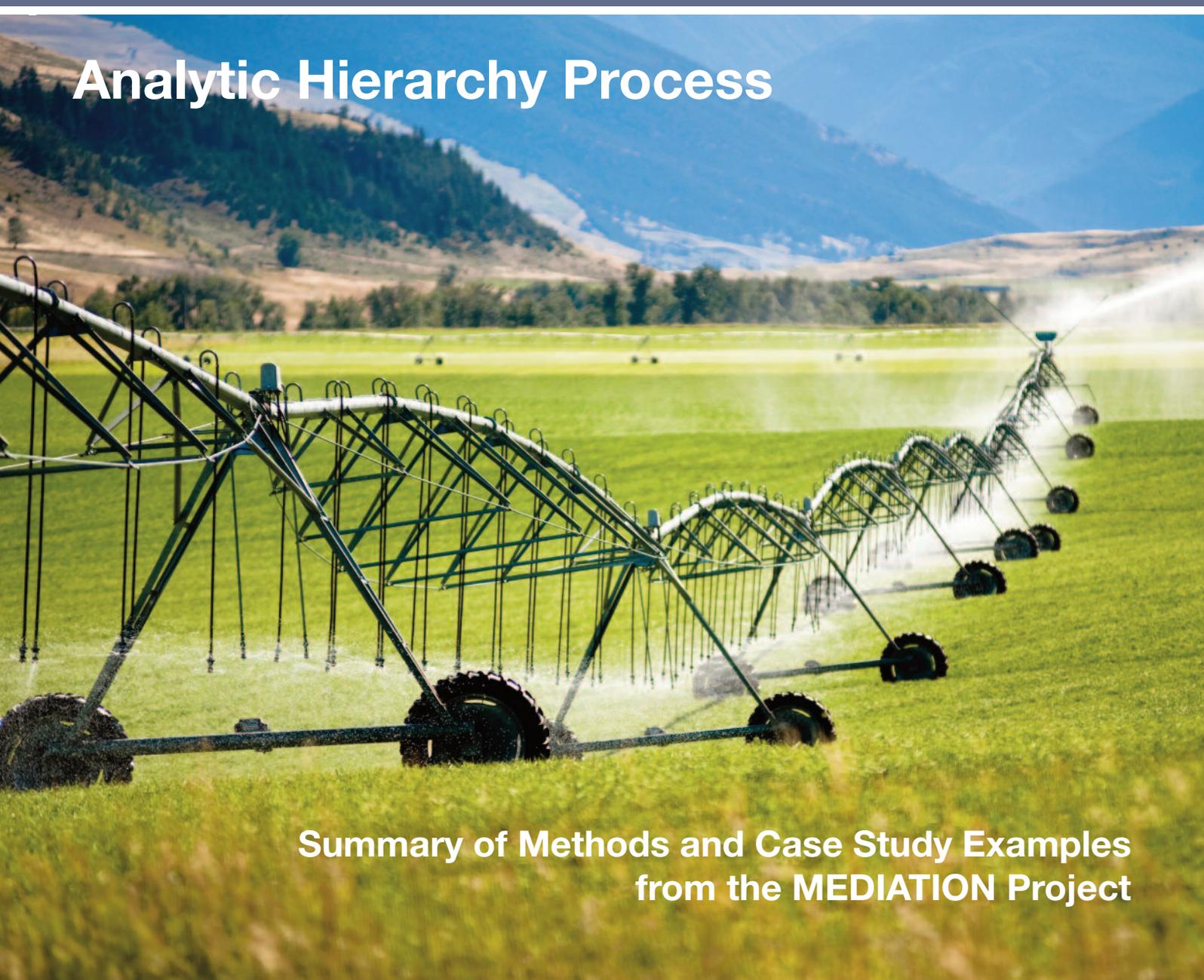


Decision Support Methods for Climate Change Adaption

7

Analytic Hierarchy Process



Summary of Methods and Case Study Examples
from the MEDIATION Project

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 have been used to provide information and guidance for the MEDIATION Adaptation Platform and are summarised in a set of technical policy briefing notes.
- One method that is potentially useful for adaptation is the Analytic Hierarchy Process (AHP).
- AHP is a form of multi-criteria analysis that undertakes pairwise comparisons using expert judgements to derive priority scales. The method helps to consider tangible and intangible elements together, allowing these to be traded off against each other in a decision-making process.
- The method is applied by making comparisons using a scale of absolute judgements that represents how much one element dominates another for a given attribute. The derived priority scales are then synthesised and the various weighted scores are aggregated.
- The approach has high relevance for adaptation as it can evaluate options in situations of high complexity, considering different time horizons, uncertainty and multiple and interdependent variables requiring multi-dimensional trade-offs.
- The review has considered the strengths and weakness of the approach for adaptation. The main strength is the ability to directly compare tangible and intangible elements, taking into account the opinions and preferences of a wide range of people in the analysis of complex problems. It also provides a simple ranking that is easy to communicate.
- The potential weaknesses relate to the increased complexity of application and time taken to apply the approach if many criteria, sub-criteria and options are considered, and the somewhat subjective nature of the approach.
- Previous applications of AHP for adaptation have been reviewed, and Mediation case study applications of the tool are summarised.
- The review and case studies provide useful information on the types of adaptation problem types where AHP might be appropriate, as well as data needs, resource requirements and good practice lessons.

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 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 an 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 analytic hierarchy process, 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 7) provides a summary of the **Analytic Hierarchy Process (AHP)**. 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 Adaptation Platform.

Description of the Method

Analytic Hierarchy Process (AHP) is a form of multi-criteria analysis (see Policy Briefing Note 6) that is used to analyse complex decisions where multiple perspectives need to be considered. It was developed by Saaty (1980) to help decision-makers find the option that best suits their goal and understanding of the ‘problem’, while taking into consideration factors that cannot be quantified.

AHP is very flexible and can be adapted to different needs and contexts. Criteria (or attributes) and sub-criteria can be decided in advance by the expert or through a participatory process with stakeholders to increase transparency, dialogue and ownership of the process and outcome. There is no upper limit to the number of criteria or sub-criteria, except for the time that is required to do the comparison.

Criteria can be both tangible and intangible and defining them can involve as many participants as required. The number of alternatives to evaluate can also vary, though they should be as mutually exclusive as possible. The types of decision situations in which the AHP can be applied include *choices*, *ranking*, *prioritisation*, *resource allocation* and *conflict resolution* and clearly these have relevance in many areas of climate adaptation.

A series of steps are involved in undertaking the method (Saaty, 1980: 2005: 2008):

1. Define the ‘problem’ or adaptation challenge, i.e. the need and purpose of the decision (goal), listing the alternatives to evaluate (e.g. adaptation options), setting-up the criteria and sub-criteria (attributes) by which to evaluate the alternatives (or adaptation options) and identifying the stakeholders and groups to involve in the process.
2. Structure the issue, including the decision hierarchy, and identify the top-level criteria, the intermediate criteria, and the set of options.
3. Undertake the pairwise comparison. This compares the elements to one another, two at a time, with respect to their impact/ importance on an element above them in the hierarchy. This

| The AHP Scale for Comparison | | |
|------------------------------|------------------------------------|---|
| Values | Relative importance | Explanation |
| 1 | Equal importance | Two elements contribute equally |
| 3 | Moderately more important/better | Experience and judgment moderately favour one element over another |
| 5 | Definitively more important/better | Experience and judgment strongly favour one element over another |
| 7 | Much more important/better | One element if highly favoured, its dominance is demonstrated in practice |
| 9 | Extremely more important | All evidence favours one element over another |

uses numerical values (e.g. as in the scale below) to conduct the pairwise comparisons, constructing a set of pairwise comparison matrices. Several matrices are produced to compare the alternatives (e.g. adaptation options) with respect to each criteria, and the criteria with respect to the goal.

4. Calculate relative priorities. This can be done using a spreadsheet, or software, such as ExpertChoice.¹ The values in Step 3 are processed to obtain numerical priorities or weights for the criteria and alternatives. Depending on the problem at hand, a priority or weight can refer to importance, preference or likelihood.

5. Aggregate priorities. The final step is to aggregate relative priorities to produce overall priorities (final evaluation metrics) which sum to 1.0.

The Application to Adaptation

AHP has been used in a wide variety of fields including engineering, business strategic management, education and quality assessment. The approach has high relevance for the analysis of climate adaptation related decisions, given it is useful where a range of stakeholders are dealing with issues that have a high degree of complexity, that involve uncertainty and risk, and include subjectivity, i.e. human perceptions and judgments. It is also potentially useful when the outcomes have possible long-term consequences (Bhushan, 2004).

The tool has a particular relevance where important elements of the decision are difficult to quantify or compare, or where different expertise, goals, and world-views are a barrier to

consensus-building and communication.

In the context of climate adaptation, the method can be used to compare a set of adaptation options against a set of defined criteria using participants' experience and judgment about the issues of concern. It allows the comparison of diverse elements that are often difficult to measure in a structured and systematic way using a scale. This makes it particularly relevant for sectors or key criteria where quantification is challenging.

The first applications of the approach to climate change were in the context of the global negotiations on climate change (Ramanathan, 1998) and later in mitigation policy instruments (Konidari and Mavrakis, 2007). AHP is now increasingly being applied in the area of climate change adaptation. It was applied using a participatory approach for the integration of indigenous knowledge within adaptation strategies in the Tabasco Plains of Mexico (Ponce-Hernandez and Patel, *forthcoming*), in the evaluation of adaptation options for human settlements in South East Queensland (Choy et al., 2012), in the integration of GIS modelling to look at crop impacts in Australia (Sposito, 2006) and to explore the impacts of storm surge and sea level rise in Canada and Caribbean (Lane and Watson, 2010). Yin et al (2008) applied AHP to evaluate adaptation options for the water sector in the Heihe River Basin in north-western China, resulting in a higher preference for institutional options for managing water demand (imposing constraints on large consumers, water conservation initiatives through water user associations, and transferrable water allocation permits), rather than 'hard' engineering options for increasing water supply.

¹ <http://expertchoice.com/>

The AHP method can evaluate adaptation options against a range of different criteria in the context of an overarching climate adaptation goal by comparing them to one another, two at a time (pairwise comparison). These comparisons are made using a scale that represents how much more one element is preferential to another given the criteria and options chosen are as mutually exclusive as possible.

Strengths and Weaknesses

A key part of the MEDIATION project has been to identify the strengths and weaknesses of different approaches. A summary of some of the strengths and weakness is outlined below.

The main strength of AHP is the ability to directly compare tangible and intangible elements, taking into account the opinions and preferences of a wide range of people in the analysis of complex problems. This allows it to be used in contexts in which other decision tools cannot be used. The approach also provides results in a simple

ranking that is easy to communicate. As well as the application in areas where quantification or valuation is difficult, it can also compare options against qualitative criteria, even in areas which are not directly comparable using conventional decision support techniques.

The potential weaknesses relate to the increased complexity of application and time taken to apply the approach if many criteria, sub-criteria and options are considered, and the somewhat subjective nature of the results (although an inconsistency index can be calculated. The use of software can also conceal conflicting value judgments.

Case Studies

The MEDIATION study has reviewed existing literature examples that have applied AHP to adaptation. The project has also undertaken two case study applications, summarised in the boxes below

Key strengths

- Can be applied to complex problems where decision elements are difficult to quantify or not directly comparable.
- Relatively simple approach and produces simple rankings that are easy to communicate.
- Does not require information on economic benefits and monetary valuation, and so it is applicable to areas that are difficult to value (e.g. ecosystems), difficult to quantify (e.g. equity) or that are contentious.
- Can accommodate a wide range of disciplines, opinions and groups of people who do not normally interact.

Potential weaknesses

- Results change as new options / alternatives are considered in the analysis.
- Becomes complicated if many criteria and options are considered. Some criteria are not independent so this can bias or complicate the way in which they are assessed.
- Subjective scale can lead to biases and it is subject to human error.
- The use of software can conceal conflicting value judgments.
- Linked to the previous point, trans-disciplinary capacity building can be undermined at the cost of the expediency (Cartwright et al., 2012)

Case Study 1 – Adaptation options for agriculture in the Guadiana River Basin, Spain

The first case study was focused on the Guadiana river basin in south-central Spain, with an application of AHP to adaptation in the agricultural and water sectors. This basin is expected to be one of the most seriously affected by climate change in Spain, with potentially high impacts on irrigated agriculture. The case study began by specifying the adaptation strategies being considered by policy-makers at the national and regional level, representing the starting point for a stakeholder-driven appraisal and prioritization of potential options.

Options and criteria

The Government of Extremadura initiated its Climate Change Strategy in 2009, which included a Climate Change Adaptation Plan for the Agricultural Sector (Junta de Extremadura, 2011). This aimed to identify the main impacts on the sector and define adaptation measures to guarantee its viability, minimizing the negative consequences of climate change as well as maximizing potential new opportunities.

The Plan contained seven programmes to tackle adaptation to climate change for the agricultural sector in Extremadura: *Increasing Water Availability; Management and Planning of New Crops; Reduction of Vulnerability against Extreme Climate Conditions; Plant Health; Research and Development; Training and Information for farmers; and Leveraging positive impacts*. Drawing from these programmes and the specific measures they included, the AHP aimed to prioritize adaptation options in the Guadiana River Basin. Four options were identified according to their feasibility and their relevance for the area under study, and a range of criterion were chosen. These are summarised in the hierarchy tree in Figure 1.

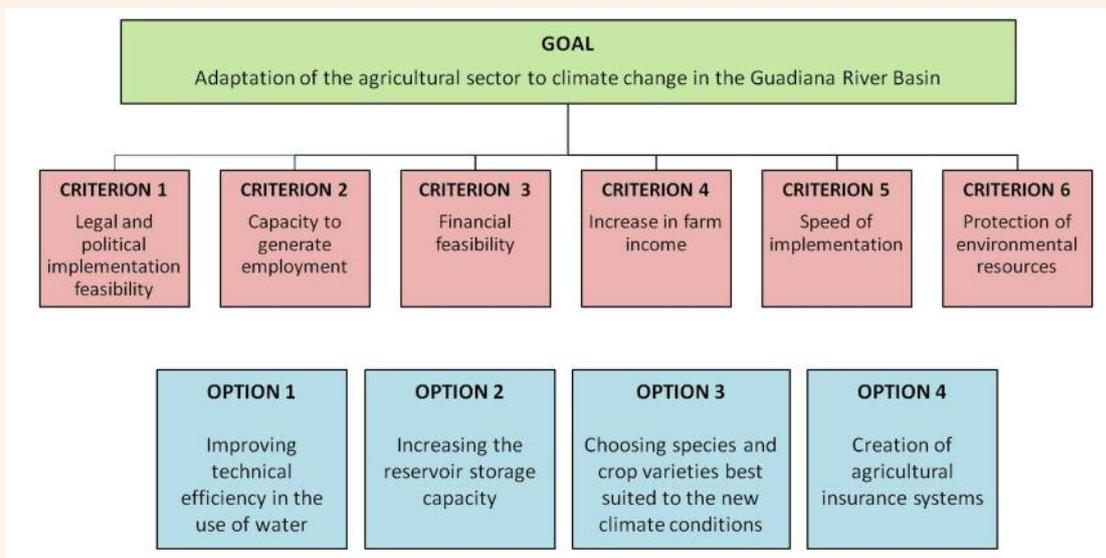


Figure 1. AHP hierarchy for agricultural adaptation options.

The next step was to carry out a pairwise comparison, comparing individual elements to one another, with respect to their impact or importance on an element above them in the hierarchy. Firstly, participants were asked to compare the relative preference for each of the measures with every criterion. For example, for the first criterion, feasibility of legal and political implementation (of the chosen measure), participants compared one option against another in relation to the ability of each option to be designed, supported and implemented from a legal and political standpoint. This exercise was repeated with each of the six criteria. Secondly, participants were asked to assess the relative importance of each of the criteria with respect to the achievement of the goal. i.e. they compared the relative importance of each criteria for the adaptation of the agricultural sector to climate change in the Guadiana River Basin. Answers were processed using the decision-making software Expert Choice. The results are shown below in Figure 2.

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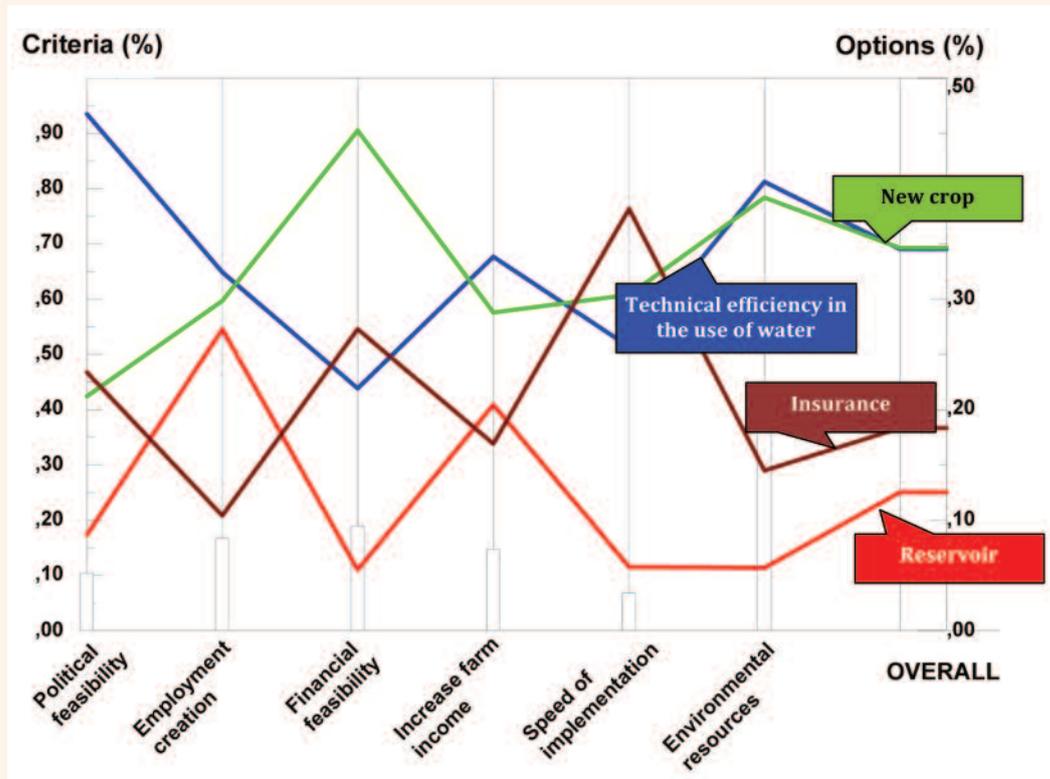


Figure 2. Aggregate results from the AHP exercise for adaptation options.

The aggregated results show that the options **Choice of new crop varieties best suited to new climate conditions** and **Improving technical efficiency in the use of water** were equal first position in the ranking. **Creation of agricultural insurance systems** ranks third and finally **Increase reservoir storage capacity** ranks fourth. **Choice of new crop varieties best suited to new climate conditions** and **Improving technical efficiency in the use of water** performed well under all selected criteria, ranking first except for financial feasibility and speed of implementation, whereas **Creation of agricultural insurance systems** ranked first due to its lower cost and ease of implementation. The **Increase reservoir storage capacity** option was ranked low in aggregate terms and was highly controversial and criticized by most respondents, who made reference to the high cost and large environmental impact of this option.

When analysing the criteria, the protection of environmental resources was the most influential criterion at the aggregate level with a weight of 35.4%, followed by financial feasibility and capacity to generate employment. The protection of environmental resources was the dominant overall criterion given support by all respondent groups, even farmers. Similarly financial feasibility was highly ranked by most groups, especially policymakers.

The AHP analysis showed that at an aggregate level, options related to private farming (new crops and irrigation efficiency) ranked highest, public-funded ‘hard’ measures (reservoirs) ranked lowest, and public ‘soft’ measures (insurance) fell in the middle. Environmental criteria were preferred to socio-economic and technical criteria. There were, however, differences in the ranking between groups. Whilst environmental organisations and academics ranked climate change options similarly to the average aggregate, policy makers preferred ‘soft’ measures (insurance) and discarded large irrigation infrastructures (probably due to financial, political and environmental constraints). Farmers’ priorities were technically-oriented, giving the highest ranking to the construction of water storage infrastructure.

Case Study 2: Adaptation Options for Viticulture in Tuscany, Italy

Wine production is one of the most important, traditional economic activities for Tuscan farmers, and viticulture shapes the Tuscan hills unique landscape, which has high tourism benefits (Trombi et al. 2011). Recent wine production has moved to high-quality production, with lower yield, less chemicals and increased value, and there is an increasing number of agri-tourism farms (Trombi and Bindi, 2008). However, climate change will increase temperatures, and is considered likely to decrease precipitation and increase variability (Moriondo et al., 2011). These changes have the potential to lower yields and increase the variability of production and quality of wine (Bernetti et al., 2012; Moriondo et al. 2013). Whilst there are many potential adaptation options for preserving the quality and quantity of production, further analysis and appraisal is required to identify which options can successfully be applied to the particular context of Tuscan viticulture.

Appraising options

The **goal** of this AHP exercise was to identify “*the best adaptation measure for Tuscan viticulture in a climate change scenario*”. The analysis identified the following three adaptation **options**:

- **Selection**: set up a genetic selection program in order to make the current cultivated varieties more suitable for projected climate conditions. This option was chosen based on expert judgment, and because it could help in the analysis of the preferences expressed;
- **Relocation**: relocation of the vineyards towards higher elevations, to reduce the impact of changes in temperature and keep cultivation in conditions similar to the present; and
- **Switch**: switch to other, southern varieties, more suitable for the warmer and drier conditions projected for the region.

The “Selection” option was chosen on the basis of expert judgment, while the other two (“Relocation” and “Switch”) were chosen on the basis of a previous study (Moriondo et al., 2011).

Four **criteria** were used in the AHP exercise: Economical Profitability and Cost, Technical Feasibility, Social-Institutional Acceptability and Flexibility of the Measure. The selection of the criteria was based on expert judgment. The hierarchy is shown in the Figure below.

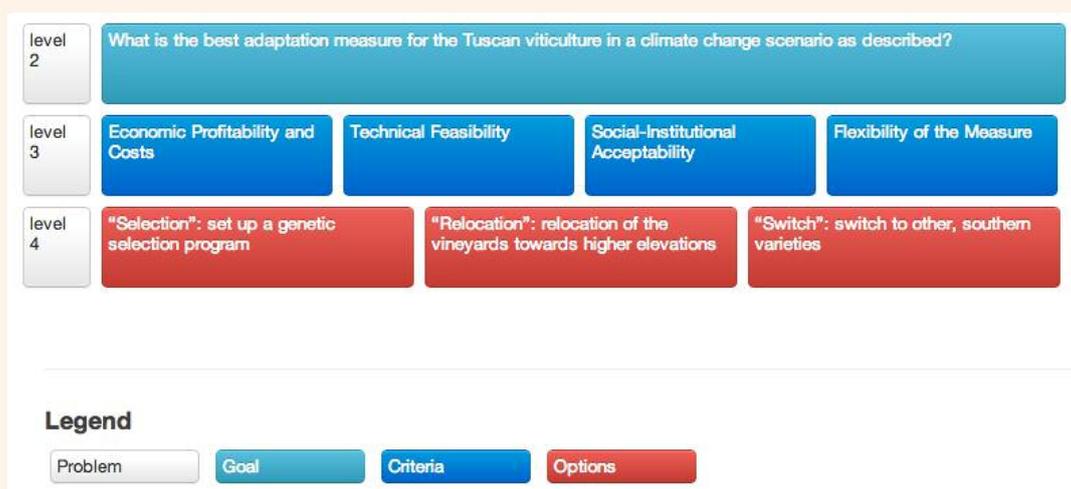


Figure 3. Hierarchy of the AHP exercise in the online tool.

A range of local stakeholders were selected and participated in the AHP exercise including technicians, landscape architects, representatives from the scientific community, producers’ associations/extension services, agriculture, an environmental association and a politician/administrator. A web-based application² was developed to allow the remote participation of the stakeholders and to increase the probability of a higher number of participants. The software reproduced the steps of the AHP method,

with an animated help function to facilitate the user during the process.

Results

The stakeholders chose the **Selection** option as the best adaptation measure for Tuscan viticulture (0.603) by some margin, followed by **Relocation** (0.200) and then by the **Switch** (0.197) option (Table 1).

Economic profitability and costs was ranked as the most important criterion by the stakeholders, at 0.470 (Table 2) and performed well against all the other criteria (Table 3). Technical feasibility was ranked as the second most important criterion (0.262), and performed well against the Social-Institutional acceptability criterion (3.492), and slightly better than Flexibility (1.578). The Flexibility of the measure was ranked third (0.141) and was considered only slightly more important than the Social-Institutional acceptability, which was ranked as the least important criterion (0.127) in the decision process.

Table 1. Stakeholders' prioritisation of the adaptation options

| Option | Priority |
|------------|----------|
| Selection | 0.603 |
| Relocation | 0.200 |
| Switch | 0.197 |

Table 2. Stakeholders' prioritisation of the criteria.

| Criterion | Priority |
|---|----------|
| Economic profitability and costs | 0.470 |
| Technical feasibility | 0.262 |
| Flexibility | 0.141 |
| Social-institutional acceptability | 0.127 |

Table 4 shows the performance of each option against the others, under all the criteria: e.g. the **Selection** option performed quite well under all criteria compared to both other options. i.e. the **Selection** option was considered from moderately to definitively better/more important than **Relocation**, in particular, with respect to Flexibility, Social-institutional acceptability, and Technical feasibility (first data row of Table 4). The **Selection** option showed a similar performance with respect to the **Switch** option. The **Relocation** option ranked slightly better than the **Switch** option (second data row of Table 4). However, the **Switch** option, was chosen once by stakeholders, when compared with **Relocation**, due to its slightly better Technical feasibility (red cell in third data row of Table 4). The results reveal that the most preferred option is **Selection**, which allows current cultivated varieties to continue and the preservation of tradition, quality and brand. It is also perceived as profitable, flexible, easy to implement and would probably incur less resistance from society than the other options.

Table 3. Criteria performance

| | ECO | FLX | SOC | TEC |
|-----|-------|-------|-------|-------|
| ECO | - | 2.917 | 3.016 | 2.749 |
| FLX | 0.343 | - | 0.922 | 0.634 |
| SOC | 0.332 | 1.085 | - | 0.286 |
| TEC | 0.364 | 1.578 | 3.492 | - |

Table 4. Options performance for each criterion

| | ECO | FLX | SOC | TEC |
|-------------------|-------|-------|-------|-------|
| Relocation | | | | |
| Selection | 2.816 | 3.857 | 3.857 | 3.762 |
| Switch | | | | |
| Selection | 3.068 | 1.943 | 3.286 | 2.886 |
| Switch | | | | |
| Relocation | 1.335 | 1.238 | 1.057 | 0.712 |

The exercise allowed different stakeholders – who often do not often communicate with each other – to interact, and to produce a final, coherent and quantitative result, highlighting priorities for further research.

² For more information about the web-based AHP application, please contact Giacomo Trombi (giacomo.trombi@unifi.it).

Discussion and Applicability

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

The approach is considered particularly applicable when assessing both quantitative and qualitative criteria, even those which are not directly comparable using conventional decision support techniques. While promising, it is necessary to understand the limitations of the approach e.g. the evaluation and analysis can become more complicated the higher the number of options and criteria / sub-criteria that are included. However, the ability to compare tangibles and intangibles and incorporate a range of preferences from different actors is highly relevant where differing decision lifetimes, time horizons, scales and uncertainty are important considerations.

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Further information

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To find out more about the MEDIATION project, please visit:
<http://mediation-project.eu/>

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