood management measures were considered for the portfolio analysis: Hard Defences; Flood Warning Systems, and Property Level Resistance. These were considered against the range of climate and socio-economic uncertainty through to 2050.

Flood event frequencies were analysed and the portfolio returns were measured by the economic efficiency (net present values (NPV), i.e. benefits minus costs in monetary terms) of the flood management options. Benefits included damage avoided to residential and business property, cars and infrastructure, as well as health impacts avoided. The costs were derived from the capital and operating/maintenance costs of each option.

The figure below shows the results of a 2-option portfolio analysis. Each point in the figure represents an individual portfolio comprising of two adaptation options. The figure shows a clear, positive, relationship between return and variance, reflecting the fact that whilst the expected net present value will be higher with the inclusion of some options (e.g. Hard Defence), there is a trade-off with a higher uncertainty of return.

The figure also highlights that there are a number of portfolios that are sub-optimal (i.e. those plotted in the south-east quadrant relative to another portfolio).



Two-option Portfolio Analysis: Flood Management:
Assuming independence of options. Source Hunt (2009).

The results above assumed that individual options are independent of each other. However, the implementation of one option may affect the effectiveness (i.e. the benefits) of others. As an example, the implementation of a hard defence system is likely to reduce the subsequent flood risk to properties and so reduce the (economic) benefits from property-based measures or warning systems.

When option interdependence was included in the analysis, the return-variance trade-off could still be identified, but the relationship was not as strong as illustrated above.

Discussion and Applicability

The review and case studies provide a number of practical lessons on the application of Portfolio Analysis to adaptation. They provide useful information on the types of adaptation problem types where the technique might be appropriate, as well as data needs, resource requirements and good practice examples.

Clearly PA is a key tool for helping to identify and analyse alternative portfolios of adaptation options. It has a clear application in cases where adaptation actions are likely to be complementary in reducing climate risks. The technique is not relevant when one option addresses the full range of uncertainty in climate impacts.

Portfolio Analysis has a high resonance with the concepts of iterative risk management, and addresses uncertainty by encouraging diversification (a key part of risk management) with the use of portfolio mixes. It can be used for economic analysis, but can also work with non-monetary (physical) metrics and therefore can be applied in non-market sectors, such as for ecosystem based adaptation (as in the forest case study in the box).

However, the approach 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.

Furthermore, 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.

The formal application is data and resource intensive, requiring a high degree of expert knowledge, which is also a factor in considering applicability.

Finally, in considering the application of portfolio analysis to adaptation, a number of good practice lessons are highlighted. As identified in the second case study on flood risks, there can be issues of inter-dependence between options, and it is therefore good practice to take these into account within the PA analysis.

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Further Reading and Reference Sources

MEDIATION Policy Briefing Note 1: Method Overview.

Further information

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To find out more about the MEDIATION project, please visit:
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