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Four Essays On Decision Support For Climate Change Adaptation

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Contents

All'ingegnere caccia leoni (anziani) e all'agronomo di San Giobbe

Introduction

Sustainable development is a long-term process. Many investment and policy decisions have long-term consequences. Infrastructure like power plants, roads, and dams often last for decades and need to be useful throughout their lifetimes. Policies such as rural development plans, risk management strategies, and building codes and standards can influence development for equally long. Both investment and policy decisions then will shape and be shaped by the future (Bleakley and Lin, 2010, Gusdorf et al., 2008).

Therefore, to make robust plans we must consider the performance of our investments and decisions in the near and long term. A robust plan is a plan that performs acceptably well, no matter what the future brings.

Limited inclusion of stakeholders, disagreement among decision makers, and deep uncertainties[1] about the long-term future, such as climate change, pose formidable challenges to decision making for sustainable development. Throughout my diverse field experiences, I have seen these challenges lead to gridlock and to arbitrary decisions, lead to enormous losses, and derail development efforts.

Quantitative analysis is often indispensable for making robust policy choices for development. However, sustainable development is a political, rather than a purely technical process (Kersten et al., 2000). The communities need to determine sustainable development goals and the choice of planning options. Therefore, tools and technology can assist decision-makers, but cannot substitute for the decision making process. The type of models to be used depends on understanding the process of formulating and implementing these policies and plans. The tools must be useful to a specific purpose.

This thesis focuses on how we can make sound investments to promote sustainable development, despite these challenges. This objective is to develop and pilot methods of decision making that help identify robust investment decisions.

There exists plenty of decision-making methodologies, from simple heuristics to more sophisticated methods (Hallegatte et al., 2012). A wide array of authors recognise their value in supporting decisions(Althuizen et al., 2012, Holsapple, 2008). And yet, while the toolbox of participatory methodologies and decision support systems for sustainable development has grown rapidly, few have been adopted in practice. Even the exchange of experiences amongst projects with similar objectives is very limited (Giupponi and Sgobbi, 2013). There are several technical and institutional reasons for this limited adoption, which we will not discuss here. However, an important factor is that decision makers often do not know what tools are

[1]Deep uncertainty occurs when the parties to a decision do not know - or do not agree on - the likelihood of future events, the best model for relating actions to outcomes, or the value of potential outcomes (Lempert et al., 2003)

available to improve their planning capacity, or are not motivated to use them (Bonzanigo and Kalra, 2014).

The following questions then remain:

- Can our tools facilitate sound planning amid political constraints and priorities and deep uncertainties about the future?
- Can we motivate and equip analysts and decision makers to better manage the decision process for sustainable development?

My thesis seeks to answer these questions and support real-world climate change adaptation planning by combining:

- Decision support tools and modeling to facilitate evidence-based consensus,
- Participatory processes to ensure representativeness, and
- Innovative analytical tools to manage uncertainty.

I use these methods individually and in combination to develop and apply four decision processes for climate change adaptation and sustainable development. Each decision process occurs in a specific decision context: one municipal, two regional, and one national decisions. In this thesis, the decision problems focus on long term (sustainable) development of specific areas, with consideration of potential climate change impacts.

In this thesis, climate change adaptation and sustainable development are highly interlinked. The link between climate change and sustainable development stems from the fact that climate change is a constraint to development, and sustainable development is a key to capacities for mitigation and adaptation (Osman-Elasha, 2009). It follows that strategies for dealing with sustainable development and climate change have many common elements so that applying them together creates synergies. I believe that this is the case for both developed and developing countries.

The Decision Framework: NetSyMoD

The 4 decision processes described in this thesis follow (and reinterpret) the steps of a state-of-the-art decision frameworks, the NetSyMoD approach (Network Analysis - Creative System Modelling - Decision Support) (Figure 1). NetSyMoD provides a flexible, comprehensive, and operational decision support framework for facilitating participatory decision making processes in various fields related to the environment, including climate change adaptation (Giupponi, 2014, Giupponi et al., 2006).

Within NetSyMoD, "decision" includes any process in which a choice has to be made by examining the available information on a given problem. Typically, the choice consists in the selection of the preferred alternative within a given set of option. The process begins with stakeholders working together to define their objectives, the options, and the information available. These participants to a decision next engage with experts to generate and interpret decision-relevant information. Decision makers then revisit choices and objectives based on this information. The proposed approach is aimed in particular at facilitating the integration of environmental, social, and economic concerns into planning, via quantitative explorations

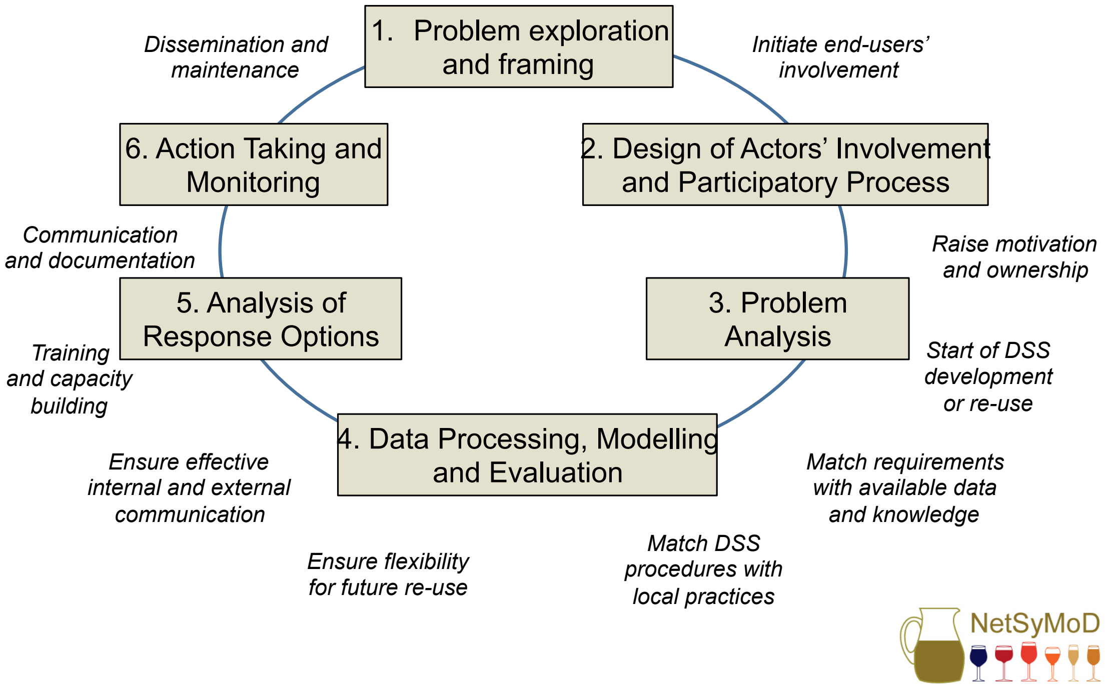

FIGURE 1: The NetSyMod Framework, (Giupponi, 2014)

of the problem at stake. Moreover, it is designed to facilitate the involvement of interested parties in the formulation of strategies and decisions (Giupponi et al., 2006).

A generic decision making process is formalised in NetSyMoD as a sequence of six main phases (Figure 1):

1. *Problem exploration and framing.* This step concerns problem exploration and the setup of the decision process and specific objectives. It is carried out jointly by analysts and decision makers. It answers the question "What is the overall problem to address?"

2. *Design of actors' involvement and participatory activities.* This step answers the question "Who are the key actors to a decision, what are their stakes, and what is their relationship with each other?"

3. *Problem analysis.* This step includes the first participatory exercise, where decision makers identify what the metrics of success, options, and risks are.

4. *Data processing, modelling, and evaluation* This step concerns the collection and elaboration of data and their evaluation according to the defined objectives. Analysts use models to relate metrics, options, and risks.

5. *Analysis of response options.* Here, analysts identify the conditions under which the various options fail or succeed. Analysts and decision makers compare the scenarios available and the tradeoffs between the different metrics. Analysts and decision makers iterate upon earlier steps to examine more options or modify features of options, explore a wider range of plausible risks, and consider additional metrics.

6. *Action taking and monitoring.* This step concerns the implementation of the decisions, monitoring its effects, and possible revisions and adaptations.

Importantly, NetSyMoD and other decision frameworks aim at improving the effectiveness, not the efficiency of a decision (Santana, 1995). Efficiency refers to how an institution uses its resources, such as available funding, staff, and time, to achieve a decision. Effectiveness instead refers to the extent to which the decision taken meets the objective in the short to long term. This means, if the decision performs well under uncertain future changes.

The focus of this thesis is on the latter. Being this work part of a PhD thesis, and since these decisions concern long term changes, I could not follow the process through to the decisions' implementation and monitoring. However, I show that sometime the tradeoff between effectiveness and efficiency is not as stark as initially thought.

Three Objectives Of Decision Support...

In a 1960 RAND publication, Charles J. Hitch urged that "We must learn to look at our objectives as critically and as professionally as we look at our models and our other inputs." (Hitch, 1960, p.19). When I began to work on decision support, I thought that every decision analysis or process should lead to a concrete investment or policy design. However, I realised that sometimes, the objective is broader and longer-lived than a single investment choice. Overall, a decision support process helps decision makers to prioritise amongst options. Yet, since the world develops as a consequence of decisions, not of analysis, this thesis argues that one major objective of decision analysts is to convince policy makers to think of the right questions. How will my system react? Are the assumptions transparent? What risks make my decision vulnerable? What can I do to reduce these risks? Is the process inclusive? Am I exploring the right decision criteria? And so forth. At the same time, it is fundamental to show that a robust analysis can help answer these questions and make informed decisions. Finally, it is important to communicate that to make an effective decision does not necessarily require an infinite amount of resources and technical skills. At all stages, the decision analyst should emphasise that her/his role is to provide information for the decision makers to take a decision, not to provide the answer per se.

The hypothesis is that there is no silver-bullet in decision support tools, yet iterations between qualitative analysis and quantitative evaluations have great potentials to help overcome the above mentioned challenges for sustainable development.

Therefore, in this thesis I explore 3 main streams of possible objectives of decision support, even when it is not possible to follow the process through to the decision's implementation. I believe that all of these, individually or in combination, can increase the chance of making better decisions in the real world for climate change adaptation and sustainable development. These three objectives are:

1. **To promote the widening of agendas and stimulate creativity in decision making**. From their emergence in 1970s, decision support tools' supporters promised that they would enable decision makers to develop better and more creative solutions to the problems they face (Elam and Mead, 1990). Helping decision makers think of the right question(s) and consider a broader set of options is particularly relevant in long-term decisions, which should consider the impact of climate and other changes. Decision makers are struggling to mainstream climate change into their agenda. Not least because there is a significant mismatch between the scale of analysis of climate change and that of a typical project (influenced by political time, for instance). Moreover, decision makers

often dismissed taking actions on climate change as incompatible with other development objectives. Decision analysts can help decision makers think of how to introduce new concepts, like climate change, into their planning processes. In the case of future changes, analysts can provide tools and information that translate the issue into a communicable and manageable one. Chapter 1 and 4 explores how this can be achieved in practice.

2. **To help coordinate top down policy design with needs, transformations, and preferences from the ground**. This is a crucial support of any successful policy. Analysts can set up very sophisticated decision processes with decision makers, but without a structured dialogue with the beneficiaries, the chances of a policy achieving its target remain limited. Sometimes it happens that despite years of policy efforts, adoption is limited. This usually depends on drivers and constraints on the ground that policy makers may have interpreted inaccurately. Analysts can identify drivers and constraints to the implementation of a policy, by studying the receiving system. Similarly, analysts can test the sustainability of decisions and monitor it as time passes. Or else, they can evaluate the conditions for adoption and help find solutions. This thesis addresses the coordination between top down policy design and bottom up preferences and priorities into two projects, described in Chapter 2 and 3.

3. **To disseminate and help mainstream tools for the support of good planning**. Research suggests that having practical tools to solve a problem can increase one's awareness of the problem and motivation to solve it (Coombes and Devine, 2010, Kolb, 1984). A straightforward demonstration of these methods may motivate and equip analysts and decision makers to better manage the decision process for sustainable development. However, sometimes, analysts or decision makers need specific tools. For instance, an important source of bad decisions is illusions of certainty, which often lead to action with disastrous consequences (Boulding, 1975, Kalra et al., 2014). Nevertheless, planners and decision makers generally dislike uncertainty and tend to neglect it, with disastrous consequences. Chapter 4 provides a clear demonstration on how analysts and decision makers can manage deep uncertainties when making an investment decision.

These three objectives could also be seen as consequential, in some cases. First we convince the decision makers of broadening their agenda to include decision issues like climate change. Then, we make sure that the policy addresses the needs and the preferences on the ground. Finally, we equip other analysts and decision makers to be able to apply themselves the right decision tools.

To achieve these three objectives, the whole decision support process is important, not only the quantitative analysis, or the participatory process. The process allows the decision maker to map prior experience and understanding onto the newly proposed decision models, and by doing so, to improve the effectiveness of the decision. For a plan to become a decision, decision-makers need to buy into it and feel its ownership. Otherwise, a decision support process becomes a "bag of wind, [...] a worthless diagram" (Boulding, 1975). Moreover, decision support processes help smoothening conflicts between stakeholders, which are often the cause for a decision to come to an impasse.

However, decision makers need the quantitative analysis to inform them of the tradeoffs between the choices available. The quantitative analysis is therefore necessary to provide robust information to support the decision. Via the quantitative analysis we can test the performance of the solutions according to the chosen metrics and under different scenarios. In complex decision problems such as those related to long-term investments, it is difficult to manage these steps (and provide sound evidence-based information) without some modelling support.

An example of a successful combination of participatory and quantitative analysis is the process that led to the unanimous approval - for the first time in the State's history - of Louisiana's Comprehensive Master Plan for a Sustainable Coast (Groves et al., 2014). In that context, analysts were able to mobilise stakeholders' consensus in the conflict-ridden State via a combination of hard modelling, tools to visualise the tradeoffs between the options available, and continuous communication. Through this process, analysts were able to create the first comprehensive solution for Louisiana's coast to receive broad support from the Louisiana public and the many agencies engaged in protecting the Gulf Coast. The Master Plan is now being successfully implemented.

Again, the winning formula comes from the integration of analysis and discussion, as suggested by the NetSyMoD framework.

...Within Different Decision Contexts

Once the objective of the analysis is clear, analysts set up the planning process. Ideally, decision analysts have large resources - time and money -, the client has high computation skills, and there is large amount of data available. In real life this rarely occurs. It is the task of analysts to be able to juggle between the various contexts. This thesis demonstrates that good planning is possible, even in contexts with reduced data availability, or limited resources.

The first two phases of the NetSyMoD framework help analysts identify the characteristics of the decision problem. Who are the parties involved? What is/are the objective(s)? What is the timeframe of the decision? What are the resources and data available? These factors define the type of analysis that we can apply to support a decision. Therefore, I have conceptualised a decision context according to five main characteristics: (i) data availability, (ii) experts' knowledge, (iii) resources (time and money), (iv) deep uncertainties, and (v) conflicts between stakeholders (Figure 2).

As the following chapters describe, in some cases I followed closely the NetSyMoD steps, whereas in others, I focused mainly on the analytical phases. Each time, I chose the focus according to the specific objective of the decision process. For instance, Chapter 4 does not address a full decision support process. Rather, it speaks to a technical audience and discusses the merits of a different way of doing economic analysis - for supporting a more robust lending choice. My message is that decision analysts must keep enough flexibility given the contexts and the peculiarities of each decision process. As John Briscoe remarked at the Stochkolm Water Forum, 2014, "all solutions are provisional and local" (Hearne, 2014). Analysts must be ready to approach each problem from the context, and not try to mold the context to fit with their methodology. This is crucial for providing the best information to decision makers given the context of the analysis. I believe that this also increases the likelihood of replicability of the method by the decision makers involved. A formalised decision process however is an important guide - and this can be easily exported from one decision context to another. The next paragraphs describe the decision contexts of the four chapters.

In Chapter 1, decision makers were struggling to find an agreement on the future developments of their municipality. Moreover, being a low-altitude winter resort, they were worried

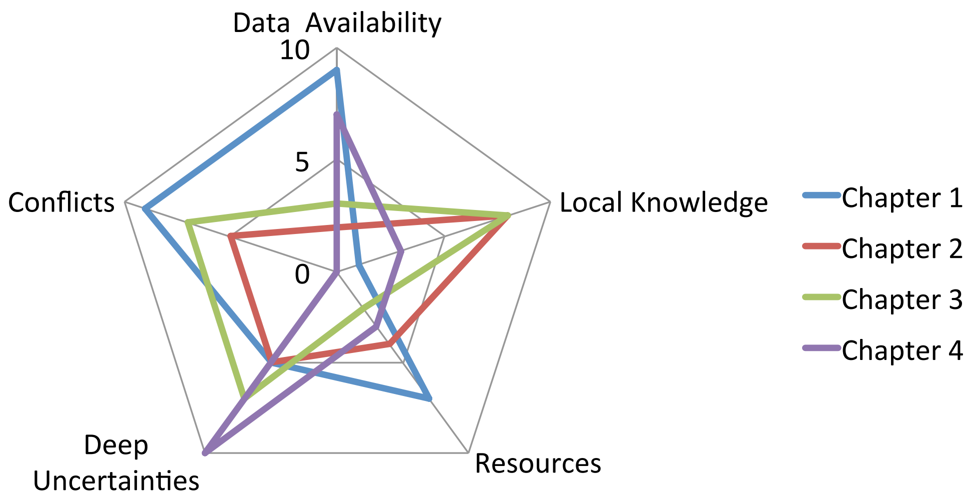

FIGURE 2: In the graphs, 10 indicates optimal availability or high degrees of, whereas 0 indicates unavailability, or low degrees of a given condition.

about climate change but they neither knew what it meant in practice nor how they should deal with it. Hence, the Veneto Region asked us to support the local decision process. The decision support application described in Chapter 1 aimed at finding solutions for effectively integrating a climate change adaptation perspective into local discourses on sustainability and tourism development. Figure 2 (blue line) shows that the first decision context (Chapter 1) is characterised by high uncertainties (i.e., it is highly vulnerable to climate change) and riddled with conflicts between the different actors. Lots of data is available, whereas local knowledge on the topic is extremely limited. The peculiarities of the context enabled us to embed tourism and physical models in a participatory multi-criteria decision support tool to enable evidence-based planning for sustainable winter tourism in the Dolomites of Italy.

In Chapter 2, decision makers needed to design the new Rural Development Plan. Due to EU regulations, for the first time they needed to explicitly mainstream climate adaptation. They were not experts in the topic and largely assumed that farmers would not be either. When we were consulted, we suggested that this may not be the case. Farmers have always been adapting. In this project (Figure 2, red line), we had little data on autonomous adaptation, but we could capitalise on the local knowledge (of farmers and Irrigation Boards). Conflicts were arising between farmers and decision makers, and farmers and other water users. The Government had limited time and resources. We designed an online participation tool to first collect contributions of hundreds of farmers about their adaptation practices and then elicit their preferences for water saving measures in Northern Italy. The data collected provided a large support basis for the Region to design its Rural Development Plan.

In Chapter 3, decision makers were struggling with the promotion of conservation agriculture. Conservation agriculture rests on the assumption that no or minimum soil labour, a specific crop rotation, and leaving the residues on the field help stabilise yields even in a variable climate. Despite decades of successful demonstration trials, adoption of conservation agriculture in Central Morocco remained limited. The National Institute of Agronomy (INRA) asked us to carry out a sustainability analysis of conservation agriculture in the region, which could provide the basis for a more targeted policy design. Decision makers possessed scant data on why farmers have not been adopting the technology package, which on paper seemed more robust to drought and more reliable than current practices. Online tools in this case were not an viable option, nor there were sufficient resources for a thorough data collection exercise. However, local agricultural institutions and extension services, who work closely with farmers, had much expertise on the topic (Figure 2, green line). We developed a Bayesian Decision Network (BDN) to maximise the integration of the available data with experts' knowledge. This tool helped us derive useful information on what the policy should focus on. It also allowed us to introduce the climate uncertainty dimension in the analysis of the policy's sustainability.

Finally, decision makers at the World Bank and in other institutions struggle to deal with the deep uncertainties related to long term changes. The reasons are often lack of knowledge about the tools and concerns on the investment needed to do an uncertainty analysis. Chapter 4 is a demonstration that compares traditional and innovative analytical methods for better dealing with uncertainties. It revisits an investment decision which was riddled with uncertainties about future developments of the energy market, discount rates, capital costs, and inputs' availability, to mention a few. A traditional sensitivity analysis may miss crucial vulnerabilities of the project (Figure 2, purple line). Chapter 4 shows that methods like Robust Decision Making (RDM) can be readily applied. In the study, we used the same economic models and data that analysts used in the original analysis; we just used them differently. The analysis provides more robust information on what the best course of action may be than the original study. Being specifically focused on the analytical steps, this Chapter leaves out the phases on explicit stakeholder involvements.

The Thesis Content

Chapter 1: Sustainable Tourism Planning And Climate Change Adaptation In The Alps: A Case Study About Winter Tourism In The Dolomites

A vast body of literature suggests that the European Alpine Region is one of the most sensitive to climate change. Winter tourism is closely related to climate variations, especially in mountain regions where resorts are heavily dependent on snow. Policy makers need support to integrate a climate change adaptation perspective with local discourses about sustainability and tourism. The chapter reports the development and application of a participatory decision support process for the analysis of adaptation strategies for local development of an Alpine tourism destination, Auronzo di Cadore (Dolomites, Italy). This experience suggests that an efficient combination of modelling capabilities, decision support tools, and participatory processes, can substantially improve decision making for sustainability. In particular, the chosen combination of methods and tools facilitated the involvement of local actors, stimulated the local debate on climate change adaptation and possible consequences on winter tourism, encouraged creativity and smoothened potential conflicts. Moreover, it eased the integration of the qualitative knowledge and the preferences of the involved actors with quantitative information. At the end of the process, decision makers possessed sound information on the sustainability of the various strategies explored.

Chapter 2: From The Exploration Of Farmers' Autonomous Adaptation To The Design And Evaluation Of Planned Interventions In The Veneto Region, Italy

There is an increasing call for agricultural water management to adapt to climate change, yet efforts in this direction often consider only the policy-dimension, or planned adaptation perspective. However, it is crucial to include an assessment of farmers' autonomous adaptation into the design and evaluation of rural policy measures. Amongst others, this helps avoid doubling efforts and ensure the effectiveness of the policies proposed. Moreover, farmers are the primary receivers of climate proofing agricultural policies. Hence, it is fundamental to include farmers in the strategies' design phase. The project described in this chapter, carried out in the Veneto Region of Italy, proved the advantages of approaching adaptation as a continuum between autonomous (i.e. implemented by farmers independently of public policies) and planned (i.e. as a result of policy implementation), rather than addressing the two separately. We first collected farmers' perceptions of and adaptation to change through an online questionnaire. We then identified the major determinants of their choice to adapt through a multinomial probit model. We analysed farmers' expectations of effectiveness of five different adaptation options for water conservation, via an ad hoc online decision-support system tool, mDSSweb. Our study provided policy makers with information on how different typologies of farmers are (not) adapting their practices to climate change. We clearly identified which groups of farmers the policies should target first and with what type of support. Both policy-makers and farmers reacted positively to our approach and expressed interest in up-scaling it to become more inclusive.

Chapter 3: Exploration of Conditions for the Adoption Of Conservation Agriculture Via Bayesian Network Modelling. A Case Study From The Semi-Arid Region Of Central Morocco

Research in the Settat Region, Morocco, proves that under optimal conditions conservation agriculture increases yields, reduces labour requirements and erosion, and improves soil fertility. However, after nearly two decades of demonstration and advocacy, adoption is still limited. This chapter investigates the critical constraints and potential opportunities to adoption for different typologies of farms. We measured the possible pathways of adoption via a Bayesian Decision Network (BDN). BDNs allow the inclusion of stakeholders' knowledge whilst at the same time they are supported by a robust mathematical background. We first developed a conceptual map of the elements affecting the decision about tillage, which we refined in a local workshop with farmers and researchers. We then involved experts in the elicitation of conditional probabilities tables, to quantify the cascade of causal links that determine (or not) the adoption. Via BDNs, we could categorise under which specific technical and socio-economic conditions no tillage agriculture is best suited to which farmers. We, by identifying the main constraints and running sensitivity analysis, were able to convey clear messages on how policy-makers may facilitate the conversion. As new evidence is collected, the BDN is updated to obtain evidence more targeted and fine tuned to the adoption contexts.

Chapter 4: Making Informed Investment Decisions in an Uncertain World: A Short Demonstration

Governments invest billions of dollars annually in long-term projects. Yet deep uncertainties pose formidable challenges to making near-term decisions that make long-term sense. Methods that identify robust decisions have been recommended for investment lending but are not widely used. In this chapter, we seek to help bridge this gap and, with a demonstration, motivate and equip analysts to better manage uncertainty in investment decisions. We first review the economic analysis of ten World Bank projects. We find that analysts seek to manage uncertainty but use traditional approaches that do not evaluate options over the full range of possible futures. Second, we apply a different approach, Robust Decision Making (RDM), to the economic analysis of a 2006 World Bank project, the Electricity Generation Rehabilitation and Restructuring Project, which sought to improve Turkey's energy security. Our analysis shows that RDM can help decision makers answer specific and useful questions: *How do options perform across a wide range of potential future conditions? Under what specific conditions does the leading option fail to meet decision makers' goals? Are those conditions sufficiently likely that decision makers should choose a different option?* Such knowledge informs rather than replaces decision makers' deliberations. It can help them systematically, rigorously, and transparently compare their options and select one that is robust. Moreover, we demonstrate that analysts can apply RDM using the same data and models typically used in economic analyses. Finally, we discuss challenges to applying such methods and how they can be overcome.

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Chapter 1

Sustainable Tourism Planning And Climate Change Adaptation In The Alps: A Case Study About Winter Tourism In The Dolomites

This chapter is a paper written by Laura Bonzanigo[a,b]; Stefano Balbi[c]; Carlo Giupponi[a,b]. We submitted this paper in July 2013 to the Journal Of Sustainable Tourism. In April 2014 we received the reviewers' comments and have resubmitted it in May 2014. The paper is still under review.[1]

1.1 Introduction

The World Tourism Organization started warning about the possible negative implications of climate change for winter tourism and sports since 2003 (World Tourism Organization (UNWTO), 2003). The Alpine Region in Europe is among the world's most vulnerable areas to climate change. The mean temperature of this region has increased up to +2°C for some high altitude sites over the 1900-1990 period against +0.78°C in the last 100 years at a global level (Beniston, 2006, Solomon et al., 2007). With a certain degree of local variability, glaciers have lost 50% of their volume since 1850 and snow cover is decreasing especially at the lowest altitudes and in fall and spring. Nowadays, already 57 of the main 666 ski resorts of the European Alps are no longer considered snow-reliable (OECD, 2007).

Nevertheless, an economic development paradigm based on snow, whether natural or artificial, is still somehow surviving in the tourism destinations of the Alpine region, notwithstanding the maturity of the traditional ski product and the stagnation of the market demand (Macchiavelli, 2009). This mode of development should instead be considered with care, particularly

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within a climatic change perspective, which may lead to a dramatic decrease in snow precipitation across the Alps in the next few decades(World Wide Found (WWF), 2006).

Hence, before decisions are taken regarding further snow-based development plans in Alpine tourism destinations, planners must evaluate their sustainability and take action accordingly, because "how tourism responds to climate change is absolutely critical to the sustainability of tourism" (Scott, 2011). Sustainable tourism should promote economic and social progress by building on the existing natural capital, which is indeed very rich in the Alps. Planners need to find compromises between economic, social, and environmental interests. An active and effective participation of all the stakeholders involved in local development is a precondition for finding such compromises, and in turn for the planning to succeed.

Several cooperation research projects have been dealing in recent years with the issue of adapting to climate change in the Alps with the financial support of the European Commission through the Interreg Alpine Space Programme . The ClimAlpTour project explored in particular the relationships between climate change and tourism, bringing together institutions and scholars from all countries of the Alpine region. The project analysed 22 pilot areas across the Alps with diverse environmental, social, and economic conditions with the aim of raising the awareness of stakeholders - including tourists, local population, and businesses - on the impact of climate change on tourism economy of the Alps and on possible adaptation strategies (Urbanc and Pipan, 2011, Weiermair et al., 2011).

In developing the ClimAlpTour approach, it was soon recognised that to isolate climate change and treat it as self-standing issue would have been ineffective for several reasons: (a) at the local level, the risk is extremely high of both/either raising limited participation interest, and/or falling into useless discussions between negationists and catastrophists with the related hidden economic interests behind them; (b) tourism is a very interconnected economic activity depending on tangible and intangible goods and services of both natural and anthropogenic origin; (c) the winter alpine tourism is strictly linked to multi-scale dynamics such as demography and economic development of the areas of origin of the tourists and it is currently suffering for the maturity of the market demand, the growing opportunities for tourism further away, and the negative economic context in Europe. Therefore, climate change adaptation (CCA) in the ClimAlpTour project was interpreted as a rigorous process of tourism planning for sustainability, consistently with recent orientation of international organisations (OECD, 2006, UNDP-UNEP, 2011)supporting the idea of mainstreaming CCA into consolidated pre-existing policies, in particular into those aimed at sustainable development.

The paper focuses in particular on how to integrate a CCA perspective into the local discourse about sustainable tourism development. We refer to a case study in the Italian Dolomites, Auronzo di Cadore (Figure 1.1). This particular study, although not unique in style (see for instance a similar study: Loibl and Walz (2010)) adds a useful contribution to the issue of CCA in Alpine tourism destinations for several reasons. Firstly, the method presented is itself an effective tool to promote an understanding of the link between tourism and sustainable development, which is also consistently encapsulated in the discourse on vulnerability to climate change (IPCC, 2014). Secondly, although we refrain from generalising given the highly contextualised nature of the results, the outputs of our project help understand the dynamics of destinations with similar characteristics. Finally, the methods developed can be easily applied to different tourism contexts in which local development is an issue, with joint consideration of sustainability and CCA, even beyond the Alpine tourism context (Weaver, 2011).

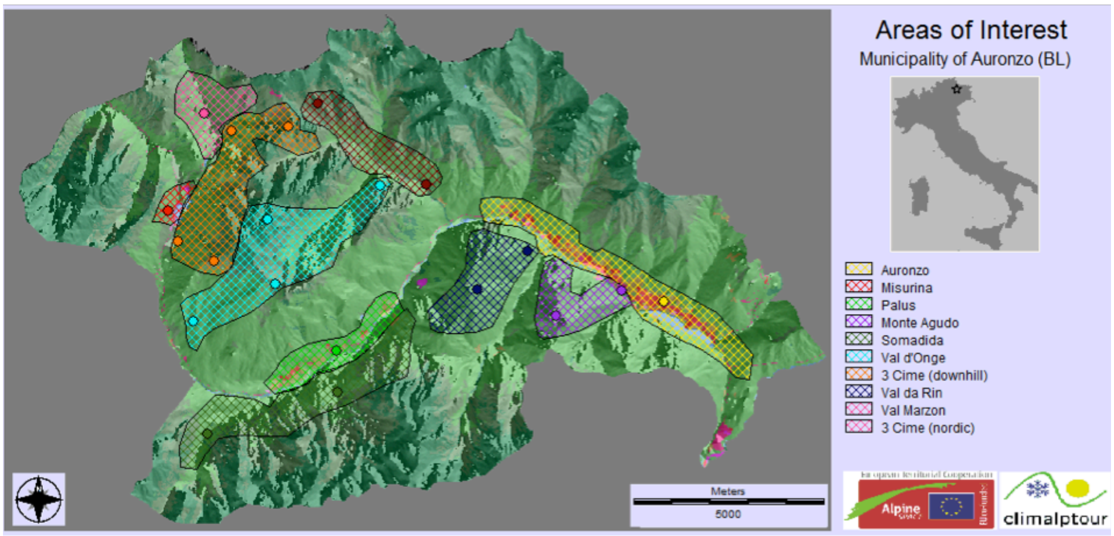

FIGURE 1.1: Map of the Municipality Auronzo di Cadore, Italy

After a brief description of the case study, the *Methods* section presents the adaptation to the case study of a pre-existing methodological framework NetSyMoD (Network Analysis - Creative System Modelling - Decision Support, Giupponi et al. (2006)) and the contribution of the various disciplinary approaches to the analysis. The *Results* section describes what emerged in terms of sustainable adaptation options for the Auronzo di Cadore Municipality, and finally, we will discuss these with consideration of the potential of the broader message that can be extrapolated from the case specific analysis.

1.2 The Case Study Region

The Municipality of Auronzo di Cadore is located in the Dolomites (Belluno Province, in the Veneto Region), in the North-East of Italy. It covers a vast area (22,000 ha), which includes the Lake of Misurina and the 'Tre Cime di Lavaredo', a UNESCO heritage site, and the villages of Auronzo di Cadore (866 m above the sea level), which hosts nearly the entire population of the Municipality of approximately 3,600 inhabitants, and Misurina, a small settlement 25 km away from Auronzo di Cadore, placed at an altitude of 1,754 m.

It is a well established tourism destination, with 75 per cent of yearly arrivals in summer and 25 per cent in winter The main tourists' typologies in winter are families that practice skiing as secondary activity, while their primary objective is to relax in a pleasant and healthy environment. Yet ski tourism has traditionally been the first winter tourism product in Auronzo and the last investments in the Auronzo ski station have been significant and completed in 2009.

The total hosting capacity is of approximately 7,300 beds of which around 1,700 in the hotel sector and the remainder in the extra-hotel sector (B&Bs, lodgings, and so forth). 75 per cent of the hotels beds are located within low to medium range facilities. In 2012, approximately 69,000 arrivals and 290,200 tourist nights were registered, showing a slight decrease from the previous year. The last 15 years have witnessed the increase of arrivals but the contraction of average stays, from around 8 to around 4 days.

Notwithstanding the presence of two small downhill ski areas and two cross-country ski centres, some hotels do not even open for the winter season. The four ski lifts of Mount Agudo, which reach a maximum elevation of 1,600 m, connect seven ski pistes for a total 15 km. In the locality of Palus San Marco, halfway between Auronzo di Cadore and Misurina, there lays the Somadida Forest, one of the Province's largest, which becomes a cross-country ski centre (with nine loops of a total 52.5 km) during the winter season. The Marmarole sled dog centre and an ice-kart circuit are also located in Palus. In addition, Misurina, which has an hosting capacity of approximately 500 beds, is endowed with two ski lifts of Col de Varda (from 1,756 m to 2,220 m) that connect five ski pistes, and 17 km of cross-country ski loops.

Recently, the Municipal Council began to consider options for stimulating winter tourism. At present, there exist several projects of traditional ski areas development. The most ambitious is located in Marzon valley, a few km from the main village, which would connect the valley to the ski area of Misurina (with an average altitude over 2,000 m).

1.3 Methods

1.3.1 The Methodological Framework

One severe preoccupation of the Municipality is how to increment winter arrivals. After a preliminary consultation with the Municipal Council and other local actors, the most frequent driver for the lower arrival in winters seemed to be the deficient skiing infrastructure. We agreed to orient project activities towards a broader study on how to develop winter tourism in the next 20 to 30 years, which included other modes of development besides traditional ski development, and which kept into consideration the possible impacts of climate change (warming effect on snow availability) and an unfavourable market demand (ageing population).

It is generally agreed that stakeholder participation can increase the likelihood that development decisions are more readily accepted, as the inclusion of different actors enables the accounting of different values and needs (Reed, 2008, Richards et al., 2004). Therefore, the Auronzo di Cadore case study was designed to involve the local community, not only the Municipal Council, in a discussion about the future of their tourism destination, and more specifically about the prospects for strengthening its winter tourism performances in a sustainable way. In doing so, the two main objectives were to raise awareness on possible climate change impacts and promote the elaboration and discussion of potential strategies for locally sustainable development.

To these aims, we adopted a methodological framework, *Network Analysis - Creative System Modelling - Decision Support* (NetSyMoD, Giupponi et al. (2006)). We adjusted it to the case study requirements, making use of a combination of several tools, including a new ad hoc version of a decision support tool generally utilised in conjunction with NetSyMoD, the Mulino Decision Support System (mDSS, Giupponi (2007)[2]) for an efficient management of stakeholders' involvement in policy analysis. The tool integrates various data categories and information (model outputs, statistics, expert knowledge) for the assessment of a range of potential adaptation strategies, in order to support the identification of preferred options.

The NetSyMoD approach is based upon a participatory process unfolding the following sequence of phases: (i) a preliminary analysis of the problem and of the main local actors; (ii) a

[2]The new version of the mDSS software (mDSS5), originally conceived during the EU FP5 project MULINO (*MULtisectoral, INtegrated and Operational Decision Support System for sustainable use of water resource at the catchment scale*) can be downloaded from http://www.netsymod.eu/mdss.

creative modelling procedure to conceptualise the problem at hand, further developed into an operational integrated model for the simulation of alternative scenarios and options; (iii) the design of the decision support system and the processing of raw data; and, finally, (iv) the analysis of possible solutions to the given problem (i.e. alternative options for local development and CCA strategies) by means of multicriteria decision methods (MCDM). The participation of local actors and experts was managed through a tailored implementation of this sequence of steps culminating into two workshops for the ideation and discussion of the set of alternative adaptation options for winter tourism (first workshop), and for their evaluation on the basis of quantitative assessment and the preferences of local actors (second workshop).

1.3.2 Setup Phase: Analysis of the problem and of local actors

The complex nature of combine social-ecological problems, such as tourism planning under climate change adaptation, requires a transparent process that embraces the largest diversity of (local) knowledge and values (Reed, 2008). The first step then required the definition of the Auronzo di Cadore Municipality in terms of categories of actors (i.e. all potential stakeholders/experts to be involved or affected by the decision under investigation) and their main activities, in an attempt to represent all interests (see Balbi et al. (2011) for the setting up of the case study). We identified five broad categories of actors on the basis of preliminary interviews with local decision makers, namely governmental, tourist hotelling, outdoor activities and entertainment, tourism management bodies, and services non specifically designed for tourism (local shops, gymnasium, etc.).

We selected a set of 18 sub-categories capturing the stakes that the introduction of changes in the supply side of current tourist system, whether directly or indirectly, would have touched upon (Table 1.1). Given the competitiveness and different developments of the two main tourism destinations within the Municipality - Auronzo di Cadore and Misurina -, it was necessary to consult representatives of each category from both areas. For instance, both Presidents of the two skiing schools, the managers of the two skiing areas, and hotel owners in both destinations were contacted.

We aimed the structured interviewing phase primarily at assessing the reciprocal relationships amongst actors for the identification of the key actors, and the characterisation of their role and position with respect to the problem at stake, i.e. medium to long term development of winter tourism in the Auronzo di Cadore Municipality. The questionnaires included four main parts:

1. General information about the interviewee and the institution/group that s/he represented.
2. Social network identification, where the interviewee listed the frequency, quality, and nature of his/her institution's interactions with the others on the list.
3. Position analysis, where s/he could express opinions on the potential strategies to adopt and the criteria to value the final choice against.
4. Conflict analysis over the use of natural resources for tourism purposes (for instance deforestation for construction of downhill skiing infrastructure).

The questionnaire also collected information about the various actors' opinions on the development of winter tourism in Auronzo di Cadore that constituted a fundamental input for the

TABLE 1.1: List of actors working in the tourist sector, as identified in Auronzo di Cadore

Category		Sub-Category	Selected Actors	Interviewed	At WS1	At WS2
Government	1	Public Administration	2	1	1	1
	2	Technical office	1	1	1	1
	3	*Regole*[1]	2	1	0	0
Hospitality	4	Hotels/Restaurants	7	3	3	2
	5	Chalets	5	2	0	2
	7	Estate-agents	2	0	1	0
	8	Construction companies	2	0	0	0
Entertainment	9	Ski Schools	3	2	1	2
	10	Ski Resort	2	1	1	1
	11	Ski-unrelated activities	4	1	2	1
	12	Alpine guides	3	1	1	1
	13	Italian Alpine Club	1	1	1	1
Events' management	14	Tourist office	1	1	1	1
	15	Tourism board	1	1	0	1
Facilities	16	Commercial	4	2	3	1
	17	Press	2	1	0	0
	18	Emergency[2]	3	0	0	0
		Total	51	20	17	16

[1]Family-run communal bodies; [2] Alpine Rescue, Civil Protection, etc.

pre-selection of indicators and options for the MCDM phase, to be discussed at the first workshop. Respondents were at the end asked to mention other potential contacts for the workshop (the so-called "snowballing technique", that reduces the possibility of leaving key actors unaccounted for). As a result, the initial list of 41 contacts was enlarged to comprise 51 individuals (Table 1.1). All categories of actors were covered with 20 successful interviews.

Once the interviewing round was completed, we elaborated the data with two Social Network Analysis (SNA) softwares that supported respectively the quantitative and graphical analysis of the results (B for more details).[3] The various institutions are visualised as nodes, with the edges that unite the nodes indicating the existence, directions, and intensities of institutional interactions. Quantitative indicators are calculated (e.g. centrality, betweenness) to provide a comprehensive and detailed description of the local network (see Supplementary Material, Appendix B for further details).

The output of this phase was a second selection of stakeholders to be invited to the two workshops (Table 1.1). A second selection both limits the risk for the participatory process to be hindered by some powerful groups and ensures a high rate of representativeness (the highest number of sub-categories represented) whilst at the same time maintaining the workshop in a manageable size in order to enable active participation by all the participants (ideally between 15 to 20 participants).

This phase identifies the actors and their relationships within the local social context. It singles out those who should take active part in the decision making process. Very importantly, this phase identifies the intended end users of the decision procedure and, via support tools, it introduces them to the process and raises their motivation and ownership.

[3]AGNA for quantification of social indicators (http://www.oocities.org/imbenta/agna); Pajek primarily for visualisation of the social network (http://pajek.imfm.si/doku.php?id=download)

1.3.3 Qualitative assessment of the alternative strategies (First Workshop)

The first workshop aimed at both creating a shared model of the system (i.e. the main elements of the socio-ecosystem of the Auronzo di Cadore destination for winter tourism) and exploring possible strategies for local development, with consideration of what is known so far about the possible climate change trends of the coming 30 years, with all due uncertainties.

We generally divide this session into two phases: (i) a brainstorming one, or diverging phase, focused on future scenarios[4] and in particular on a set of plausible development and adaptation strategies, and (ii) an evaluative one, or converging phase, where these were evaluated and the participants' preferences in terms of what factors should characterise the winter tourist portfolio were elicited.

Before the workshop, in preparation for the diverging phase, three spatially explicit alternative strategies were hypothesised for the area, on the basis of the outputs of the questionnaire and their relative developments and infrastructure. We mapped these elements as alternatives to a Business as Usual (BAU) setting, where everything would remain unaltered[5]. The three strategies differed in terms of use of natural, social, and economic resources, but they retained the common objective of strengthening winter tourism in the area.

In the Ski-Intensive (SKINT) strategy, a high tech downhill skiing centre was envisaged, with new lifts, hotels, and restaurants to frame the skiing offer, including artificial snow making facilities. Alternative-Skiing (ALTSKI) comprised instead a new typology of skiing resort: free-ride skiing, nordic skiing, and snow rackets trails, with all the (lighter) infrastructure connected to these outdoor activities. Finally, Beyond-Snow (BYDSNW) promoted the abandonment of investments in downhill skiing (and artificial snow), in favour of turning the Municipality into a resort specialised on wellness and family tourism, with an increase in the non-snow related offer (spas, restaurants, shopping).

These visual representations of the current socio-ecosystem of Auronzo di Cadore with the distinctive features of the hypothetical strategies (e.g. existing and proposed ski pistes, new infrastructures, etc.) supported the discussion in the diverging phase for (i) reasoning over different possible strategies that other alpine tourism resorts are currently exploring; (ii) imagining how diverging development approaches may be implemented in the local context; and (iii) providing a manageable framework of analysis for the research. The authors acted as facilitators for the elicitation and organisation of local knowledge and personal views, in order to refine and further develop the strategies that had been previously preliminarily sketched.

In order to contextualise the local actors' strategic views for winter tourism, the climate change dimension was introduced in the discussion, by presenting the projected climatic impacts of two SRES scenarios and a Current scenario, where the climate remains unaltered. The chosen scenarios were B1, a future with more efficient technologies and socio-economic development oriented towards services, and A1B, which pictures rapid globalisation and economic growth with high exploitation of available energy resources and warmer climate as compared to B1 (Nakicenovic and Swart, 2000). Climate impacts of the three scenarios were presented to the

[4]Scenarios are here considered as hypothetical sequences of events constructed with the purpose of focusing attention over causal processes and decision points in accordance with Eden and Ackermann (1998). Hence a scenario represents a possible future with an explicit effort to understand the forces that shape it.

[5]The development of visual representation of the cognitive map with the elements characterising the strategies was carried out by means of a specific piece of software (IHCM Cmap, downloadable at http://ftp.ihmc.us/) used also at the workshop for real time annotation and sharing of the views of local actor. Spatial maps were developed in Google Earth, downloadable at http://www.google.com/earth/index.html.

Table 1.2: Impact of climate change on the Auronzo di Cadore Municipality with respect to the current situation

		Current	2011-2030		2030-2050	
			A1B	B1	A1B	B1
Variation of average winter temperature on 20 years period ($^{\circ}C$)		-	+0.6	+1.2	+1.6	+1.2
Variation of average winter precipitation on 20 years period (%)		-	+5.8	-6.1	+7.9	+8.3
Average number of days with more than 30 cm of natural snow	Auronzo	54	42	15	22	25
	Misurina	121	116	107	110	115
Average number of days with at least 30 cm of snow (with snow-making)	Auronzo	84	76	49	52	54
	Misurina	124	121	116	116	120

From Balbi et al. (2013)

participants, with particular emphasis on changes in local snow availability (Table 1.2), where the difference in natural snow days between Misurina and Auronzo di Cadore is due to the higher altitude of the former.

In the evaluative phase, each participant carried out a preliminary evaluation of the Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T) of the strategies elaborated and discussed during the brainstorming (SWOT Analysis, (Hill and Westbrook, 1997), keeping in mind the climate impacts presented. The SWOT analysis allows identifying the internal (S,W) and external (O,T) factors that are favourable and unfavourable to achieve that objective, and supports discussion and eventual refinement of a project.

This second phase focuses on the analysis of the problem. It allows individual perspectives to be explored in participatory activities such as workshops and participants to agree on a common definition of the problem and the objectives of the analysis. Problem analysis is also crucial to frame and orient the design of subsequent activities: data processing, modelling and evaluation procedures to be possibly supported by DSS tools.

In addition, participants were asked to express their opinions on a list of possible key elements, which characterise winter tourism destinations developed by other ClimAlpTour project partners, namely: activities on the snow, outdoor activities not directly dependent on snow availability, outdoor activities in resorts and lower areas, culture, entertainment (festivals, local hangouts), gastronomy, wellness, training and schools (ski and others, e.g. cooking courses, yoga), hosting facilities and hospitality, adaptation (artificial snow-making), and transportation (use of cars in the resort).

We evaluated those elements, all related to the tourism service supply side by means of the revised procedure proposed by Simos (1990) for weight elicitation: we extracted the relative weight of different component in portfolio according to the relevance for the objective of improving the attractiveness for winter tourists, as perceived by each participant. This allows capturing stakeholders' beliefs at the beginning of the participatory process. This exercise is very useful also to analyse how the participatory process influenced initial believes, as a consequence of the mutual learning between participants and scientists and the integration of local knowledge with academic models.

1.3.4 DSS design and data processing

In this phase the knowledge of the problem developed so far is used for designing and implementing the set of procedures and software tools needed for the analysis of the performance of the alternative options in terms of several criteria and under different plausible futures.

We used the mDSS tool (Giupponi, 2007) to support the conceptualisation and formalisation of the model of the local socio-ecosystem and of the decision problem, by means of the DPSIR framework DPSIR is widely adopted in the international literature and, very importantly, in many policy references, in Europe and elsewhere, thus facilitating coherent communication of research activities to a broader public.

We expanded the original DPSIR Scheme into a DPSIRS-ED framework, by introducing a consideration of alternative scenarios (S) and a sixth category of nodes (Exogenous Drivers, ED). EDs represent those forces that influence the local socio-ecosystem from outside the decision context, thus beyond the possible range of influence of local responses, yet that should not be ignored when designing solutions to a given problem (R), as they may significantly affect their implementation outcome. Typically, they are climate change and macro-economic variables, often considered in the definition of future scenarios.

In the DPSIRS-ED interface provided by mDSS5, indicators to be used for the quantitative description of the system and for the assessment of the expected effects of the proposed alternative strategies are attached to the pertinent nodes, and the set of alternatives is allocated to the R node (B for more details).

After the DPSIRS-ED formalisation, indicators to be used for the assessment are directed from the nodes to the Design interface, which visualises the structure of the Analysis Matrix (AM) for the analysis of the alternative options by means of MCDM. Indicators were selected on the basis of the actors' preferences elicited in the SNA questionnaire and during the first workshop, and experts' feedback on their relevance for the area, with consideration of their potential change as a result of the implementation of the different strategies. In particular, indicators provide the identification of the multiple criteria (rows), whereas the development strategies (R) define the columns of AM interface. The AM cells are filled with the results of data processing for the quantification of the expected performances of the strategies, resulting from surveys, modelling, and contributions from local experts, briefly described in the Results section. An AM is filled in for each of the three scenarios.

Required inputs for the assessment of the strategies for Auronzo di Cadore were: (i) downscaled climate change scenarios; (ii) the list of development and adaptation strategies; (iii) the estimated effects of the strategies on the set of the selected evaluation criteria, quantified by means of indicators; (iv) the preferences of the involved stakeholders. The mDSS5 toll is able to store this information, having at its core the AM filled with the data expressing the performance of each strategy according to every selected indicator.

Indicator data are then normalised according to ad hoc value functions expressing the contribution of each criterion to the overall objective of sustainable development, and allowing for their aggregation by means of the multicriteria decision rules provided by mDSS5 (i.e. Simple Additive Weighting, Borda rule, Electre[6]). The selected method of normalisation for this project was the min-max that rescales the results from 0 to 1 assigning 0 to the minimum value and 1 to the maximum value (i.e. Y= (x-min)/(max-min), for those indicators expressing a notion of benefit, i.e. air quality, and reversed min and max values for costs, i.e. water consumption).

[6]For more information on the different decision rules provided by mDSS5: www.netsymod.eu/mdss

The aggregation rules in turn calculate an overall performance score attached to each strategy, to eventually explore preferences and trade-offs between alternative strategies based upon their strengths and weaknesses quantified by means of the selected indicators. However, in order to obtain those final outputs, stakeholders' opinions in terms of relative relevance of each criterion had to be elicited with a weighting procedure included in the activities of the second workshop.

mDSS5 is an extremely transparent and user-friendly tool. We believe that to use a transparent interface between the analysis and the dialogue with stakeholders is necessary to manage and communicate the information flow between various process phases, including exchange, transformation, integration, validation, judgement/valuation, and documentation of gathered knowledge(Giupponi et al., 2008).

1.3.5 Second Workshop: Analysis of the alternative strategy options

The second workshop was held in Auronzo di Cadore in September 2010 and it fulfilled five main objectives:

- To present the methods and tools utilised for the evaluation of the strategies defined during the first workshop.
- To present the quantitative analysis work that followed the first workshop, both in terms of indicators and models.
- To elicit weights for the evaluation criteria.
- To explore possible rankings and trade-offs of the strategies through the MCDM functionalities of the DSS tool.
- To contribute in general to local debate on tourism, as a legacy of the ClimAlpTour project.

In the initial phase of the workshop, participants were guided through the elaborations carried out for the quantification of the indicators. Emphasis was placed on the Agent-Based Model (ABM) (Bousquet and Le Page, 2004) Auronzo WinSim 1.0 (AWS1.0)[7]. AWS1.0 is a new research tool that has been developed to support the participatory process described in this paper. In particular, it captures the potential responses of the tourism demand side to the changes in the supply side, thus virtually capturing the preferences of a category that was not represented in person during the participatory process, which included representative from the tourism supply side. The purpose was to simulate the future dynamics of several socio-economic indicators in the development strategies envisaged in the first workshop.

Weight elicitation is a necessary step of MCDM. Hence, for the weight elicitation exercise, a template was handed to participants where they had to insert scores for each of the selected decision criteria. In particular, participants were asked to distribute a total of 100 point to the seven criteria, where the most important ones received the highest score.

[7] AWS1.0 is an ad-hoc model developed with local primary and secondary data that is able to simulate the tourism demand and supply side in Auronzo di Cadore in the coming decades, its heterogeneous elements, the behavioural rules and their change in space and time (Balbi et al., 2013).

Results of the weighting procedure were compiled in real time in the mDSS5 tool, thus obtaining the final ranking of the strategies according to the preferences of each participant. This allowed participants to explore the diversity of opinions, trade-offs, and discuss possible compromise solutions.

1.4 Results

1.4.1 Outcomes of the first workshop

During the first workshop, stakeholders refined the four proposed development directions, visualised as cognitive and spatial maps and highlighted fundamental and redundant aspects of each of them. In the maps reported in Figure 1.2 there appear the heterogeneous areas of interest in which the main elements characterising the strategy ALTSKI may take place, as an example. We repeated the same exercise for the remaining directions of investments considered (B for more details). Little disagreement emerged on what elements should be included in each strategy.

Out of the list of possible key elements which characterise winter tourism destinations, there emerged that the factor ”traditional activities on the snow (downhill, cross-country skiing)” was given the highest score in terms of relevance for the attractiveness of tourism destinations, whilst the factor ”artificial snow-making” received one of the lowest. In the discussion that followed, stakeholders did not seem to consider the possibility of making artificial snow an asset for a destination. They agreed on the one hand that the destinations should diversify, but manifested a scarce consideration of possible effects of global warming. Moreover, the following results emerged from the SWOT analysis, which allowed refining the strategies further:

- An objective agreement on the idea of a re-organisation of the tourism sector with a better valorisation of the uniqueness of the Municipality’s territory
- A general awareness on the necessity to differentiate the tourism offer: for instance, alpine-skiing in Misurina and other activities in Auronzo di Cadore and other lower-lying areas
- An overall concord on the need to differentiate the category "tourist" to respond more adequately to varied needs: foreigners for spring breaks, families for weekends, off-piste skiers, cross-country skiers, tourists with second-homes, and non-sporty mountain lovers.

For more details on the SWOT, analysis see B. The list of indicators suitable to the evaluation of the strategies derived from both priorities identified by stakeholders before and during the first workshop and our judgements developed throughout former project activities and literature reviews. For instance, uniqueness and beauty of the territory was often mentioned by participants, hence our stress on those indicators with environmental relevance, whether direct or indirect. Competitiveness of the neighbouring resorts, another primary concern of our stakeholders, was considered in multiple ways. On the one hand, the innovation criteria is a semi quantitative expert judgment that encapsulate the perspective of being different from

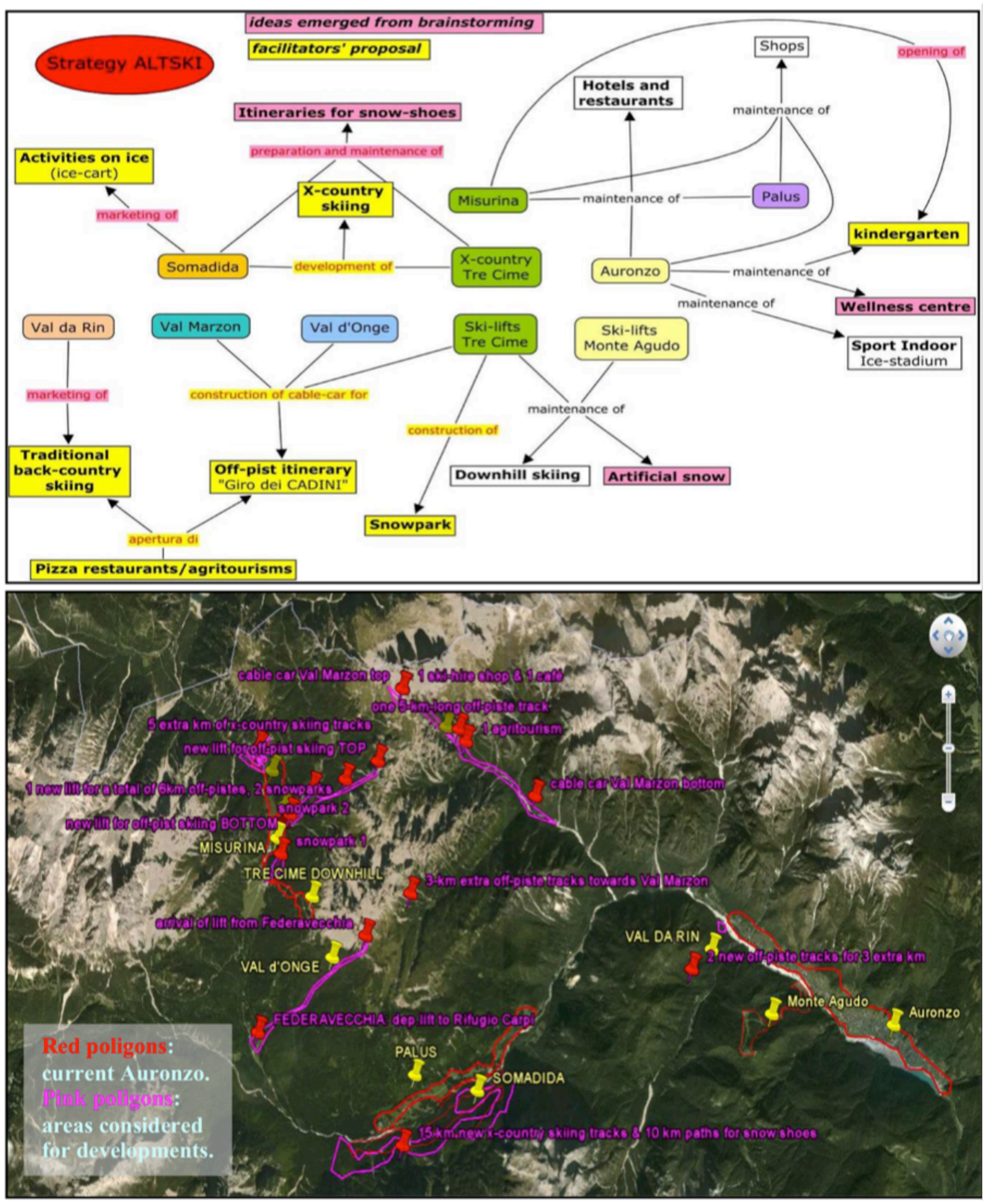

FIGURE 1.2: Creative System Modelling: Cognitive mapping (top) and spatial mapping (bottom) of areas of interest of ALTSKI

competing destinations thus attracting different tourists. On the other side AWS1.0 considers the competition pressure of neighbouring destinations in the computation of its different outputs (for details about AWS1.0 see Balbi et al. (2013)).

The final 15 indicators selected were investment costs, energy consumption, tourists' expenditure, total garbage disposal, water consumption for snow-making, air quality, Sites of Community Importance (protected areas, according to the EU Habitats Directive 92/43/EEC) affected, erosion, arrivals, tourists' peaks, synergies with summer tourism, long term sustainability, innovativeness, labour opportunities in the tourist sector, and visibility of skiing areas.

Given that the impact on the area of the strategies depended on their expected performance in the future, indicators, we computed the indicators' performances for the three different climate change scenarios (Current, A1B, B1), and their related storylines to simulate socio-economic developments. We quantified indicators both through data collection and with the support of modelling tools, namely (i) AWS1.0 for employment opportunities, energy consumption for snow making, number of tourists, and tourism peak; and (ii) system dynamics simulations for erosion . In addition, we conducted spatial analysis to compare the environmental impact of the strategies, particularly in terms of protected areas affected, erosion, and visibility. When a quantitative evaluation was not possible, experts' qualitative judgement was collected and averaged - for long term sustainability, innovativeness, and synergies with summer tourism. For additional information on the computation of indicators, see B.

Before the second workshop, we normalised the values resulting for each indicator (in each scenario) and build a non-dimensional Evaluation Matrix (EM). The 15 normalised indicators were utilised to give quantification to seven composite criteria, which whilst still capturing the various dimensions of sustainability and maintaining a functional link to the indicator based assessment, facilitated the communication with stakeholders. The seven criteria were:

1. Environmental impact (e.g. the strategy improves the environmental quality of the location)
2. Economic costs with environmental relevance (e.g. the strategy implies economic values which negatively impact the environment)
3. Impact on local economy (e.g. the strategy improves the local people's revenues)
4. Impact on the tourist sector (e.g. the strategy attract more tourists but in a more distributed way)
5. Strategy feasibility (e.g. the realisation of the strategy is not impeded by major barriers)
6. Innovativeness (e.g. the strategy add elements of novelty to the traditional tourism perspective thus making the destination unique)
7. Long term sustainability (e.g. the strategy well balances the economic, social and environmental dimension also in the long term, after 2030).

In order to avoid involving stakeholders in technical details of the various indicators while keeping the exercise feasible in a reasonable time at the workshop, we obtained weights for the seven criteria and then rescaled and equally subdivided amongst the pertaining indicators as reported in Table 1.3. In other words, the criteria framework represents the interface between the more quantitative assessment and its subjective and social value-based component.

TABLE 1.3: From collective weighting of evaluation criteria to single indicators' weights

Criteria	Criteria's average scores*	Indicators	Indicators' scores**	Indicators' weights***
Effects on environmental quality	19.06	Erosion	19.06	8.17
		Air quality	19.06	8.17
		Visibility	19.06	8.17
		Water consumption for snow-making	19.06	8.17
Economic costs with environmental relevance	8.25	Total garbage disposal	8.25	3.54
		Energy consumption	8.25	3.54
Effects on local economy	26.31	Tourists' expenditure	26.31	11.28
		Labour tourism sector	26.31	11.28
Effects on tourism sector	16.19	Arrivals	16.19	6.94
		Tourism peaks	16.19	6.94
		Synergies with summer tourism	16.19	6.94
Strategy feasibility	9.19	CSI affected	9.19	3.94
		Investment costs	9.19	3.94
Long term sustainability	11.56	Long term sustainability	11.56	4.95
Innovativeness	9.44	Innovativeness	9.44	4.05
Sum	100			100

*Scores collected from participants are summed and averaged, by Simple Additive Weighting;
** Each of the indicators composing a criteria gets the score attributed to that criteria;
*** The individual scores are rescaled so that their sum will again be 100.

For the same sake of simplification and facilitation of transparency and communication with local actors, the Simple Additive Weighting (SAW) was used as multicriteria aggregation rule, which multiplies the normalised values of each indicator by its weight and then sums them up for each strategy. Weights were inserted in mDSS5 as aggregated, but also divided per category of participants.

The preferred strategy, according to group's aggregated weighting, was BYDSNW for the three climate scenarios (see B for more details). The relative contribution of the performance of each indicator to the overall score of a strategy is visualised via their height in the histograms (Figure 1.3). BYDSNW seems more suited for Auronzo di Cadore, compared to the others, due to several factors, but mainly for: (1) long term sustainability; (2) synergies with the summer tourism; and (3) capacity of incrementing the tourist arrivals and their expenditure, and in turn increase labour opportunities. The latter, for instance, is due to the fact that BYDSNW is the most efficient strategy in terms of building on the existing bulk of tourists and attracting new typologies which are more prone to spend in loco, whereas ALTSKI and SKINT tend to substitute Auronzo di Cadore's primary tourists (i.e. less active tourists) with competing tourists' typologies (i.e., more active tourists) rather than building on them.

ALTSKI is robustly performing as the second-best option, proving nearly as effective as BYDSNW in the Current and B1 climate scenarios. Yet, a more extreme future with considerable less snow precipitations (A1B) may significantly penalise this strategy. A SKINT strategy results to be particularly deficient in terms of investment costs and environmental impacts, but it would be desirable in terms of creation of job opportunities, increase of tourists' expenditure and containment of seasonality.

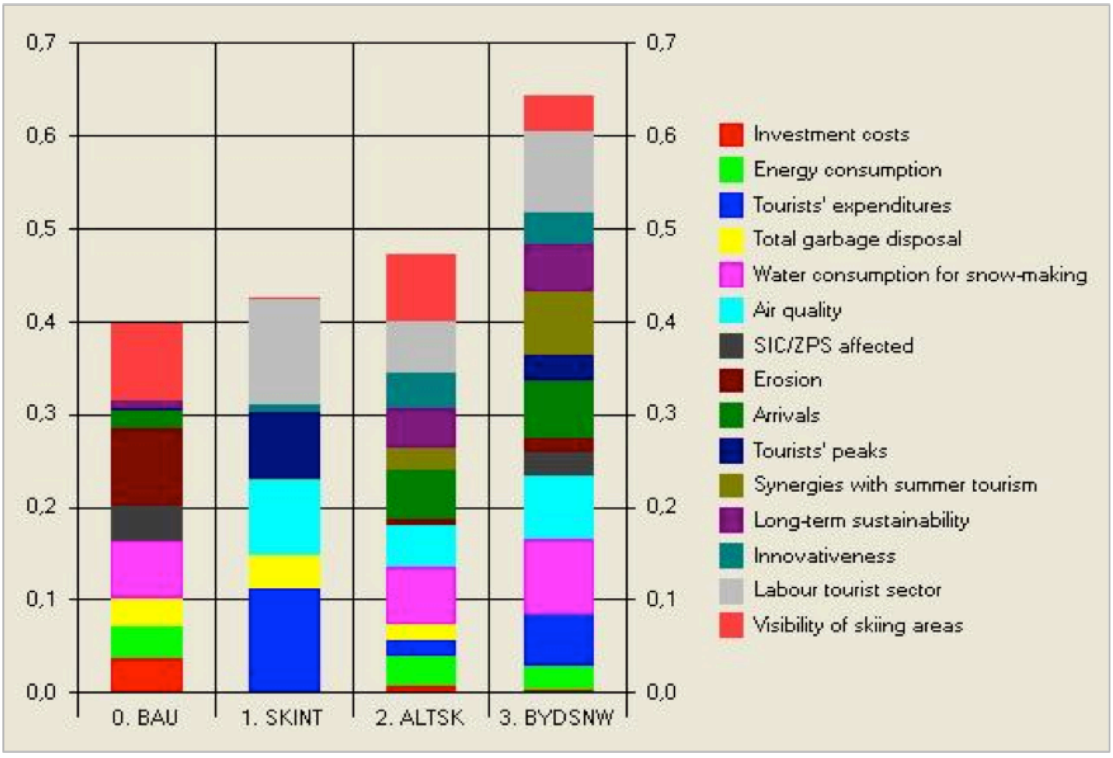

FIGURE 1.3: Outcomes of strategies' evaluation for the scenario A1B, with the SAW aggregation rule

These results did not seem to surprise the majority of participants, notwithstanding the fact that during the first workshop the participants attributed the highest importance, in terms of influence in the choice of the destination, to snow-related activities. Hence, one may conclude that the perception on the desirability of, and the value attributed to, snow-related activities changed throughout the participatory process as a consequence of merging local and scientific knowledge and structuring the information in an indicator-based framework. The methodology applied facilitated the dialogue on the future of Auronzo di Cadore on sustainability grounds that before the workshops seemed unconceivable. One example is a possible move away from the development of ski intensive activities in favour of an alternative focus on non-downhill skiing. Until the project started, the former claimed more favour, despite obvious drawbacks, such as strong competition by neighbouring municipality and unfeasible concoction to more popular resorts. This final phase dedicated to the exploration of the results and effects of subjective judgements stimulated very active and concrete discussions by the stakeholders. They could clearly visualise the contributions of quantitative assessment and subjective preferences to the overall performances of the strategies. An important driver for the discussion was also the possibility to visualise both average results and individual/ and category ones.

1.5 Discussion

1.5.1 Considerations on the results of the exercise

Investing on the development of winter tourism away from activities based on snow appeared to be the preferable solution for a destination with the characteristics of Auronzo di Cadore, in view of potential future climatic and socio-economic trends. A BYDSNW strategy should however be linked to a project for the enhancement of local public transportation as the in-destination transfer needs of tourists may significantly increase. An ALTSKI strategy could successfully mediate between the lifts industry, which has already invested a lot in the past, and the possible futures that the local winter tourism will have to face.

Apart from the snow-related risks and costs, a SKINT strategy could undermine the bulk of Auronzo di Cadore's traditional tourism rather than building on it, turning such a choice into a strategic error in the medium to long term. Lift operators should rather take into account the optimisation of the existing downhill skiing infrastructure and the related services, since Auronzo di Cadore is certainly well characterised to focus on traditional skiing families and BYDSNW activities, whilst Misurina could well become a point of reference for the ALTSKI emerging paradigm.

Given the already high cost of energy for the accommodations compartment, in particular, local planners should focus on this issue before any new investment is made. A sound reflection about renewable energy based heating systems might be appropriate and could be part of a new marketing strategy to characterise the destination.

Even without investments in new structures and facilities, a strategy may be to focus on other issues that have not been considered here such as the development of a public transportation linking Auronzo di Cadore to Misurina, or the enhancement of the standards of hospitality through investments in training. All development strategies other than a BAU approach have the merit of improving the tourism multi-seasonality.

It must be acknowledged here that the framework of the assessment is limited by the fact that the four strategies considered were somehow extreme alternatives. They could unlikely be implemented in a self-standing manner, while a possible real world solution could arise from the integration of elements belonging to different strategies. Similarly, the three scenarios utilised are unlikely to reflect the full range of possible futures. However, since the objective of the exercise was to stir discussion on the topic of winter tourism development, this proved to be a successful way to approach the issue. The final discussion touched on the need to extrapolate some features from each strategy to create an implementable combination.

1.5.2 Considerations on the participatory approach

The ClimAlpTour workshops provided the first opportunity for having around the same table all the main representative actors of the local community in a collaborative setting. The objective was to set up a stimulus to initiate an innovative approach to planning for winter tourism development with consideration of possible local effects of climate change trends, and this was largely achieved.

One of the most significant outcomes was the awareness of stakeholders of the need of defining a commonly agreed and innovative trademark for "Auronzo di Cadore in winter" and act accordingly. Although economic rationale scored one of the highest levels of importance, stakeholders were deeply aware of the importance of environmental indicators. In the discussion that followed the exercise, the uniqueness of the local landscape and the obligation to promote the UNESCO heritage brand, remained at the forefront. In terms of the preferred strategy, as expected, participants agreed that the only option implementable would be a mixture of the strategies analysed.

Participation was intense and constructive. Stakeholders demonstrated awareness not only of current drawbacks and strengths of their tourism sector, but they were also open to explore the future risks related to climate change. In addition, they showed great creativity in identifying tailored strategies for a better future and also openness to evolve and change their consolidated paradigms, with the common aim of contributing to the sustainability of local community and thus to their own future welfare.

The participatory techniques adopted limited the unavoidable tensions between different perspectives. As a consequence, a wide variety of viewpoints emerged around the topic of winter tourism management, particularly spurred by the analysis of the outputs of the DSS tool, and especially by the discussion on the histograms that resulted from the weight elicitation procedure.

These participatory techniques facilitated a longer term discussion than the usual short term political and administrative strategies. The pilot exercise carried out in Auronzo di Cadore in specific had an exploratory character and as such, it did not pretend to lead to immediate concrete implementation plans. However, the collaborative attitude developed through the participatory process culminating in the two workshops reported above has clearly left an impact on the local community and its main socio-economic actors, as also highlighted by the participants' feedback. This will be a key, if not the utmost, factor for facing future challenges in the Municipality of Auronzo di Cadore.

Finally, the results of the workshop highlight that a preference towards a less intensive infrastructural development strategy is gaining grounds as a likely way to achieve environmental, social, and economic sustainability. The identification of the best or optimal solution to be adopted by local decision makers was not the ultimate objective of the exercise, nevertheless an alternative mode of development *won*, despite the fact that in the beginning a traditional winter tourism development seemed to be advocated (downhill skiing, artificial snow,..).

1.6 Conclusions

The observation of what happened to the Alpine glaciers over the last century is already demonstrating that the sustainability of the current socio-economic model of development of many tourism destinations having snow as the main driver of success should be reconsidered. Climatic change in the Alps is therefore not just a matter of scientific debates about uncertain projections in the far future, but one of the main variables to be considered in nowadays planning activities, together with the other usual driving forces of tourism, such as economic and demographic trends.

Whilst it is evident that our capabilities for providing economic agents with reliable future projections or even predictions is still very limited, it is also quite clear that there exist skills and tools, which could significantly improve current efforts to plan local development of Alpine communities, despite future uncertainties. Discussing climate change within the frame of local sustainable tourism stimulated the involved actors to rethink the established paradigms and solutions, with proactive contributions from different perspectives, which did not have previous traditions of collaboration within participative processes.

Participation is needed for several reasons within this context, above all because sustainability policies frequently have multiple objectives, which cannot be optimised simultaneously (e.g. tourism inflows and environmental quality). This is an inherent characteristic of the problem at stake: what does sustainable tourism mean? How much environmental quality can we give up to improve the economics of tourism? Therefore, there emerges the need to look for compromise solutions, i.e. the balance between conflicting incommensurable values and dimensions (Munda, 2004).

Methodologically sound participatory approaches with the support of Information and Communication Technologies (ICT), such as simulation models and decision support systems can also provide the exchange platforms and protocols between local knowledge, interest, views and preferences and scientific approaches allowing for quantitative assessment in a transdisciplinary setting.

The approach described in this paper, which allowed to integrate quantitative scientific approaches (e.g. ABM and system dynamic modelling) with qualitative expert knowledge and stakeholders' views and preferences (e.g. ranking and weighting exercises), proves particularly effective for Auronzo di Cadore, but also opens scope for its broader applications in other Alpine destinations and other development contexts, beyond winter tourism adaptation strategies. After the pilot activities in Auronzo di Cadore, the same approach was adapted to be implemented in similar contexts also in four other cases in Italy and Slovenia.

Moreover, all the ICT tools utilised for the implementation of the NetSyMoD approach are freely available for download from the Internet and therefore, more and different uses are possible in the near future. Further developments are currently in progress to provide a new internet based opportunity for the management of the process, thus bringing the participatory process into a new e-participation context (Bojovic et al., 2012), which may increase the potentials of applicability of the proposed approach.

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Chapter 2

From The Exploration Of Farmers' Autonomous Adaptation To The Design And Evaluation Of Planned Interventions In The Veneto Region, Italy

This chapter is a paper written by Laura Bonzanigo[a,b]; Dragana Bojovic[a]; Alexander Maziotis[c]; Carlo Giupponi[a,b]. This paper has been accepted by the Journal Of Regional Environmental Change. We are waiting for its publication.[1]

2.1 Introduction

Agricultural productivity is sensitive to global change and to climate variability (Anwar et al., 2012, Boko et al., 2007, Fischer et al., 2005, van Vuuren et al., 2007). Although the climate impacts remain ambiguous, there is an increasing call for agricultural water management to adapt to climate change. Adaptation to climate change refers to "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities" (Parry et al., 2007).

Adaptation can be planned or autonomous. Planned adaptation is the result of a deliberative policy decision. In agriculture, planned adaptation typically includes improved irrigation infrastructures, increasing water supply by building reservoirs, and investment in new climate services. Instead, autonomous adaptation comprises those individual initiatives triggered by actors' perceptions of a changing climate. Common autonomous adaptation measures in agriculture include on-going adjustments of farm management, typically shifting sowing time,

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changing or diversifying crop varieties and livestock species, improving nutrient and pest control management, and varying water management technologies or introducing irrigation (Anwar et al., 2012, Bradshaw et al., 2004).

An increasingly important question for mainstreaming climate change is whether agricultural adaptation can be expected to occur autonomously or whether government intervention has a role in promoting the process, and if so, what shape this role should take (Maddison, 2007). Studies show that autonomous adaptations alter significantly the impacts of climate change, by reducing negative shocks on yields and income (Leclère et al., 2013, Reidsma et al., 2010).

Yet farmers have always been adapting to changing conditions and it may be difficult, if meaningful, to isolate whether climate change is the main driver behind their adaptations. Most climate-proofing measures overlap with existing programmes and policies for agricultural development, food security, and integrated natural resources management (Bokel, 2009). Farmers' adaptations are the results of the perceptions of multiple signals (climate, market, policy), integrated within the same decision making process for tactical and strategic choices in the farm. Thus, government interventions need not consider climate change adaptation in isolation, but as an opportunity to strengthen further the agricultural systems.

The range of socio-economic and environmental factors that influence farmers' choices indicates where it would be most appropriate to invest in adaptation, hence policy makers should devote special efforts to their identification (Deressa et al., 2009). The knowledge of what beneficiaries need the most, how, and why, can direct policies to targeted interventions. Overall, this can inform the prioritization of plausible investments, for a maximisation of the available resources.

However, at least in Europe, the majority of both studies on impacts of climatic variability on agricultural productivity and policies for rural development fails to consider autonomous adaptation possibilities (Leclère et al., 2013). Some studies on autonomous adaptation exist for African case studies that try to identify drivers and constraints for local adaptation (Deressa et al., 2009, Malik et al., 2010, Nhemachena and Hassan, 2007). Even when they account for autonomous adaptation, these studies rarely combine the determinants of autonomous adaptation with the design of rural policies. Separating autonomous and planned adaptation misses the benefits of collecting cross-referenced information via an enhanced and iterative communication between top-down and bottom-up policy-making.

Several regions around Europe are designing their new Rural Development Plans for the forthcoming 2014-2020 programming period (European Commission, 2005). Key priorities are a more efficient use of water in agriculture to deal with more frequent water scarcity and the identification of priority areas for mainstreaming climate change adaptation (European Commission, 2013a,b). Policy makers plan to achieve this objective through, amongst others, the development of ad-hoc methodologies for the identification of regional strategies for a better use of water, which should be built upon a strong knowledge base on the state of practice in the region (Regione Veneto, 2012).

This study argues that information on autonomous adaptation should shape governmental intervention, supporting these efforts in the Veneto Region of Italy. Regional experts recommend particular care in coordinating actions at regional and farm level, in an effort to avoid loss of policy efficacy (Coldiretti, 2013).

Yet, we are not aware of any regional study that estimates on-going changes at the farm level or involves farmers in a prioritization of the policy-options available. We propose the use of eParticipation, a Multinomial Probit (MNP) model, and Multi Criteria Analysis (MCA) tools for collecting and processing information on adaptation measures, both already in place and expected to be promoted by policies. Via these tools, we evaluated the key drivers, constraints, and needs of autonomous adaptation in the Veneto Region. Our findings suggest key areas for policy intervention.

Therefore, the objective of this study is to join information on autonomous adaptation with the design and evaluation of planned intervention, in order to guide policy makers to mainstream climate change adaptation. The next section presents the case study area; Section 3 describes our methodology; Section 4 presents results and Section 5 summarises the policy messages; Section 6 concludes the paper.

2.2 The Veneto Region and the Rural Development Plan

The Veneto Region lays in the North-East of Italy, with a population of about five million people. The Utilised Agricultural Area (UAA) is 8,114 km^2, nearly half of its territory. 119,384 registered farms have an average size of 6.7 hectares (ha, ISTAT (2012)). The major crops are maize (33%), forage (24%), wheat (11%), vineyard (9%), soybean (8%), and horticulture (7%) (Veneto, 2011). More than 50% of the UAA is irrigated, with different methods and varying efficiency. The majority of farms still practice only emergency irrigation, with mobile pumps and irrigators (Zucaro and Povellato, 2009).

The main challenges that the Veneto Region's agriculture will face over the coming years relate to the maintenance of profitable farming activities while facing rising environmental constraints and increasing conflicts for water resources between different water users (agricultural, domestic, and industrial). In recent years, the area has already been experiencing more frequent droughts and heat spells. Climate models show that annual temperature may increase by 1 to 2°C, and availability of the water resources, including precipitation and runoff, may decrease by 5 to 15% by 2025, according to some climate projections and with all due uncertainties (Kamari et al., 2008).

The current proposal for the Rural Development Programme sets out to address these challenges, in accordance with European regulations (European Commission, 2005). It proposes the efficient use of resources and the transition to a low-carbon and climate resilient food production and forestry as one of the priorities, putting particular emphasis on a more efficient use of water, to reduce the vulnerability of the agricultural system. Furthermore, among the priorities, the Programme sets the transfer of knowledge and innovation and social inclusion. In that vein, and as supported by the Veneto (2011), the Programme envisages the improvement of information services, with a focus on internet diffusion. It aims at delivering the provision of Internet access to all the citizens, promoting eGovernance.

2.3 Methodology

For the identification of regional adaptation measures to increase the water use efficiency in face of climate and other challenges, we tested the usability and the added value of an eParticipation framework, an online approach developed by Bojovic et al. (2012), for the collection of:

- farmers' perceptions of change and the major adaptation measures in place (survey one);
- a multi-criteria evaluation of a portfolio of plausible policy options for the Rural Development Plan (survey two).

The first questionnaire aimed at collecting information on changes in farmers' practices due to broader changes. It inquired about present and expected changes in the environment, economy, policy, and society. It also analysed whether cropping practices and water management have already undergone some changes in recent years and whether farmers saw a need for adaptation due to variability in climatic conditions and other changes. The time frame of the questions referred to either the past 20 years, or the past 5 years. Instead, the second online questionnaire had the primary aim to test the acceptability of the policy measures that the Region wanted to include into the RDP. The options proposed included also suggestions from the first questionnaire. These two surveys appeared as a link on an online AgroMeteorological Bullettin for two months in Summer 2011 and 2012, respectively. This period of the year was chosen because of the higher usage of the online Bullettin by farmers. The main users of the Bulletin are farmers. We analysed the key drivers and barriers of adaptation within the framework of a MNP model on the database collected during the first online survey. During the next cropping season we also sent the second survey's link to representatives of the ten Irrigation Boards in order to compare their priorities with those of the farmers. Then, finally, with the data collected during the second questionnaire, we were able to rank and compare farmers' and Irrigation Boards preferences towards possible adaptation policies in the agricultural sector.

2.3.1 The MNP Model for the identification of the key drivers of adaptation

The findings of the first questionnaire allowed us to identify the adaptation measures in place and farmers' preferences for further adaptation investments. Yet, we still did not know what drives farmers' choices of adaptation measures. We developed a MNP model to analyze the determinants of farmers' choice of adaptation strategies. The rationale is that the identification of drivers and constraints to autonomous adaptation highlights potential entry points for planned interventions.

Several studies in the past employed univariate models (probit or logit) or heckman sample selection models when the number of choices is two (whether to adopt or not, Bryan et al. (2009), Deressa et al. (2011), Fosu-Mensah et al. (2012), Kabubo-Mariara (2008)). Multivariate choice models are also employed (Nhemachena and Hassan, 2007, Piya et al., 2013) when the number of choices available is more than two by allowing the exploration of factors conditioning specific choices or combination of choices and also they allowing for self-selection and interactions between alternatives (Deressa et al., 2011).

The most commonly cited multivariate choice models in unordered choices are multinomial logit (MNL) and MNP models (Deressa et al. (2009), Gbetibouo et al. (2010), Hassan and Nhemachena (2008), Seo et al. (2009). However, the major limitation of the MNL model is the assumption of the practices to be mutually exclusive, i.e. the property of independence of irrelevant alternatives (IIA), which is not true in reality because a single farmer can simultaneously adopt more than one measure (Piya et al., 2013).

In such situations, the estimation of a MNP model is more appropriate Golob and Regan (2002), Nhemachena and Hassan (2007), Piya et al. (2013). Both MNL and MNP are appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies

(Hausman and Wise, 1978, Wu and Babcock, 1998) and are important for analyzing farmer adaptation decisions as these are usually made jointly (Ajao and Ogunniyi, 2011). Because a MNP model relaxes the IIA property and overcomes the shortfall of the MNL technique, it was employed in this study. The MNP model assumes that the error terms follow a multivariate normal distribution and are correlated across choices (Cameron and Trivedi, 2005). The MNP is frequently motivated using a latent-variable framework. The latent variable for the jth alternative, $j = 1, ..., J$, is

$$y_{ij} = x_i \times \beta_j + \epsilon_{ij} \tag{2.1}$$

where the $1 \times r$ row vector x_i includes the observed independent variables for the ith farmer, β_j are the parameters to be estimated and ϵ_{ij} are distributed independently and identically standard normal. The farmer chooses the alternative k such that:

$$y_{ik} \geq y_{il} \text{ for } l \neq k \tag{2.2}$$

Normalization of the variance-covariance of the error terms avoids the identification problem i.e. inconsistent answers for the probability of selecting a specific alternative k over a set of J alternatives (Cameron and Trivedi (2005) and the Appendix for more detail). Therefore, the choice probabilities are rather complicated expressions involving a $j - 1$ dimensional integral, so that maximum likelihood estimation using numerical integration is only possible with a limited number of alternatives (Verbeek, 2014).

Finally, the parameter estimates of the MNP model provide only the direction of the effect of the explanatory variables on the dependent variable. The estimates do not represent the actual magnitude or likelihood of investing in adaptation, which is instead expressed by the marginal effects for a continuous explanatory variable or the average effects for dummy variables. The marginal effects measure the expected change in probability of a particular choice being made with respect to a particular change in a given independent variable (Deressa et al., 2009).

In the case of dummy variables, the average effect measures the expected change in probability of a particular choice being made with respect to whether an individual has a characteristic or not (Jones, 2007). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients (Hassan and Nhemachena, 2008).

2.3.2 An online decision support tool, mDSSweb, for the participatory evaluation of planned adaptation options

The EC Guidelines on developing adaptation strategies (European Commission, 2013b) mainstream the added value of actors' involvement in discussing and deciding on criteria and their weightings for the prioritisation of adaptation options in order to select a set of options with a high level of acceptance.

We built an online decision support system tool,mDSSweb, and tailored it for the evaluation of adaptation options in the Veneto Region.The platform operationalizes MCA evaluation techniques to judge all options against their potential contributions towards a problem's solution, through the elaboration of selected criteria's values (for details on the development of the online tool, see Bojovic et al. (2012); and for details on mDSS, Giupponi et al. (2006)).

We selected a portfolio of plausible planned adaptation options based on the results from the online questionnaire and in consultation with regional policy makers and experts involved in the design of the Rural Development Plan:

A. To expand the capacity of water reservoirs (building new ones, rehabilitating old ones). This measure does not consider direct interventions on farm management, but we included it in the evaluation because it is currently in the agenda of the regional administration.

B. To support the reorganisation of the production system towards less water demanding crops;

C. To finance the installation of high-efficiency irrigation systems at the farm level (i.e. sprinkler or drip irrigation);

D. To enhance the existing information services for farmers (i.e. agro-meteorological bulletins); and

E. To promote new information systems to support farm management and in particular crop choice on an annual basis (i.e. seasonal forecasts).

We derived the criteria for the measures' evaluation from the interests and concerns expressed by the farmers in the first phase:

i. Contribution to farmers' income;

ii. Cost benefit effectiveness for society;

iii. Technical effectiveness for reducing vulnerability to climate change;

iv. Containment of conflicts over water resources between agriculture and other sectors;

v. Overall contribution to rural development;

vi. Contribution to environmental protection; and

vii. Practical feasibility.

The participants could evaluate the performance of each measure towards a given criterion via a Likert scale, with the possibility to select one of five options, from very good (5) to very poor (1). They could then weight the relative importance of each criterion. In order to characterise the respondents, we added to the multi criteria exercise three compulsory questions on farm location and size, main crops, and irrigation technologies in place.

2.4 Results And Discussion

2.4.1 Perceptions of change and adaptation strategies in the Veneto Region, Italy

The online questionnaire was a successful means for collecting information about farmers in the Veneto Region. In the two months of the first online survey, we collected 587 completed

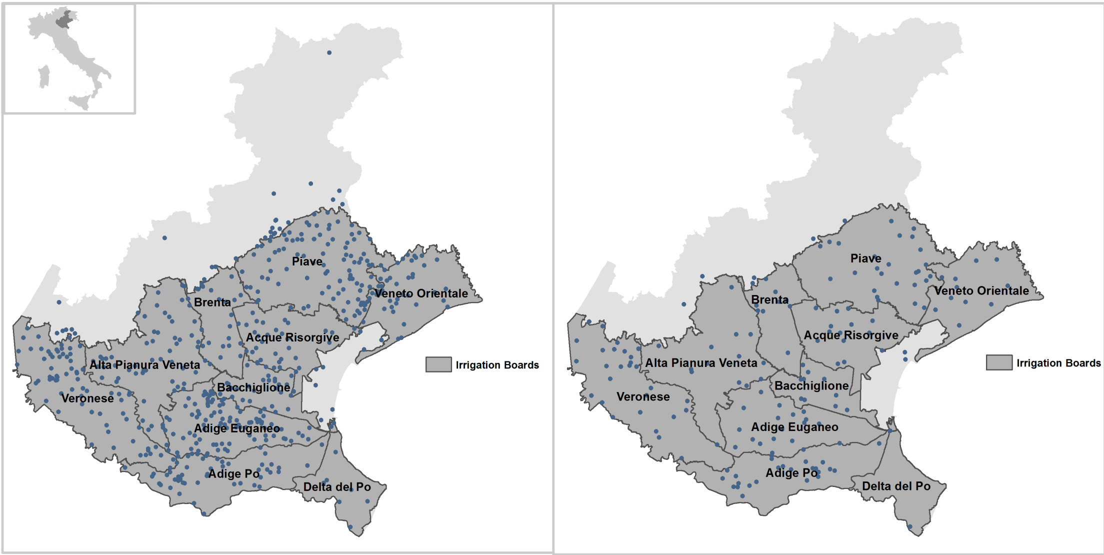

FIGURE 2.1: The sample's distribution. The answers of the two online surveys are well distributed spatially across the Veneto Region's agricultural area (marked in dark grey by the boundaries of the ten Irrigation Boards). On the left, the blue spots indicate the answers of the first questionnaire (aggregated per municipality), which was carried out in Summer 2011. On the right, the blue spots indicate the coverage of the second questionnaire, which was completed in Summer 2012.

questionnaires. Although self-selected - i.e. entirely voluntary, dependant on the Internet familiarity and proactivity of participants - the sample was well distributed, both geographically (Figure 2.1) and socio-economically, including farmers from different age-groups and with different educational backgrounds. Moreover the sample presents farms with different UAAs, agricultural practices and levels of income-sharing between agriculture and other activities.

Based on the data collected from these 587 farmers, this section briefly summarizes farmers' perceptions of climate change and the measures they consider appropriate to these changes.

Three quarters of respondents have adapted their farming practices to environmental, social, and economic drivers in the past five years. The diversification of cropping patterns, changes in land management techniques and irrigation technologies are the most frequent adaptation measures, whereas shifting sowing dates and changing irrigation turns through agreements with the Irrigation Boards are the least practiced (Table 2.1). 87% of those who have not adapted still claim to be aware of environmental changes and 84% of those declare that they will need to adapt their agricultural practices in the near future.

About 90% of the respondents declared to have observed one or more significant environmental changes in the past ten years (Table 2.1). The main concerns for the next 15 years include economic changes (94%), followed by environmental changes (79%), and social (63%) and individual (56%) changes. This is a significant sign that any manifestation of farmers' adaptation not only depends on perceptions of climate change. It is instead the result of combined reactions to the signals of multiple drivers and pressures, which should be carefully considered when planning rural development policies.

TABLE 2.1: Farmers' perceptions of local environmental changes and main adaptation measures

Past Environmental Changes	%	Adaptation Measures	%
Seasonal Shifts	50	Crop Diversification	32
Precipitation	47	Soil Management	29
Temperature	39	Introduction of Integrated Pest Control	29
Drought Frequency	36	Irrigation Technologies	28
Flood Frequency	14	Crop Change	23
Biodiversity Losses	10	Water Volumes	24
Water Availability	8	Weed Control	22
		Sowing Times	16
		Changes in Irrigation Turns (Irrigation Boards)	16

Total sample: 587 respondents. Note that we imposed no limit on the number of changes perceived or adaptation measure that could be selected

2.4.2 Empirical specifications of the variables of the MNP model

The dependent variable in our empirical estimation is the choice of an adaptation package. For analytical simplification, we grouped the adaptation measures we asked about in the first survey into two broader categories. One included crop and soil management changes (*CSMC*: crop substitution, crop diversification, soil management changes, shifting sowing times, different strategies for weed control, and integrated pest control) and the other contained adaptation options for irrigation management (*IMC*: different irrigation turns, changes in allocation of water volumes, and modernisation of irrigation technologies).

Therefore, we divided farmers into four groups, according to the possible combination of adaptation strategies farmers could have adopted. According to the results of the first survey, 25% of farmers have not adapted (i.e., *CCAnone*). Of those who have adapted, 45% have modified only their crop and soil management (i.e., *CSMConly*); 15% have changed their irrigation management practices only (i.e., *IMConly*), and 40% have done both crop and water management changes (i.e., *bothCCA*). The *CCAnone* category was employed as the reference category. We chose the explanatory variables from data availability and literature. The recent literature on the adoption of new technologies and adaptation strategies in the agricultural sector highlights how a few socio-economic characteristics of the farm, such as age and education of the farmer, and institutional factors, such as climate information, usually determine autonomous adaptation (Below et al., 2010, Borsotto et al., 2008, Bryan et al., 2013, Defrancesco and Gatto, 2008, Deressa et al., 2008, Gbetibouo, 2009, Malik et al., 2010).

Hence, the explanatory variables for our study include socio-demographic information (age, education, percentage of income from agriculture), farms' characteristics (utilised agricultural area, crop production, and irrigation practice), farmers' perceptions over past (last ten years) and expected (next 15 years) changes in the environment, economy, policy, and society, and institutional factors, such as information on climate change, access to extension services. Deressa et al. (2009) present an extensive review of how these different variables may influence adaptation to climate change.

Explanatory variables can either be dummies (i.e. take value 1 if a farmer has a particular characteristic and 0 otherwise, such as for instance "sprinkler irrigation only"), or be inserted as aggregated categories (i.e. age, UAA, education, the percentage of income from agriculture, and irrigation structure). To allow for a flexible relationship between the adaptation packages and

TABLE 2.2: Description of independent variables

Explanatory variables	Mean	S.D.	Description
Age	2.675	0.843	Categorical(1)
UAA	2.775	0.906	Categorical(2)
Agricultural income	2.693	1.342	Categorical(3)
Maize	0.500	0.500	Dummy, 1 if there is 0 otherwise
Vineyards	0.544	0.499	Dummy, 1 if there is 0 otherwise
Trees (excl.vineyard)	0.327	0.469	Dummy, 1 if there is 0 otherwise
Fourage (incl.grassland and soybean)	0.402	0.491	Dummy, 1 if there is 0 otherwise
Industrial crops	0.127	0.334	Dummy, 1 if there is 0 otherwise
Worried about future environmental changes	0.789	0.409	Dummy, 1 if there is 0 otherwise
Irrigated farm	1.124	0.740	Categorical(4)
Sprinkler irrigation only	0.287	0.453	Dummy, 1 if there is 0 otherwise
Drip irrigation only	0.159	0.366	Dummy, 1 if there is 0 otherwise
Mixed irrigation system	0.213	0.410	Dummy, 1 if there is 0 otherwise
Perception of past temperature changes	0.458	0.499	Dummy, 1 if there is 0 otherwise
Perception of seasonal shifts	0.584	0.493	Dummy, 1 if there is 0 otherwise
Perception of changes in biodiversity	0.112	0.315	Dummy, 1 if there is 0 otherwise
Perception of changing water availability	0.096	0.294	Dummy, 1 if there is 0 otherwise
CCA necessary in the future	0.870	0.336	Dummy, 1 if there is 0 otherwise
Information on climate change (useful and available)	0.349	0.477	Dummy, 1 if there is 0 otherwise
Information on new techniques (useful and available)	0.420	0.494	Dummy, 1 if there is 0 otherwise

(1) where 1=<35 years old ,2=35-45 years old, 3=46-60 years old, 4=>60 years old;
(2) where 1 = less than 1 ha, 2 = from 1 to 5 ha, 3 = from 5 to 20 ha, 4 = more than 20;
(3) where 1=<25%t of income from agriculture, 2= 25-50%, 3= 50-75%, 4= >75;
(4) where 0 = no irrigation, 1 = only emergency irrigation, 2 = structured irrigation.

the categorical variables (Kebede and Adane, 2011, Verbeek, 2014), we grouped the categorical variables into as many categories as those utilised for their identification in the questionnaire. For instance, we divided age into four groups: under 35 (*age1*), between 36 and 45 (*age2*), between 46 and 60 (*age3*), and above 60 (*age4*) years old (Table 2.2).

This division into categories allows the analysis to capture, and give more emphasis to, the variety of the sample. Although several studies in the past used both education and age as proxies for farmer's demographic characteristics, we dropped education from the final model specification due to multicollinearity among the socio-demographic variables and its low statistical significance. Therefore, we maintained only age, UAA, the percentage of income from agriculture, and irrigation infrastructure as proxies for, respectively, farmers' experience, and the size and structure of the farm. To estimate the MNP model for this study we normalized one category, which is normally referred to as the "reference state", or the "base category" (Deressa et al., 2009). In this study, we employed the *CCAnone* category as the reference state. Moreover, we omitted from the models one category for each categorical variable in order to avoid the "dummy variables trap" that would create perfect collinearity in the regression models if a dummy variable were included for every category (Jones, 2007, Verbeek, 2014). In this study, *age1, UAA1, agrIncome1* and *irrigation0* define the "reference individual", a farmer who is under 35 years old, with a farm less 1 ha, income from agriculture less than 25% and with no irrigation.

Together, the reference state and the reference individual are the constant term of references for the outcomes of the model. The estimated coefficients should be compared with the reference category, namely both *CCAnone* and the reference individual (*age1; UAA1; agrIncome1*, and *Irrigation0*). For instance, looking at the qualitative effects (Table 2.3, Regression) from the regression estimation of *CSMConly* for the UAA, classes 2, 3 and 4's positive coefficients signifies that they are more likely to adopt this adaptation package, compared to the reference farmer who is in UAA1. A different pattern emerges for age, whose reference category is a farmer under the age of 35. Although not statistically significant, the qualitative effects show that those who are between 36-45 and 46-60 years old are less likely to select *CSMConly* than those farmers under 35, whereas those who are above 60 are more likely to choose this strategy than the younger ones.

2.4.3 MNP Model's Results

In the initial run, we added all explanatory variables, but several of them were dropped as not significant and being highly correlated to each other. We ran two tests to justify the drop of redundant variables, the Variance Inflation Factor (VIF) and the Ramsey specification test. The VIF test for all the explanatory variables was 1.85, which means that there is no issue of multicollinearity. The Ramsey test failed to reject the null hypothesis that the model has no omitted variables, with F taking a value of 0.64 and probability of 0.5885. Therefore, there is no issue of multicollinearity and misspecification.

Therefore, the final choice of the explanatory variables for the MNP application was first run using Ordinary Least Squares (OLS) estimation and further tested for multicollinearity and misspecification.

As mentioned above, however, MNP parameter estimates do not express the magnitude of change. Although Table 2.3 reports both regression and marginal values, the discussion focuses on the latter. Below there follows an overview of the most significant outputs of the MNP model.

Utilized Agricultural Areas

Farm size is a relevant determinant of adaptation. The smallest farms (<1 ha) are more likely to introduce irrigation management changes than larger ones. On the contrary, the positive signs in *CSMConly* show that farms with more than 1 ha are more likely to adopt this package than the small farms, by 36.9, 26.6, and 34.8% respectively.

Agricultural income

The percentage of farmers' income that derives from agriculture has a positive and significant impact on *bothCCA* adaptation package: an increase in farmers' income reliance on agriculture augments the probability that they would adapt in an integrated manner by about 20%. It is unlikely that a farmer whose livelihood depends on agriculture would adapt in a mono-criterial fashion, but they are rather prone to adopt several measures at once.

TABLE 2.3: Results from the MNP autonomous adaptation model

	Regression						Marginal Values					
Explanatory Variables	IMConly		CSMConly		bothCCA		IMConly		CSMConly		bothCCA	
	C*	P*	C	P	C	P	C	P	C	P	C	P
age2	-0.594	0.184	-0.349	0.363	-0.319	0.427	-0.048	0.286	-0.034	0.703	-0.015	0.855
age3	-0.427	0.309	-0.259	0.478	-0.111	0.771	-0.042	0.397	-0.040	0.639	0.024	0.758
age4	-0.112	0.824	0.111	0.795	0.258	0.574	-0.032	0.524	0.004	0.969	0.060	0.551
UAA2	-0.243	0.560	***1.309***	0.001	0.301	0.479	***-0.109***	0.004	***0.369***	0.000	-0.097	0.273
UAA3	-0.072	0.875	***1.094***	0.013	0.529	0.240	***-0.092***	0.064	***0.266***	0.019	-0.009	0.928
UAA4	-0.529	0.370	***1.404***	0.006	0.677	0.194	***-0.138***	0.000	***0.348***	0.005	-0.023	0.838
Agricultural income2	0.636	0.139	0.205	0.574	***0.931***	0.017	0.032	0.595	-0.112	0.156	***0.203***	0.030
Agricultural income3	-0.062	0.903	0.163	0.665	0.449	0.281	-0.036	0.477	-0.013	0.893	0.105	0.297
Agricultural income4	0.178	0.593	0.085	0.751	***0.837***	0.005	-0.018	0.666	-0.094	0.151	***0.203***	0.001
Maize	-0.435	0.163	0.300	0.212	0.404	0.115	***-0.100***	0.012	0.065	0.273	0.087	0.109
Vineyards	**-0.502**	0.060	-0.249	0.261	-0.301	0.194	-0.045	0.180	-0.007	0.902	-0.024	0.621
Trees (excl. vineyard)	0.047	0.868	0.354	0.136	***0.670***	0.007	-0.043	0.166	0.012	0.834	***0.131***	0.015
Forage (incl. grassland and soya)	0.301	0.342	0.215	0.407	0.104	0.703	0.027	0.510	0.034	0.587	-0.015	0.798
Industrial crops	0.722	0.114	0.057	0.873	0.012	0.976	0.129	0.126	-0.040	0.624	-0.046	0.521
Worried of future environmental changes	0.4872	0.116	0.049	0.838	**0.478**	0.073	0.043	0.185	-0.071	0.251	**0.095**	0.069
Irrigated farm1	0.477	0.122	0.209	0.393	***1.560***	0.000	-0.017	0.644	***-0.170***	0.006	***0.364***	0.000
Irrigated farm2	0.332	0.336	0.112	0.686	***1.568***	0.000	-0.037	0.339	***-0.202***	0.002	***0.404***	0.000
Sprinkler irrigation only	-0.393	0.197	0.042	0.868	-0.153	0.567	-0.049	0.127	0.055	0.375	-0.029	0.592
Drip irrigation only	**-0.628**	0.100	-0.228	0.449	-0.084	0.793	**-0.063**	0.059	-0.028	0.706	0.032	0.660
Mixed irrigation system	-0.441	0.167	-0.099	0.710	-0.307	0.286	-0.041	0.214	0.033	0.628	-0.049	0.406
Perception of past temperature changes	-0.275	0.278	***0.397***	0.053	-0.137	0.536	**-0.057**	0.064	***0.156***	0.002	-0.075	0.102
Perception of seasonal shifts	0.103	0.682	-0.032	0.877	0.199	0.369	0.008	0.799	-0.042	0.411	0.052	0.266
Perception of changes in biodiversity	0.361	0.392	***0.758***	0.031	0.497	0.178	-0.019	0.666	**0.142**	0.071	0.005	0.948
Perception of changing water availability	-0.182	0.704	0.154	0.681	0.574	0.130	-0.054	0.168	-0.031	0.704	**0.149**	0.074
CCA necessary in the future	-0.042	0.905	0.345	0.249	0.281	0.370	-0.042	0.428	0.073	0.309	0.034	0.599
Information on climate change	0.295	0.288	***0.525***	0.021	***0.706***	0.004	-0.021	0.510	0.046	0.396	***0.105***	0.044
Information on new techniques	***0.846***	0.001	***0.520***	0.016	***0.879***	0.000	0.052	0.110	-0.010	0.844	***0.125***	0.008
Constant	-0.606	0.427	***-1.944***	0.004	***-3.581***	0.000						
Diagnostics												
Base category	No Adaptation											
Number of observations	502											
Wald chi-square	159.71											
Log likelihood	-553.004											

Note: **Bold***(italic)*(underlined) significant at **10%***(5%)* (1%) probability values, respectively. [*C=coefficients; P=probability values

]

Crops

Our results suggest that on average, farmers are 10% less likely to adapt the *IMConly* adaptation package if they grow maize. This is not surprising as the majority of maize farms are already equipped with irrigation facilities, whereas other cereals and forage farms are generally only irrigated during heat and drought events. Growing trees (excluding vineyard) is instead a positive and significant indicator for the *bothCCA* adaptation package, as their presence in the farm increases the likelihood of a farmer to opt for this adaptation package by 13.1%. Fruit trees grow in the most temperate areas of the Veneto Regions, but there too in recent years farmers suffered a decrease in water availability. The marginal impact of the other crops selected for the model is not significant.

Irrigation system

Having access to irrigation, even if only with mobile structures, significantly increases the likelihood of opting for the *bothCCA* adaptation package, respectively by 36.4 and 40.4% in farms with emergency and structured irrigation, compared to those with no access to irrigation. Let us remember that the water management package included not only high-efficiency irrigation technologies, but also changing irrigation turns and varying water volumes applied. This may explain why the likelihood of choosing the *bothCCA* adaptation package is very high also amongst those farmers with a structured irrigation already (48.9%). Having installed drip irrigation only decreases by 6.3% the likelihood of the adoption of the *IMConly* adaptation package. Again, this is consistent as drip irrigation already reduces significantly the water volumes needed and the dependency on irrigation turns, as water is stored in reservoirs. Moreover, again, it is unlikely that farmers would adopt one measure only in isolation.

Awareness of future changes

Concerns about further environmental changes significantly increase the likelihood of investing in *IMConly*. It is a more medium to long-term investment than most crop and soil management changes, which can be modified more temporarily to respond to seasonal conditions. Nearly the entirety of the sample expects economic change, which could be a clear indicator that change in the Veneto Region depends primarily on market drivers. Yet, with a more in depth analysis of the single measures, rather than adaptation packages, there emerges that farmers concerned about economic change privilege crop changes (33%), more related to market trends, rather than crop diversification (23%), more related to a farm's sustainability. The opposite is true for those farmers who expect further environmental changes, of whom 34% diversify crops and 22% change their cropping patterns. However, since most farmers are aware of both changes, results suggest that mainstreaming climate change into rural development policies may reinforce also more general measures for economic development.

Perception of changes

Perception of past temperature changes reduces the likelihood of adapting to *IMConly* by 5.7%. In our sample, 75% of participants have access to at least emergency irrigation, hence this may have helped them protect their productivity against short-term temperature anomalies. This may also signify that farmers do not see these anomalies as part of longer trends of climate change. Perception of changes in biodiversity increases the likelihood of choosing *CSMConly* by 21.8%. This may be attributed to the fact that 22% of farmers have adopted integrated pest management and 29% new methods for weed control (Table 2.1), which are often coupled with more efficient irrigation technologies, for instance in case of fertigation, which is the application of fertilisers through irrigation. Those who believe that overall water availability is decreasing are 14.9% more likely to adopt *bothCCA*.

Access to information

Information on climate change and new techniques has a significant and positive impact on the likelihood of choosing all three adaptation packages (with probability levels between 0.000 and 0.021). Specifically, the likelihood of *bothCCA* increases by 12.5% with access to information on new techniques and by 10.5% with access to information on climate change. *BothCCA* thus seems the most long-term and sustainable option to adopt for decreasing the vulnerability of farms to (climate and other) changes.

2.4.4 Results of the online evaluation of policy measures

We collected 180 answers: 170 farmers and ten Irrigation Boards. We sent the questionnaire to the Directors of each of the ten Irrigation Boards of the Veneto Region. Although self-selected also in this second round, the farmers' responses are geographically distributed across the Veneto Region - all seven provinces and ten Irrigation Boards were covered (Figure 2.1). Moreover, the sample covers the different aspects of agricultural activity in the region, from lowland maize producers to highlands vineyard and other permanent crops, the various types of irrigation management, and the regional variability of farm sizes. The highest participation rates were in the Irrigation Boards of Piave (18.5% of all the responses), Veronese (17.3%), and Adige Po (16%). Higher participation in these areas might depend on both their drier weather and the dense presence of high water requiring crops (especially maize), which increases their vulnerability to climate change.

The preferred adaptation measure was investments in high-efficiency irrigation technologies (Figure 2.2). This preferred option remained consistent across our sample groups, even when looking at sub-categories (different farm sizes, and irrigation technologies). Spatially however, we could identify some sub-areas of preference. Figure 2.3 illustrates the spatial distribution of the winning answers. However, these spatial results should be considered with care as the number of answers varies per municipality. Overall, many respondents indicated that irrigation technology should be improved beyond the farm level too and indeed, the measure suggesting the use of reservoirs for water storage ranks as the second best.

High ranking of the measure on the use of reservoirs for flood retention and water storage was discussed in phone interviews, where some participants expressed concern that the installation of high-efficiency irrigation systems at the farm level is too costly a measure, and that for some municipalities securing water reserves is the priority. This policy is overall well accepted, and easy to justify politically, but it may induce conflicts with other stakeholders and in particular those who live close to the areas to be flooded (typically abandoned quarries). Farmers evaluated the shift towards less water demanding crops as the least appealing of the five options. Although it reduces the vulnerability to water scarcity, it requires important structural changes in farm management and it usually concerns less market-valuable crops. Nearly half (41%) of the preferences for this measure originates from farmers that practice

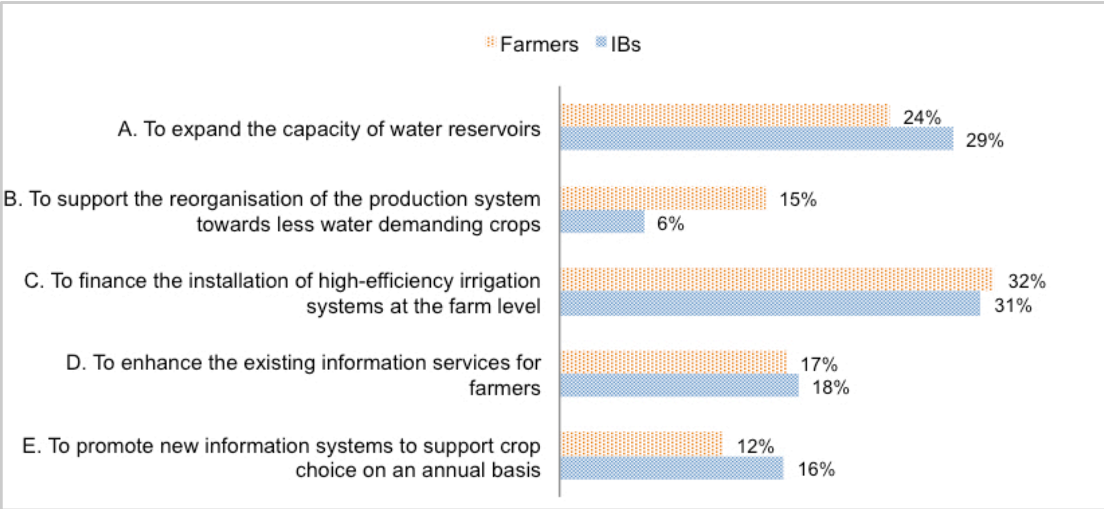

FIGURE 2.2: Farmers' and Irrigation Boards' preferences

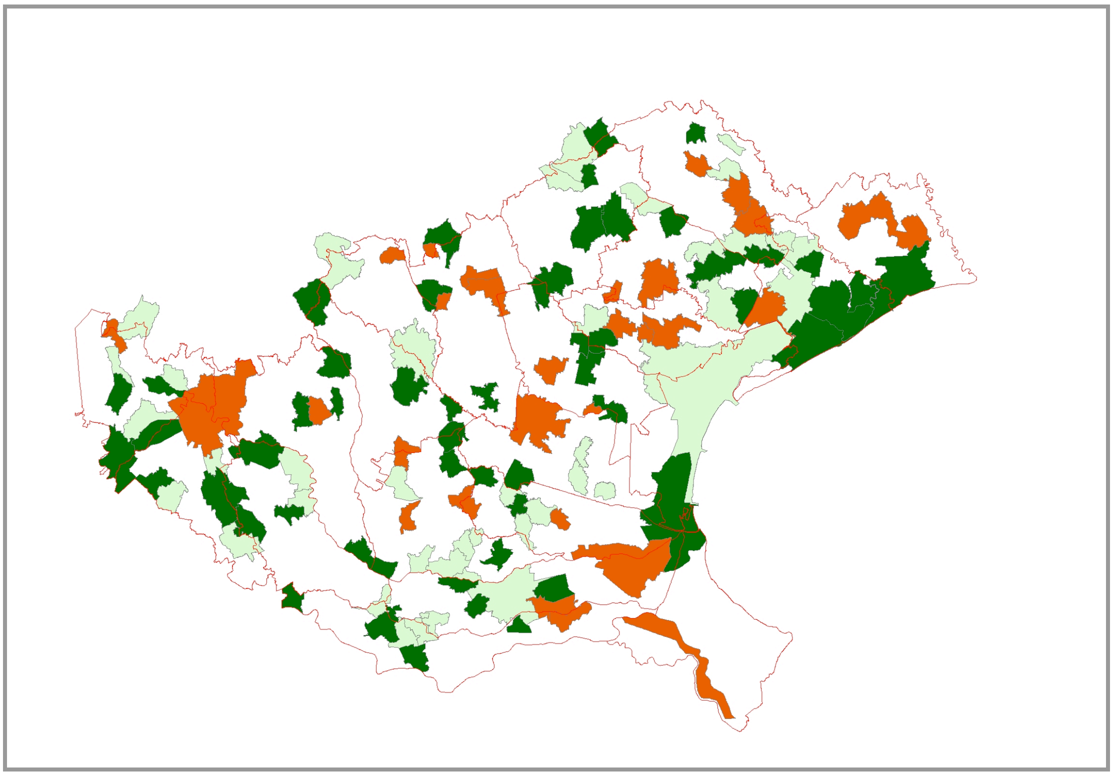

FIGURE 2.3: The spatial distribution of the two winning strategies: in dark green option C, high efficiency irrigation - and in red option A, the expansion of water reservoirs. The other options are aggregated in light green. Note that the map is only representing the area covered by the 10 Irrigation Boards. We collected no answers in the mountainous areas.

surface irrigation. Information services also scored low in the policies' ranking, particularly seasonal forecast services.

2.5 Key findings and policy recommendations

During this study, we collected and processed information on:

- What influences farmers perceptions, what autonomous adaptations they put in place, and what their needs are
- What the expected efficacy of different adaptation policies is to address those needs
- Which drivers and constraints lay behind the choice of different adaptation packages, versus no adaptation.

With this information we can develop operational recommendations for the mainstreaming of climate change adaptation into the design and implementation of the Rural Development Plan. We do not argue that our sample is representative. Our exercise includes only a limited selection of farmers (10% of those reached by the AgroMeteorogical bulletin, but only 0.5% of the total number of regional farms). Nonetheless the number of farmers involved goes well beyond the business-as-usual, and some elements useful to derive indications for the revision of the Rural Development Plan of the Veneto Region are clearly emerging from the study.

1. To finance the installation of high-efficiency irrigation systems at the farm level

High-efficient irrigation ranked top in both farmers' and Irrigation Boards' evaluation. Farmers' general feeling was that off-farm resources (i.e. public investments) should focus first on main structural changes of the water supply system, thus they prioritised infrastructural measures as a more obvious prerogative of Irrigation Boards' and regional policies. In addition, all farmers contacted by phone for their feedback confirmed that irrigation is becoming a needed solution to buffer impacts of environmental changes in the Veneto Region and as such, rural development policies should pay specific importance to it.

Policy makers that want to prioritize this option should promote extension services on the topic and make sure they promote it in combination with other agronomic measures and in coordination with the Irrigation Boards' planning of water supply. On the one hand, access to information is a significant driver of the adoption of this measure. Instead, socio-economic factors such as farmers' experiences and the percentage of income from agriculture do not seem to drive the adoption of this measure. On the other hand, the majority of farmers (95%) who switched to higher efficiency irrigation technologies have not introduced it in isolation. More than half of our sample have also diversified their cropping patterns and/or pest and weed management practices, whereas a third of these have also shifted their sowing times. Finally, one sixth of our sample emphasized the need for coordination with the Irrigation Board as a first step towards improving irrigation management.

2. To support the reorganisation of production systems towards less water demanding crops

The measure on prioritisation of low-water-requiring crops ranked low both for farmers and Irrigation Boards, in fourth and fifth position respectively. Yet crop change was a popular autonomous adaptation measure: about 40% of the 587 farmers sample have changed or diversified their crops.

Policy makers that want to prioritise this measure as an adequate solution for climate change adaptation need to consider that the main driver behind crop change is the farm's profitability, at least for farmers whose income depends on agriculture. Our study demonstrates that these farmers generally reacted to changes in temperature and biodiversity, but nearly the entirety (96 %) of those was concerned primarily about economic changes (93%). From follow up calls, we found out that most farmers have switched to higher cash crops (i.e. from wheat to maize), which generally require more water.

Again, policy makers should promote information on potential combination of different crops that may still maximise the farm's productivity, especially in the long term. Information availability on climate and new techniques influences positively the adoption of this package. Moreover, the vast majority (93%) of those who adopted this package did so in combination with other adaptation measures. Irrigation Boards' low preference also depends on the fact that they do not consider this a feasible measure, if approached in isolation. A potential target group are farmers who have not adopted yet high efficiency irrigation techniques. Not having irrigation infrastructure in place (not even for emergency irrigation) makes it more likely for farmers to change crop and soil management practices.

3. To promote both CSMC and IMC

The combination of crop, soil, and irrigation management practices was not included as a potential planned adaptation policy. In MCA exercises, there is a preference to evaluate extreme measures and then discuss possible combinations of measures, more probable in the implementation phase.

Policy makers, rather than promoting specific adaptation measures, could more effectively advocate for water use efficient irrigation and crop and soil management practices via sensitization campaigns. Indeed it seems that access to information and awareness of changing environmental conditions were significant drivers for farmers adapting their practice. This combined approach could more easily address the specific needs of different farmers with different agricultural practices and from various parts of the Veneto Region.

This paper demonstrates that 40% of those farmers, who adapted autonomously, chose a combination of changes in crop, soil, and irrigation management practices. The higher the percentage of income from agriculture, the more likely is for a farmer to adopt this combination. Trees growers are also more likely to have adopted this package, than those cultivating other crops. The presence of emergency or fixed irrigation systems also determines this adaptation measure.

4. To invest on information services

Policy makers should focus on the improvement and dissemination of information services to farmers. Our findings demonstrate that investing in extension services and information seems an effective path to follow for mainstreaming climate change adaptation. The rate of the adoption of all autonomous adaptation measures considered in this study benefits, at least partially, from the availability of information on climate change and innovative techniques.

During the project, farmers, Irrigation Boards, and policy-makers often emphasised that in a scenario of increasing water scarcity and growing need for irrigation, information services will become an essential complement of agricultural management. However, our analysis also shows that only about half of those who are interested in extension and information services, including those related to climate change and new techniques, have access to them. Thus, there seem to be a large scope for improvement and further use of these services.

Nonetheless, new climate services score low in the mDSSweb platform exercise. Farmers' feedback on the low ranking included concern over uncertainties and low familiarity with seasonal forecasts and other new climate services, yet they also confided expectations for more dissemination by the government and their further usability. In order to increase the acceptability of these innovative services, policy makers should first focus on increasing their credibility. Building on the social networks of users is often a powerful method to convince other farmers to make use of these services. From the MCA exercise, farmers with 5 to 20 ha and those with micro-irrigation in place show a relatively higher interest than others in climate services.

2.6 Conclusion

This study collected and processed information on autonomous adaptation measures in place and expectations of adaptation policy's effectiveness, and evaluated the factors affecting the choice of adaptation measures to (climate) change in the Veneto Region. We collected data via an eParticipation framework, a flexible and highly reproducible method which allowed for extensive data collection in a short time and with limited resources. Our eParticipation framework can be easily adapted to broader audiences and different contexts combining online questionnaires and MCA tools. Further, the adoption of the MNP model allowed us to evaluate autonomous farmer's adoption measures, which help us characterise specific behaviours and priorities of different groups of farmers. We were able, by matching potential policy investments with the information on farmers' behaviour, to identify possible niches of intervention that should inform the design of the Rural Development Plan.

To our knowledge, this is the first study in Europe that joins information on autonomous adaptation with the design and evaluation of planned interventions, via a combination of qualitative and quantitative online tools, for better-tailored and well-targeted measures at a local scale.

Importantly, our study shows that climate change adaptation can be promoted more successfully if it is implemented in coordination with traditional rural development policies aimed at a more effective farm management. Farmers are economic agents that continuously adapt to different pressures and drivers, of which climate change is/may be one. It is more efficient for policy making to identify the adaptations already in place and the main drivers of change, rather than neglect them. Our results provide insights on how to enhance the use of a portfolio of adaptation measures, whatever the drivers, by maximising the complementarity between autonomous and planned adaptation.

The Internet played a fundamental role in this study. The success rate and the information we derived from the database are a powerful message for the promotion of eGovernance related activities envisaged by the Rural Development Programme. The Veneto Region is already adopting online communication channels, such as the Veneto Region's Integrated Portal For Venetian Agriculture, but further efforts are needed in this direction, as users are still a small percentage of total farmers.

The whole study was highly participatory. We sought stakeholders and potential users' feedback at all stages of the study, the large majority of which confirmed the need for such a method and would like to see it applied further, at a larger scale. However, it is only the first of a series of step that policy makers should embark on to come to a truly participatory policy design. In order to translate our messages into an exhaustive list of actions by the policy makers, a more representative selection of farmers needs to be involved in the evaluation. This will allow policy makers to gain more information about, amongst others, the changes in place; the long-term benefits and risks of their various adaptation measures; and farmers' social network which they can build upon for the implementation phase. Up-scaling our study will provide representative information for policy design, which can eventually increase farmers' resilience to climate change. Perhaps partially as a result of our study, for the first time, the Veneto Region organised in 2013 an online public consultations for finalising the new Rural Development Programme.

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Annex A, The Multinomial Probit (MNP) Model

Suppose that a farmer i chooses alternative k and therefore, the difference between the latent variable and the $J-1$ is defined as follows:

$$v_{ijk} = y_{ij} - yik = x_i(\beta_j - \beta_k) + \epsilon_{ij} - \epsilon_{ik} = x_i\theta_j + u_{ij} \tag{2.3}$$

Where $j' = j$ if $j < k$ and $j' = j - 1$ if $j > k$ such that $j' = 1, ..., J-1$. The variance and covariance of the error terms u_{ij} are defined as $Var(u_{ij}) = Var(\epsilon_{ij} - \epsilon_{ik}) = 2$ and

$Cov(u_{ij}, u_{im}) = 1$ for $j' \neq m'$. The probability that alternative k is chosen is given by the following equation:

$$Pr(i \text{ chooses } k) = Pr(v_{ilk} \leq 0, ...v_{i,J-1,k} \leq 0) = Pr(u_{il} \leq -x_i\sigma_l, ..., u_{i,J-1} \leq -x_i\sigma_{J-1}) \tag{2.4}$$

Chapter 3

Conditions For The Adoption Of Conservation Agriculture In Central Morocco: An Approach Based On Bayesian Network Modelling

3.1 Introduction

Conservation agriculture (CA) is claimed to be a panacea for the problems of poor agricultural productivity and environmental degradation, particularly in semi-arid areas that are characterised by frequent droughts and dry spells (Giller et al., 2009). Indeed, there is increasingly awareness around the world of the negative effects of conventional agriculture. For one, the World Bank views CA as a "gateway to sustainable development" (Derpsch, 2003). CA is currently promoted as a means to increase crop water use efficiency and stabilise yields, even in a changing climate (Baudron et al., 2012).

CA rests on three principles. These are: (1) minimum or no mechanical soil disturbance; (2) permanent organic soil cover (consisting of a growing crop or a dead mulch of crop residues); and (3) diversified crop rotations (Lahmar, 2010).

The performance of CA varies significantly around the world. Research in the semi-arid region of Central Morocco proves that under optimal conditions CA increases yields, reduces labour requirements and erosion, and improves soil fertility (Boughala and Dahan, 2011). However, after nearly two decades of demonstration and advocacy, adoption in the areas and globally is still limited (Acevedo et al., 2014). The main constraints seem to be the unavailability of no-tillage seeders, lack of knowledge, unconducive market conditions for the rotation (cereal-legumes, to control weeds), and residue management (personal interviews and The World Bank (2014a)). Independently of the specific reason, the low adoption rates suggest that farmers are not yet convinced about the CA technological package.

A shift from tillage, plough-based agriculture to CA-based agriculture is not a simple matter of technical change (Lahmar, 2010). The specific climate and pedagogic conditions, farm management settings, market contexts, technical conditions, and socio-economic drivers, all may affect a farmers' decision to adopt. For instance, Arrue and Cantero-Martínez (2006) show that despite the fact that most studies conducted in Spain suggest that yields are generally 10-15%

higher under CA, especially in dry years, considerations of higher yields were not determinant of farmers adopting the package. For this reason the decisional drivers of a farmer need to be considered from a system perspective. It is often not sufficient that demonstration trials show a potentially higher productivity and economic analysis suggest potential cost savings (as in Boughala and Dahan (2011)).

Rogers (2003) identifies 5 characteristics that an innovation needs to satisfy for users to adopt it. These 5 characteristics are (i) relative advantage, (ii) compatibility, (iii) complexity, (iv) trialability, and (v) observability. *Relative advantage* is the degree to which an innovation is perceived to perform better than the existing system. *Compatibility* expresses the degree to which an innovation is compatible with the existing values and fulfils the needs of the potential adopters. *Complexity* refers to the degree to which an innovation is perceived difficult to understand and/or to use. *Trialability* is the degree to which an innovation may be experimented with on a limited basis. *Observability* is the degree to which the results of an innovation are visible to others. Moreover, the efforts of the change agents in diffusing the innovation also play a role - but they are per se not sufficient.

Efforts in the region have been focusing primarily on demonstrating the relative advantage of CA versus traditional tillage (i). Local institutes first began with demonstration trials in their own experimental fields and they have recently begun to collaborate with large farmers who adopt CA on a small portion of their land. The hope is that experimenting the innovation on a limited basis (iv) which is at the same time very visible to all farmers (v) may raise more interest and confidence in the CA package (iii). After years of advocacy for CA, adoption still lingers around 1% (The World Bank, 2014a).

To my knowledge, a comprehensive and quantitative assessment of the conditions for adoption by the different typologies of local farms (i.e, compatibility and complexity) does not yet exist. Most past research on adoption focus on ex-post, rather than ex-ante assessments (Baudron et al., 2012, Moussadek et al., 2014). Research found that even in Europe, the lack of knowledge on CA systems and their management and the frequent incompatibility with either their farm system or the fields' physical conditions, made it difficult and socio-economically risky for farmers to move away from tillage (Lahmar, 2010).

We seek to help bridge this gap. In this study, we propose an analytical framework for an ex-ante evaluation of possible policy measures to promote CA in Central Morocco. The framework focuses on the compatibility of CA with, and partially its complexity for, the existing farming system. It examines a baseline and then explores how adoption rates may change, if some constraints were removed. We therefore examine the cumulative impact of these constraints on adoption. In this study, first we identify what farmers' objective priorities for the long term's survival of their farm may be - under the assumption that these factors may influence their decision to adopt. Then, we test and demonstrate the practicality of Bayesian Decision Networks (BDN) for policy evaluation, in a context of high data uncertainty. Our hope is that the tool we develop may equip policy makers in Morocco to better manage the compatibility attribute that, together with the other 4, may influence adoption rates.

In Morocco, the severe data gap on CA compatibility with the existing farming systems makes it difficult to use more traditional data-driven system analysis. A dynamic model allows a temporal analysis and can run at once hundreds of policy scenarios. Yet, we would need to make too many modelling assumptions were we to build either a system dynamic model, or a global equilibrium model, for instance. Instead, BDNs are increasingly being used for natural resources management under uncertainty (see for instance, Barton et al. (2008)). In our study, the two main uncertainties relate to data and farmers' reactions. The main strengths of BDNs are their ability to integrate different data sources (e.g. quantitative, semi-quantitative, data-based, opinion-based), to be able to reproduce the system's behaviour even with missing data, and to account for and help communicate uncertainty.

Our analysis suggests that methods like BDN can provide decision makers with important information about the drivers and bottlenecks to adoption of a policy, or, in this case, of a technological package. Importantly, they can be continuously updates as new information is collected. This can focus decision makers' attention on the factors that most matter for adoption.

3.2 Conservation Agriculture In The Semi-Arid Region Of Central Morocco

The region of Central Morocco is the most important production area for cereals in Morocco, both in terms of share in agricultural surface and production. Our analysis includes primarily data and experts of the regions Chaouia Ouardigha and Zemmour Zaer. The region is classified as semi-arid to arid. Annual rainfall in this area undergoes large yearly fluctuations, with an average of around 386 mm. The average farm size is relatively small - about 9.2 ha of cultivated land per farmer. 50% of farmers are small-holders with up to 5 ha of cultivated land, 36% are medium farmers, with 5 to 20 ha, and the remaining 14% are large farmers, with more than 20ha. Small farmers occupy 31% of the area, medium farmers control 50.5% of the region, and large farmers 18.5%.

Crops are grown under rainfed conditions in 96.5% of the cases. At present, the predominant crop rotation in the region is cereal/cereal (84%). Only 15% of farmers apply cereal/legumes or fallow rotation, and these numbers keep decreasing. According to farmers, the decrease in using this rotation is essentially due market prices, which are more stable for cereals, and the higher labour and herbicide requirements of legumes (Boughala and Dahan, 2011).

The production system is based on crop and livestock integration. For small farmers in particular, livestock and farming systems are highly dependent on each other. Agricultural by-products represent valuable and cheap feed sources for animal production. The strong links and integration between crop production and livestock is a widespread strategy to face the risks related to climate changes and markets fluctuations.

After years of successful demonstration field tests by the National Institute of Agronomic Research (INRA) and development organisations (i.e., the World Bank), adoption of CA remains extremely limited (less than 1% of farmers have adopted it) (The World Bank, 2014b).

Researchers mention the unavailability of no-tillage seeder machine and lack of knowledge as two important constraints (The World Bank, 2014a). Farmers add both weed management issues and the incompatibility of CA with their farm management, which closely integrates livestock and farming. The latter is especially a constraint for the smallholders. Farm management and the availability of inputs vary greatly according to the farm size. For small farmers, some constraints are much more severe than for large farmers. One example is the affordability of herbicides and pesticides. However, some other constraints, such as for instance the availability of labour and of no-tillage seeders, affect all farmers equally.

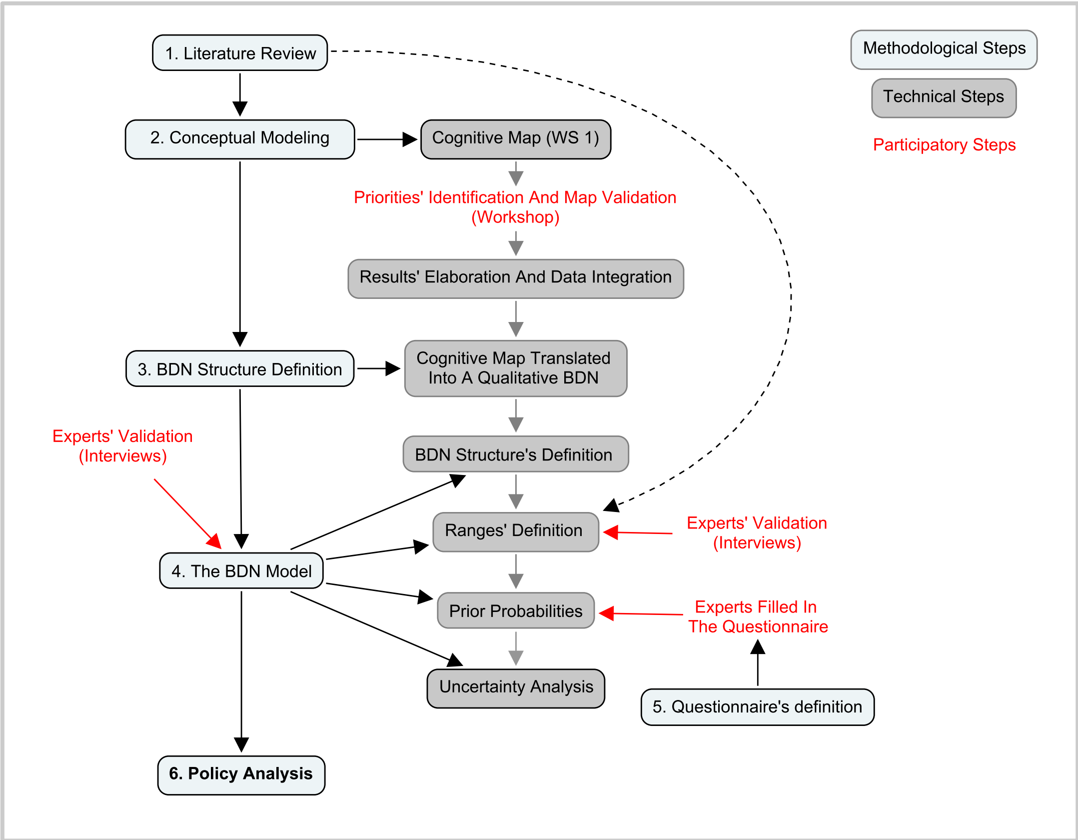

FIGURE 3.1: Coupling Multi Criteria Analysis, Conceptual Modeling, and Bayesian Network Development (adapted from Carpani and Giupponi (2010, p.266))

3.3 Materials And Methods

The overall methodological framework has four phases, all built upon processes eliciting judgments from experts and integratingwith quantitative analysis (Figure 3.1). These are:

i A Multi Criteria Analysis (MCA) evaluation to identify farmers' priorities for the long term

ii A conceptual modelling of the factors which may influence a farmer's decision to switch to CA - and their qualitative causal relationship.

iii The quantitative, fully functional, probabilistic tree structure of the BDN model.

iv Policy or scenario analysis, where we simulate different changes into the system.

3.3.1 What Affects A Farms' Productivity In The Long Term?

Often, CA supporters argue that it solves problems of erosion and water conservation, and it guarantees more stable yields. However, in most European countries, these concerns did not appear as main drivers in farmers' decisions to switch. Instead, the major driving force was the cost reduction of CA compared to conventional agriculture (Lahmar, 2010). The objective of this phase was therefore to rank local farmers' and researchers' perceptions on what may affect a farm's productivity in the long term and how these elements perform under tillage and no-tillage.

In the MCA elicitation, we asked participants to evaluate the contribution of 11 indicators to the performance of conventional agriculture and CA, via a likert scale from 0=very poorly to 5=very positively. These indicators were:

- Soil Erosion (Natural Resources Management (NRM1)
- Water Consumption (NRM2)
- Agrochemicals Consumption (NRM3)
- Diesel Consumption (NRM4)
- Straw availability (Rural Livelihoods (RLV)1)
- Contribution to Household Food Security Feasibility (RLV2)
- Access to machinery (RLV3)
- Yield Stability (Comparative Advantage (COA)1)
- Production Costs (COA2)
- Farm Income (COA3)
- Labour Demand (COA4)

Participants then weighted the relative importance of each indicator to increase a farm productivity in the long-term. We ran the session with researchers, policy makers, and farmers (see Appendix C for the questionnaire).

3.3.2 What Is The Causal Relationship Between The Variables That Affect A Farmers' Decision To Convert?

We categorised the results of the MCA evaluation into a conceptual map (second phase). A conceptual map is a graphical representation of a mental model where concepts are linked to each other through adequate graphical symbols (Giupponi et al., 2008). The map described the elements and cause-effect links that may affect a farmers' decision to adopt CA. The aim of the discussion, which took place during the same workshop as the MCA phase, was to define a shared scheme to frame the elements determining farmers' decisions. Local farmers and agronomists helped us refine our initial map.

The third phase concentrated on the construction of a BDN, coherent with the conceptual map. We had field data, but mainly from demonstration trials. At the same time, local operators possessed high empirical knowledge. And we wanted to be able to quantify the links between implementing policies and the final rates of adoption, in a way that could maximise the data sources available.

BDN models are directed acyclic graphs for joint probability distributions, where the nodes represent random variables, and the edges signify direct dependence. Each node has 1, 2, or 3 parents. Each node of the BN represent a system component and has a finite set of mutually exclusive and exhaustive states. The states or conditions of the variables can be categorical, continuous, or discrete (Carpani and Giupponi, 2010). Table 3.1 summarises how we chose the ranges of the various variables: some from existing data, like climate and soil, whilst others from literature. We validated all ranges with INRA.

Each node is associated with a probability function that takes as input a particular set of values from the node's parent variables and gives the probability of the variable represented by the node. The final outcome represents the probability that the "adoption node" will be in a particular state (i.e., adoption or no adoption), given the available evidence, the conditional probabilities, and the chosen statistical distribution governing how the probabilities combine (Balbi et al., 2014).

In other words, the BDN model represents the probabilities of relationships between the variables of a system. The probabilities that define the connection between nodes are described in Conditional Probability Tables (CPT). We filled each node of the BDN with conditional probabilities elicited either from available data, or from experts by means of a questionnaire.

The probability representing our knowledge of the subject before new evidences arrive or policies are tested is called *prior*. The prior indicates the probability that an input parameter will be in a particular state. When new data or information becomes available, the prior probabilities can be updated. Via a BDN, it is then possible to assess the causal impact that different policy measures targeting certain nodes have on the adoption rates.

Despite their remarkable power and high suitability to our problem, there are some inherent liabilities to BDNs too. The main limitation centres on the quality and extent of the prior beliefs used in the Bayesian inference processing (i.e. the CPTs elicited from experts). A BDN is only as useful as this prior knowledge is reliable. Either an excessively optimistic or pessimistic expectation of the quality of these prior beliefs will distort the entire network and invalidate the results. Related to this concern is the selection of the statistical distribution induced in modelling the data. Selecting the proper distribution model to describe the data has a significant effect on the quality of the resulting network. For sake of simplicity, in this exercise we use a discrete or Gaussian distributions.

Eliciting Experts' Knowledge

To summarise, we asked for experts' support in two different phases of the BDN model development:

1. Two local experts from INRA helped us formalise the composite indicators, validate the conceptual BDN model, and refine the questionnaire for the CPT evaluation (Table 3.1);
2. Eleven experts compiled either the full CPTs or partial subsets through the adhoc CPT evaluation questionnaire (see Appendix C for the questionnaire). These experts were 2 agronomists involved in agricultural projects in Morocco, 6 Moroccan agronomists from INRA Settat and Rabat, 2 Moroccan farmers, and a governmental agency which supports the World Bank in the implementation of campaigns for the promotion of CA.
3. The same two local experts from INRA validated the behaviour of the model with full CPTs.

TABLE 3.1: Nodes And Ranges Of The BDN Model

Variables	Units	Source	Low	Medium	High	Notes
Climate	Ombrothermic Index	Balaghi et al. (2013); INRA Settat	Negative	Medium	Positive	Combination of monthly rainfall and average temperature, 30 years of daily data.[1]
Soil Type	Soil Hydrologic Groups	Boughala and Dahan (2011)	A	B	D [2]	
Potential Wheat Yield	ton/ha	INRA	<2	2 to 3	>3	Yield data over 20 years, Settat
Farm Size	ha	ACLIMAS (2013)	< 5	5to 20	>20	Percentage of farmers
Crop Residues Availability	%	Belmekki et al. (2013)	0-20	20-30	>30	This node expresses the integration between livestock and cropping, very strong in small and medium farms. INRA suggests that at least 30% of crop residues permits to adopt no tillage
Crop Rotation	%	ACLIMAS (2013); The World Bank (2014a)	Cereal/ Cereals (and others)	Cereals/ Food Legumes	Cereal/ Forage	Percentage of farms choosing each rotation, on average
Farm Management	Category	Experts	Bad	Medium	Optimal	This node aggregates crop rotation and crop residues availability
Attainable Wheat Yield	ton/ha	Experts; ACLIMAS (2013)	<2.5	2.5 to 3.5	>3.5	
Legumes' Incentives	Binary	Experts	No	–	Yes	These could be via prices or other incentives
Wheat Market Price	DH/ha	Boukantar and Hanson (2014)	<2,000	2,000 to 3,000	> 3,000	Currently fixed by the Government at 2,500/2,800
Potential Economic Performance (Wheat)	Composite Indicator	Boughala and Dahan (2011)	< 3,500	3,500 to 5,000	> 5,000 [3]	
Access To No Till Seeder	Category	Boughala and Dahan (2011); The World Bank (2014a)	No Access	Low Access	As Needed	
Access To Information	Category	Experts	Low	Medium	High	
Herbicides' Availability	Category	The World Bank (2014a)	Affordable And Available	Affordable But Unavailable	Unaffordable And Available	
Access To Inputs And Information	Composite Indicator	Experts	Inadequate	Medium	Suitable	Depends on availability of the machinery, herbicides, and information
Market Context	Category	Experts, Farmers	Non Conducive	–	Adequate	62 farmers interviewed by INRA Settat, plus 2 experts' judgement
Enabling External Conditions	Composite Indicator	Experts	Unsuited	Moderately Suited	Suited	This node aggregates access to inputs and information and market context.
Adoption of No Tillage	Category	Experts	No	–	Yes	Percentage of total ha

We used the eleven experts' answers to train the BDN model (Buntine, 1996). When we filled in the CPTs in the model, we considered all experts' responses as equally weighted and we took their averages (Carpani and Giupponi, 2010). However, the dispersion in the probability distributions of each outcome is a proxy of the data-related model uncertainty (Balbi et al., 2014).

3.3.3 How Do Adoption Rates Vary By Removing Certain Constraints?

Once the BDN was completed and validated, we ran several policy scenarios. We prioritised those policies that (i) addressed the constraints emerged during the MCA phase and (ii) the World Bank identified as priority actions in their latest report on introducing CA in the region (The World Bank, 2014b). According to the World Bank report, the three main constraints for the large scale implementation of CA are (i) the cultural rotation and weed control; (ii) the integration between farming and livestock; and (iii) the availability of NT seeders (p.24). So, our findings were in line.

These policy scenarios were either individual interventions (i.e., on one node), or a combination of policy packages (i.e. acting on several nodes). The policies, which we tested against the baseline, are the following.

- Policies addressing cultural rotation and weed control:
  - Changing wheat price, now fixed by a national law;
  - Subsidising legumes' prices;
  - Facilitating access to herbicides.
- Policies addressing the integration between farming and livestock:
  - Increasing availability of residues, by incentivising the farmer to leave it on the field, or by introducing alternatives for animal feed.
- Policies improving the availability of NT seeders:
  - Optimal provision of NT Seeders;
  - Medium provision of NT Seeders (available a bit later than at the optimal time, due to their scarce number);
- Policies improving access to information:
  - Optimal access to information via training and demonstration;
  - Medium access to information via training and demonstration;
  - Optimal access to inputs and information;

We also tested combinations of these policies.

- Optimal access to information via training and demonstration AND Medium access to NT seeders;
- Medium access to information via training and demonstration AND Medium access to NT seeders;

- Increasing availability of residues AND subsidising legumes' prices;
- Optimal access to herbicides AND subsidising legumes' prices;
- All policies (improving information, availability of herbicides, access to no tillage seeder; raising legumes' prices and promoting rotation and incentivising leaving residues on the parcel).

Finally, we tested the baseline and the policy, which led to the highest adoption rates, under two climate scenarios:

- Climate slightly drier than today: OI >2 in 60% of the growing season, and rains arrive either too early, or too late;
- Climate extremely dry: OI>2 in less than 40% of the season and rains arrive either too early, or too late.

We ran these policy scenarios for all farmers, and then separately for each typology of farmers (i.e., small, medium, and large).

3.4 Results' Analysis And Validation

3.4.1 Variables That Affect A Farm's Long Term Performance

Fifteen participants answered the questionnaire on the MCA. Figure 3.2 shows the average weights. Soil erosion, water consumption, farm income, and yield stability seem to be the main drivers of a farmers' decision to adopt. However, when we looked at the individual weights of the two farmers, soil erosion and water consumption scored much lower. This shows a disconnect between researchers' and farmers' perceptions on the long term advantages of no tillage.

Via the MCA preference elicitation, we tried to identify the farmers' perceptions on the comparative performance of the two systems (i.e., traditional tillage versus CA). We aggregated the participants' answers via Simple Additive Weighting and run MCA with the averages for the group and for each individual. Interestingly, out of the fifteen participants, CA scored the lowest in the 2 farmers' responses. For the other participants, CA's total score was higher than conventional agriculture [4] For both farmers, the main constraints of CA were the consumption of chemical inputs and access to the seeder, but also food security and farm income. The latter two indicator show that better information may help shed clarity on the advantages of CA. For both farmers, soil erosion and water consumption, which are often argued to be one of the main drivers of adopting CA, did not contribute significantly to a farm's long-term productivity.

The MCA exercise helped identify possible bottleneck in the adoption of CA. However, due to the lack of quantitative data, a solid MCA evaluation could not be pursued.

[4]Many other participants also had parcels of land, but they were not full time farmers

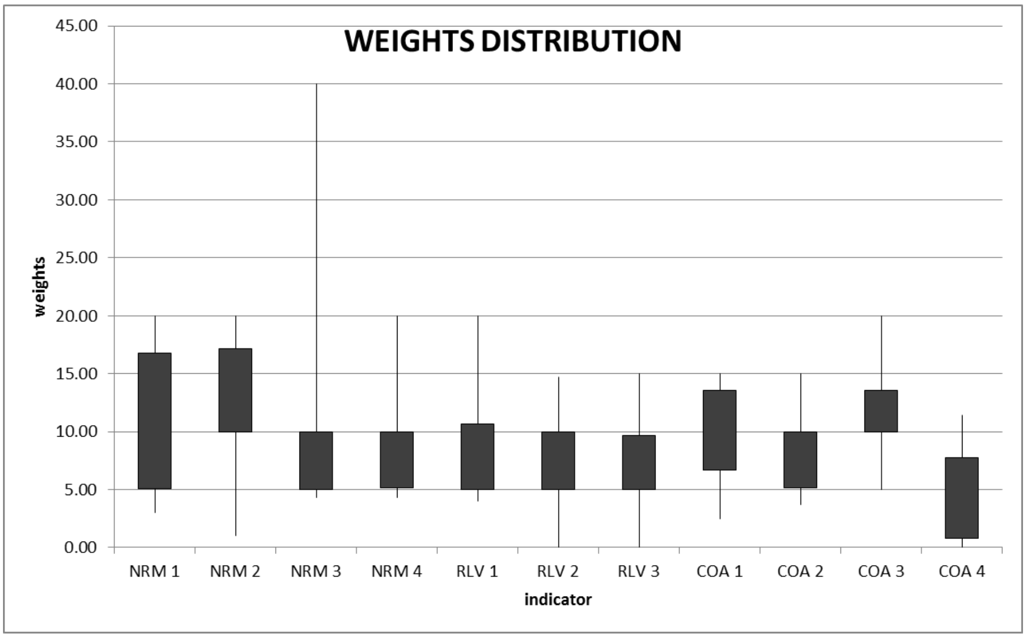

FIGURE 3.2: Results of the weights' elicitation.

3.4.2 The Bayesian Decision Network For The Adoption Of Conservation Agriculture in Central Morocco

The first output of the study is a functional BDN model for the adoption of CA in Central Morocco. The resulting BDN model contains physical (i.e., soil and climate), technical (i.e. availability of inputs), and market drivers (i.e. subsidies and market conditions), and farm management variables (i.e., farm size, rotation, residues availability) (Figure 3.3). Climate change is important as in the long-term, drier years may occur more frequently and it is proved that no tillage performs better in drier conditions. However, it seems not to be a major determinant of farmers' decisions.

We compiled each CPT with the averages values of the questionnaires collected. We carried out an uncertainty analysis by running the model in the baseline once with the values from each experts' response. The average probability of "Yes Adoption" only varied 0.05% between the maximum and minimum level. Hence we decided to keep the averages for the baseline prior. This established our prior. The adoption rates in the current context that emerged from the model's prior are in line with real rates: <1% of all farmers: 0.1% of small farmers, 1.2% of medium farmers, and 2.3% of large farmers.

The results are preliminary, but they provide indications on the strategy that a policy maker may want to follow to promote the adoption of CA. From the simulations, it emerges that constraints for the small farmers are much more severe than for medium and large farmers.

Perhaps as expected, the highest rate of adoption come from the provision of optimal inputs and information to farmers, without influencing the market or on field farming practices (Figure 3.4). Most policy makers and international organisations seem to believe that increasing the availability of no tillage seeders may solve most of the issues related with the adoption of CA, and in turn help achieve food security in the area. Our preliminary results seem to scale down the expectation of success of the introduction of subsidies for the no tillage seeder. An optimal access to seeder for may raise overall rates of adoption to 5.6% and to 10% for large

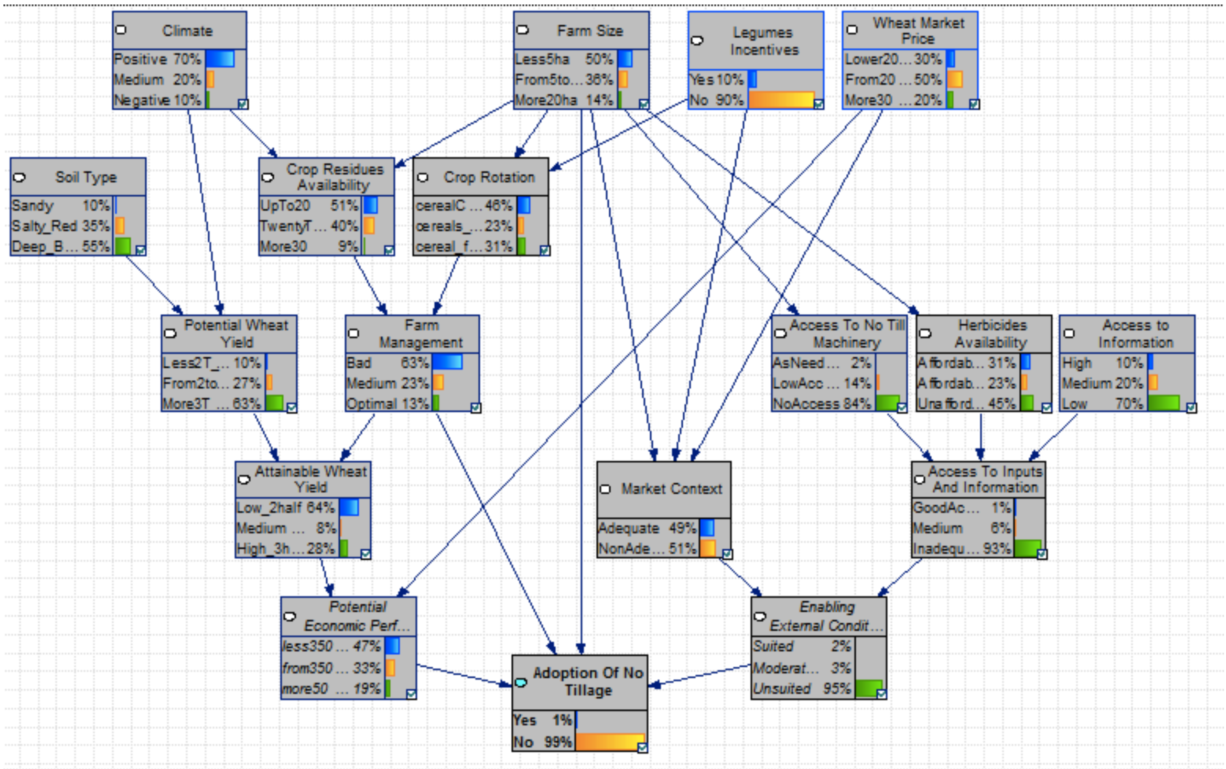

FIGURE 3.3: The BDN Model's Prior

farmers - but only to 1.7% for small farmers (Figure 3.4). This is surely an improvement but it also shows that several constraints remain to be addressed.

Information, for instance, may help raise these rates quite significantly, if coupled with the improved availability of no tillage seeder. Indeed - and although the values are preliminary - it seems that the two together may raise adoption to 10.9%. This includes an adoption rate for small farmers of 4.4%, of 17.2% for the medium farmers, and 17.6% for the large farmers (Figure 3.5).

We only ran two climate scenarios (Figure 3.5, furthest to the right). Our preliminary results show that under an extremely dry climate, with everything else staying constant, adoption rates may decrease even further (down to 0.54% from 0.9% for all farmers). Obviously, these are too few to induce any significant result on adoption. However, the model suggests that under extreme climates, a farmer may be even less ready to take the risk of switching to a new technological package. CA may help to buffer slight climate variation in already semi-dry areas, but it is not a panacea for all climate pressures, at least for some farmers.

This becomes more apparent when we look at the adoption rates under negative climate but when information about CA has improved and farmers have a medium access to the seeder. This was one of the most effective policy package amongst the ones we tested with the results obtained with experts' judgements. Compared to a non climate scenario, a negative climate reduces the adoption rates of this package by about 40% for all farmers. However, if we evaluate each farmer typology independently, we notice that the delta is much smaller for large farmers (35%) than for small farmers (54%). Again, our results depend on few experts' judgements. Yet, the system's behaviour signals that decision makers should design appropriate policy packages for each specific typology of farmers. In particular, if the objective of introducing CA is to improve food security in the area, decision makers should pay particular care to the small

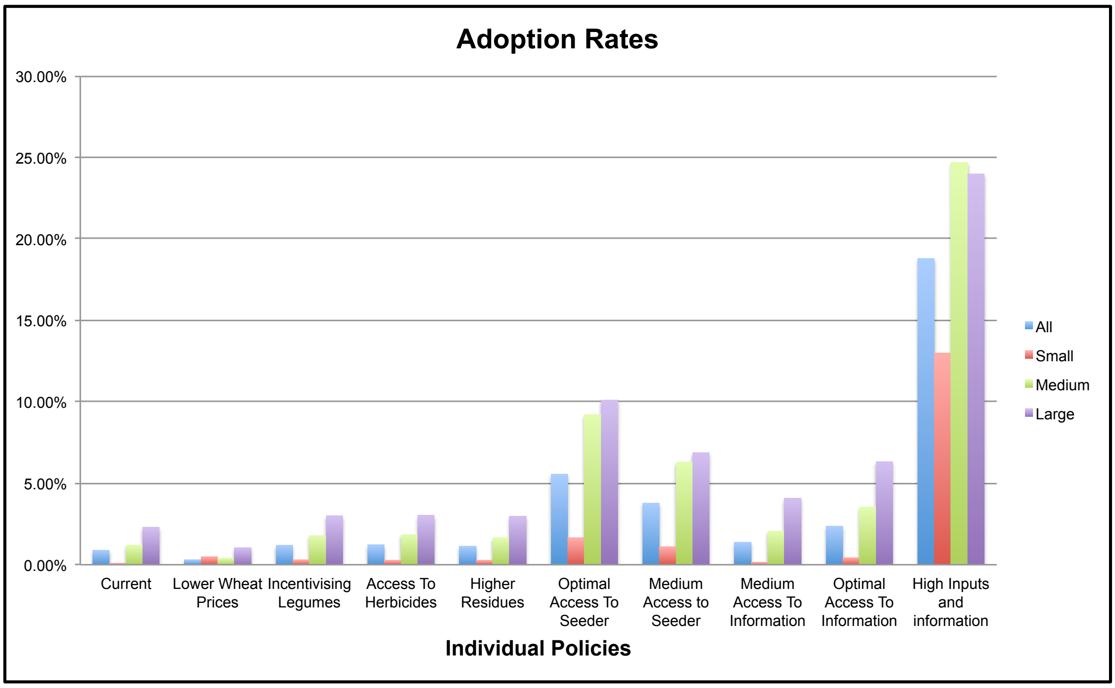

FIGURE 3.4: Adoption Rates Of The Individual Policies

farmers' constraints to the adoption - besides their generally higher vulnerability to external drivers than large farmers.

An interesting result emerges when we simulate the introduction of medium access to the seeder, optimal information and access to herbicides, more than 30% residues on the field, a cereal/legumes rotation, and incentives for legumes. The adoption rates as expected increase significantly. They are 39.3%, 40.4%, 38.7%, 36.7% respectively for all, small, medium, and large farmers. Interestingly, in this case, adoption rates are higher for small farmers. However, in terms of total surface under CA, which is the objective of the Moroccan Government's Plan Vert (The World Bank, 2014a), the rates of adoption of large farmers are much more significant.

Despite being preliminary and based on a small sample of experts, the results show that the target set by the Moroccan Government for the next 10 years is quite ambitious. For instance, in the Zemmour Zaer region, the objective is to extend CA from the current 500 ha to 60,000 ha between now and 2025 (The World Bank, 2014a). This would signify an increase of adoption rates by 90% - when according to the model, the current mix of policy measures suggests adoption rates of about 40%.

3.5 Discussion And Conclusions

In this study, we use BDN for the probabilistic assessment of the influence of different intervention on adoption rates of CA. Our results are based on the expertise of a limited group of experts. However, for a policy question like the promotion of CA in Central Morocco, the BDN model has several strengths. First, BDNs combine different data sources (i.e., empirical data and experts' judgements), and the use of conditional probabilities implicitly exemplifies uncertainty. Second, we show that BDN is an effective tool in contexts characterised by lack of data, but were experts are available. BDN allows a structured formalisation of their knowledge.

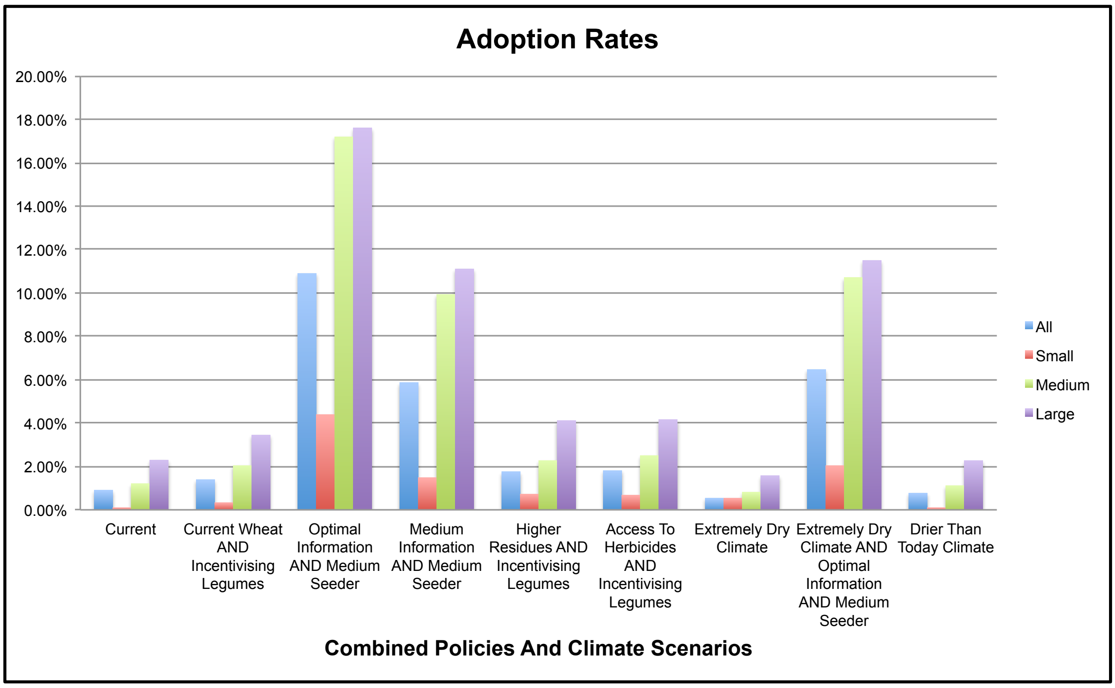

FIGURE 3.5: Adoption Rates Of Combined Policies And Under Climate Scenarios Policies

Third, the BDN model helps decision makers considers the ripple effect of various policies. Their impact varies according to the node's distance from the final decision. Finally, BDN is a useful tool to conduct exploratory scenario analyses. The BDN peculiar characteristics of being updatable as new information is collected is particularly useful in a policy project that spans across several years, like the diffusion of CA. Indeed, these technical shifts are usually achieved through a step-by-step attitude. In Morocco as in in Europe, for instance, large scale farmers are the most adopters (Lahmar, 2010). However, socio-economic changes may occur that could reverse this trend. BDN could help monitor these changes.

On the other hand, one should use BDNs with care because the results are highly dependent on the prior beliefs. Not only experts' judgements, but also the probability distribution used, can significantly affect the outputs of the analysis.

An interesting next step would be the assessment of the economic feasibility of the various policy packages that we test. If we had this data, our results could then be integrated with an evaluation of the tradeoffs, for a ranking of the actions that may increase adoption rates.

Again, these results are exploratory and do not intend to suggest specific policy actions. Nevertheless, this study shows that in order to promote adoption, policy makers need to identify the critical conditions, the bottlenecks, and their causal links. Only then, they can design effective solutions. It is important to consider the thresholds, the tipping points, and the synergic combination of the variables. In addition, when promoting adoption, it is crucial to differentiate between farmers' typologies and design appropriate strategies for each typology. Even with better inputs, for some farmers may remain difficult to adapt. If one consider Rogers's five characteristics, policy makers should not neglect compatibility. Indeed, this may threaten the success of the whole innovation diffusion process. This BDN model offers an effective and updatable support for the integration of compatibility (and complexity, via information) into ex-ante policy evaluations, with clear information on the associated uncertainties.

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Chapter 4

Making Informed Investment Decisions in an Uncertain World: A Short Demonstration

This chapter is a paper written by Laura Bonzanigo[a,b] and Nidhi Kalra[b]. A preliminary version of this paper was published in February 2014 in the World Bank Policy Research Working Papers series. In April 2014, we submitted this paper to the Journal Of Benefit Cost Analysis. The paper is still under review.[1]

4.1 Introduction

Each year governments invest billions of dollars towards development. Many of these investments in energy, land use, transportation, and other sectors are long-term and will shape the course of development in their countries. Yet we live in an unpredictable world governed by competing beliefs and preferences. Our decisions are engulfed in deep uncertainty about the long-term cost of energy inputs, the impact of climate change, and a host of other factors that shape our decisions. Deep uncertainty occurs when the parties to a decision do not know, or do not agree on, the likelihood of future events, the best model for relating actions to outcomes, or the value of potential outcomes (Lempert et al., 2003).

Deep uncertainties pose formidable challenges to making near-term decisions that make long-term sense. Governments grapple with deep uncertainties daily. Traditionally, they have asked, ”Which investment option best meets our goals given our beliefs about the future?” Such approaches, sometimes called ”Predict-then-Act”, hinge on our accurately predicting and then reaching consensus on what the future will bring (Hallegatte et al., 2012, Lempert and Kalra, 2011). But disagreements about the future can lead to gridlock. Worse, investments tailored to one set of assumptions about a deeply uncertain future often prove inadequate or even harmful if another future comes to pass. Governments and international development organizations

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increasingly recognize that current approaches to decision making struggle to meet these ubiquitous challenges (Bank, 2013, Independent Evaluation Group, 2012, Ranger, 2013, Rennkamp, 2012).

For instance, throughout the World Bank, there is a growing recognition that deep uncertainties need to be better managed in decision making (Hallegatte et al., 2012, Independent Evaluation Group, 2010, 2012). In 2010, The World Bank's Independent Evaluation Group released a report pressing World Bank staff to conduct more rigorous economic analyses of investment options (Independent Evaluation Group, 2010) and to use these analyses to inform decisions. This was endorsed by the World Bank's Board of Directors in a Guidance Note to project managers (Bank, 2013). More recently, a more explicit consideration of risk and uncertainty is also one of the key messages of the World Development Report 2014 (The World Bank, 2014).

Many methods have been developed over the last half-century to help decision makers manage deep uncertainties and make investments that are robust to the unpredictable future. These approaches ask, "Which investment option best meets our goals given that we cannot know what the future will bring?" (Kalra et al., 2014). These methods seek to identify robust decisions - those that satisfy decision makers' objectives in many plausible futures, rather than being optimal in any single best estimate of the future (Lempert et al., 2013). They have been recommended for investment lending but are not widely used in practice, leaving many decisions vulnerable to surprise. One reason may be that we do not understand well the extent to which deep uncertainties affect lending decisions, or know the usefulness and practicality of these methods for investment lending.

We seek to help bridge this gap. In this study, first we review the economic analysis of ten World Bank projects approved between 2002 and 2011 in order to understand how they managed risk and uncertainty. Then, we test and demonstrate the practicality and value-added of new methods for long-term infrastructural investment lending decisions. Research suggests that having practical tools to solve a problem can increase one's awareness of the problem and motivation to solve it (Coombes and Devine, 2010, Kolb, 1984). Our hope is that a straightforward demonstration of these methods may motivate and equip analysts to better manage uncertainty in lending decisions.

In particular, we apply Robust Decision Making (RDM, Lempert et al. (2003)) to the economic analysis of a prior World Bank project, the Electricity Generation Rehabilitation and Restructuring Project, which in 2006 sought to improve Turkey's energy security in part by increasing near-term energy supply. We use the same data and models utilised in the original analysis, but in a different way. Rather than seeking to inform electricity investments in Turkey with predictions of the future, we seek to inform them with assessments of their robustness to an unpredictable future.

The original decision was to rehabilitate an existing coal plant. Other options included building new coal-fired, gas-fired, or other power plants. Decision makers were concerned with two key metrics: a) whether the investment passed a cost minimisation metric, i.e., produced electricity at lower cost than any other option, and b) whether the investment passed a cost-benefit test, in this case had a rate of return of at least 12%. We evaluated each option according to these metrics in 500 plausible future states of the world that varied under seven different sources of uncertainty.

We used the results to answer a series of specific and useful questions:

- How do decision makers' options perform across a wide range of potential future conditions?
- Under what specific conditions does the leading option fail to meet decision makers' goals?
- Are those conditions sufficiently likely that decision makers should choose a different option that is more robust?

Our analysis suggests that methods like RDM can provide decision makers with much more salient information about the merits and vulnerabilities of different options. This can focus decision makers' attention on the uncertainties that matter most to a decision. It can make them aware of the important trade-offs and of the actions they could take to reduce their vulnerability. Ultimately, it puts the decision back in the hands of decision makers by helping them take measured risks and be less vulnerable to surprise.

Importantly, the purpose of this exercise is not to prove the original project decision right or wrong or to re-create the analysis under today's conditions. At the time of this project, for instance, climate change mitigation and the possibility of a price on carbon were not widespread concerns, and this analysis reflects the original priorities of decision makers related to energy security. The same analysis today would almost certainly include these considerations. Rather, our aim is to demonstrate that an analysis of robustness can be incorporated into projects' standard economic analyses using the same data and models, and to examine the different kinds of information that emerge from a Predict-then-Act versus a robustness analysis. Moreover, while our analysis focuses on a World Bank case study, we believe this methodology holds value for the broader international lending community.

We believe methods like RDM can be readily incorporated into cost-benefit and other economic analyses that analysts perform every day, with few additional resources. We hope this analysis will be a useful template by which projects can better manage uncertainty in their investment decisions.

4.2 Review of World Bank Projects

The typical approach to economic analysis is to conduct a cost-benefit analysis of the preferred investment option under best estimate predictions of the relevant future conditions. Consistent with the World Bank's manual on economic analyses, analysts sometimes conduct a sensitivity analysis around the best estimate projection to address uncertainty (Belli, 2001). Occasionally they may replace a single projection with a probabilistic projection, assigning likelihoods to a variety of future outcomes.

These approaches have a common underpinning. Often termed Predict-then-Act (Dessai and Wilby, 2010), they seek to characterise the future (i.e. make predictions) and then measure policy options against the characterisations to determine the best near-term course of action. Predict-then-Act forms the basis of several analytic methods commonly used to evaluate investments (Hallegatte et al., 2012, Lempert and Kalra, 2011), including traditional risk analysis, cost-benefit analysis (Arrow and Fisher, 1974), and real options analysis (Henry, 1974).

Yet the World Bank increasingly recognizes that such approaches may not help manage deep uncertainties that arise in many lending decisions (Independent Evaluation Group, 2010, 2012, Kalra et al., 2014). In this study, we sought to understand the World Bank's economic analyses in greater detail by reviewing the Project Appraisal Documents (PADs)[2] of ten projects that were approved between 2002 and 2011. PADs are compulsory documents that projects must to submit to the World Bank's Executive Board for lending approval. They contain basic information on the proposed projects, such as Country Ministries involved, project length and its objectives, a section on key risks and plausible mitigation measures, and the economic and financial analyses. The economic analysis should quantify the benefits and the costs of the proposed project and of the other options examined.

In our review of ten PADs we asked several questions:

- How many and which alternative options did the project originally evaluate?
- What uncertainties did analysts identify in the project narrative?
- Which of these were carried into the economic analysis of projects?
- How did the projects manage uncertainty?

While our small sample size lends no statistical weight to the answers, it enriches the observations made by the Independent Evaluation Group and others at the World Bank. We randomly selected investment projects in two sectors - energy and transportation - that were characterized by the World Bank's project database as addressing climate change, a deep uncertainty.

We found that project documents often identify multiple investment options but present detailed evaluations only for the already-preferred investment. The alternative options are rarely analyzed quantitatively or compared meaningfully. It is possible that analysts conducted detailed analyses prior to the project approval stage to whittle the options. Our conversations with project leaders suggest that the preferred investment is often chosen through an informal process and dialogue, not through a quantified analysis of costs and benefits. Sometimes, the results of a Technical Assistance phase inform investment lending, but this does not substitute for the lack of a clear quantification of risks. This confirms the Independent Evaluation Group's observation that economic analyses are in practice used to justify rather than inform investment decisions, because they are done once the project is already well advanced (Independent Evaluation Group, 2010).

Projects often describe many deep uncertainties in the project narrative and rationale. For instance, of the ten projects in our sample, eight note that population growth and nine note that future socio-economic developments may shape the success of the proposed project. Seven cite the uncertainty of energy supply and demand, four cite the uncertainty of urban development, and three cite the worsening of environmental conditions as relevant to future project outcomes.

However, in most projects (six out of ten) these external drivers are not included in the economic analysis. Only two projects include considerations of future water availability in their cost-benefit analysis. Another two projects include socio-economic developments in their estimation of energy and transport investments, respectively. However, even when economic analyses include these external conditions, they are not treated as deep uncertainties but rather as well understood parameters, using single best estimate projections.

[2]PADs summarize the project team's assessment of a lending project and are the basis for the World Bank's review and approval of lending projects. PADs include a project rationale, key components of the loan, potential areas of risk, and an assessment of the economic merits of the project.

There is also a disconnect between the risk section and the economic analysis in the PAD: most of the potential risks mentioned in the risk section are not examined in the economic analysis for the evaluation of the available options. Analysts address risks qualitatively, often by proposing monitoring and capacity building. In the sample projects analysed, none of the risks mentioned in the risk analysis are carried through to the economic analysis. To address uncertainty, projects assess the sensitivity of only the preferred option and with respect to only a few of the many relevant uncertainties. Nine out of ten projects assess the sensitivity of the chosen option to investment costs, yet only one tests its sensitivity to the discount rate. Moreover, projects varied the uncertainties by a small amount around their best estimate projection, often only 20%. This provides a very limited understanding of the vulnerabilities of the project.

Moreover, many deep uncertainties that could clearly affect the success of a project are never mentioned. For instance, the timely completion of a project may significantly affect the project outcomes. All of the projects we reviewed mention this as a key risk but only two included project delays in the economic analysis even though delays would affect the projects' rates of return. Similarly, the success of many investment projects depends on effective future operations and maintenance. But, particularly in developing countries, operations and maintenance of large infrastructure often falls short of needs (Foster et al., 2010, Ostrom et al., 1993). Yet many projects assume operations and maintenance will continue as planned, or that inefficiencies will be manageable, and the economic analysis does not consider how the investment would perform with degraded operations and maintenance.

Despite these shortcomings, two of ten projects do recognise that deep uncertainties affect their choices. Instead of Predict-Then-Act approaches, they seek to manage uncertainty with a handful of diverse scenarios that challenge prediction-based thinking. Scenarios can usefully encourage decision makers to assess their investment options under unexpected conditions.

However, scenario planning also struggles to manage deep uncertainties. Analysts usually only consider a small number of scenarios. Analysts also typically handcraft the scenarios, so they are subject to the same biases as analysts' predictions about an expected future. Making decisions based on diverse scenarios may also lead us again to a problem of consensus around predictions, i.e. to which scenario should we tailor our investment decision?

Collectively, these shortcomings suggest that there is room for improvement to meet the Independent Evaluation Group's recommendations of rigorous economic analysis.

4.3 Robust Decision Making

Robust Decision Making is a decision support methodology designed to help manage deep uncertainty by helping develop plans that are robust and flexible (Lempert et al., 2003). It has been applied to water resource management, (Groves et al., 2008), flood risk management (Fischbach, 2010), terrorism risk insurance (Willis et al., 2005), and energy investments (Popper et al., 2009), primarily in the U.S. Lempert et al. (2013) provide a concise summary of RDM and several case studies.

RDM is one of several methods like InfoGap (Ben-Haim, 2006) and Climate-Informed Decision Analysis (Brown, 2010), that seek to better understand how decision makers" options perform under a wide range of conditions, rather than under a single or handful of predicted conditions. The World Bank recommends RDM and similar approaches for managing uncertainty and making better-informed decisions (The World Bank, 2014). In one of the first applications in developing countries, a recent World Bank study demonstrates how RDM could help make robust flood risk management plans in Ho Chi Minh City (Lempert et al., 2013).

RDM involves four basic steps that are embedded in a process of stakeholder engagement:

1. Decision makers structure the decision problem to identify their potential options, the metrics and performance thresholds they will use to evaluate whether their options meet or fail to meet their goals, and the uncertainties that could affect the performance of the policy option according to the metrics. Analysts use models to relate these factors.

2. Analysts statistically generate hundreds of futures and evaluate the performance of their options in each of those futures. This generates a large table of inputs (the uncertain future conditions) and outputs (the metrics) for each option.

3. Analysts identify which input conditions best explain when each option meets or fails to meet decision makers' performance thresholds. These conditions describe scenarios to which each option is vulnerable.

4. Analysts and decision makers together compare the scenarios with available evidence to determine if they are sufficiently plausible to hedge against. They compare trade-offs between robustness, feasibility, cost, and other factors and select those options that best balance their needs.

Analysts and decision makers iterate upon earlier steps to examine more options or modify features of options, explore a wider range of uncertainties, and consider additional metrics. As (Lempert et al., 2013) describe, this approach can be used to time investments and develop flexible plans - ones designed to evolve as new information becomes available. RDM can be used to design individual projects, portfolios of projects, or to compare different exclusive alternatives, as we do in this study.

4.4 Making Robust Energy Investments in Turkey

In 2006, the Electricity Generation Rehabilitation and Restructuring Project sought to improve Turkey's energy security in the near and mid-term. Turkey's electricity demand had grown rapidly between 2002 and 2005, or 6% on average, and it was expected to continue to grow, potentially outstripping its supply (The World Bank, 2006). The country had issued licenses for about 6,000MW of new capacity, yet in 2006 little new construction had begun. The Electricity Generation Rehabilitation and Restructuring Project focused on solving the near term solutions as well as more systemic solutions for the medium term. In the near term, it sought to increase electricity production through supply investments; for the medium term, it sought to provide support for restructuring the sector.

The project examined eight different supply investment options for the Afsin Elbistan electricity production area: seven types of power plants and the import of energy from Bulgaria. They evaluated these projects based on two economic metrics. First, it should pass a cost-minimization criterion, producing electricity at lower cost than any of the other options. Second, the investment should pass a cost-benefit test; in this case, it should have at least a 12% internal rate of return (IRR), a benchmark commonly used at the World Bank to demonstrate economic value of investments.

At the time, decision makers originally preferred rehabilitating the existing local lignite-fired plant at Afsin Elbistan because they believed it would produce electricity the soonest. The project's economic analysis further suggested that it would meet both their cost-benefit and cost-minimization targets. The project was approved in 2006. However, it was never implemented due to legal dispute with a private company, which had signed a concession agreement with the government in 1999 for the operation of the plant and the eventual construction of a new energy production plant.[3]

We use this project to demonstrate RDM for several reasons. The energy sector is fraught with deep uncertainties that challenge decision making. It is also one of the most important sectors for long-term economic growth, and simultaneously it can shape the development path of a nation. Additionally, this particular project has detailed data and a model that enabled us to repeat the earlier economic analysis using RDM.

4.4.1 Summary of the Original Economic Analysis

The project's original economic model evaluated seven power plants' options for the Afsin Elbistan area for increasing Turkey's electricity supply, but five were addressed in detail[4]:

1. Rehabilitating the existing local lignite-fired power plant;
2. Building a new local lignite-fired power plant;
3. Building a new imported coal-fired power plant;
4. Building a new gas-fired power plant; and
5. Building a new lignite fluidized bed power plant, which would be fired by a higher quality coal than local lignite.

We replicated the analysis for these five investment options. Table 4.1 summarizes the uncertainties examined in the project's original analysis, and in our application of RDM to the project. These relate to future energy conditions, future power plant investment characteristics, and economic parameters.

The original analysis evaluated each option under a best estimate of several deep uncertainties, listed in column A of Table 4.1. Analysts' projected or assumed values are listed in column B and were based on the data available at the time. For instance, the assumed price of local lignite (6.05 US$/ton) is the levelized economic cost over a 20 year period from the expanded and upgraded local lignite supply mine (The World Bank, 2006).

The original analysis prioritized options according to their cost-minimization, specifically the discounted cost per unit of production. It showed that rehabilitating the existing plant would be the most cost effective at 3.88 cents US$/kWh, followed by constructing a new gas-fired combined cycle plant at 4.41 cents US$/kWh.

[3]The litigation was on-going at the time of project design, but both parties seemed willing to find a solution. Hence, the risk of delays (but not of failures) was considered as moderate in the Project Appraisal Document (The World Bank, 2006, p.11), though such delays were not included in the economic analysis.

[4]A wind and a nuclear plant were also considered. The wind plant was eliminated as a candidate because its cost effectiveness, which was derived from the literature, was not competitive with other options. The nuclear plant was eliminated because it would take much longer to construct.

The project also sought to ensure that the selected investment would pass a cost-benefit test, specifically having an IRR of at least 12%. It showed that rehabilitating the existing plant would have an IRR of 25% under the projection in column B, comfortably passing the 12% target. To address uncertainty, the project conducted a sensitivity analysis of the IRR to some of the projected values (column C). These values reflect 10%, 20%, or 50% deviations from the projected value. The IRR was at least 14% across all the sensitivity tests.[5] This analysis suggested that the rehabilitation project passes decision makers' economic tests of being the most cost effective option while also having high returns in the analysts' best estimate of future conditions. The project's economic analysis concludes that "the rehabilitated plant will be the least cost option for Turkey under any scenario" (The World Bank, 2006, p.58).

4.4.2 Demonstration Of Robust Decision Making

Robust Decision Making can help us more fully understand the strengths and weaknesses of our options and make a sound decision, without relying on accurate predictions of the unpredictable future. It helps us answer several useful questions:

1. How do our options perform across a wide range of potential future conditions?
2. Under what specific conditions does the *rehabilitating the existing plant* fail to meet our goals?
3. Are these conditions sufficiently likely that we should choose a different *energy investment* option?

In practice, these questions are addressed in a close collaboration between decision makers, stakeholders, and analysts. A series of structured workshops help participants frame the analysis, deliberate over interim findings and direct subsequent analyses, and reach decisions. Because we are re - creating an earlier project analysis, we focus in this section on the analytical steps and draw on the outcomes of stakeholder engagement in the original project.

Structuring The Problem

To conduct the RDM analysis, we first structure our analysis to more fully identify the uncertainties we face. In this study, we used the same uncertainties as in the original analysis, but in nearly all cases, we have expanded the range of possible values as shown in column D of Table 4.1. Figure 4.1 shows this visually for the option of rehabilitating the existing plant. The values' ranges were drawn from the literature and historical data, and from consultations with energy experts. For example, literature on investment planning biases suggests that on average, capital costs are underestimated by 28% (Siemiatycki, 2010). World Bank energy experts confirmed that for a comprehensive thermal rehabilitation project, cost overruns of 50%

[5] These results are reported directly from the project appraisal document. We reconstructed the economic model using the same formulae and data as the original model, but with slightly different time series of the price of inputs, which were difficult to replicate from the original analysis. Our model results showed the same relative performance of options. However, running the original sensitivity analysis for rehabilitating the plant in our model revealed that the IRR fell below12% when electricity prices were 4 cents US$/kWh, or when the cost of lignite is 9 US$/ton. This does not suggest that the original sensitivity analysis is incorrect, but rather that the results can be highly sensitive to slight variations in model parameters. A small sensitivity analysis may not reveal the full behaviour of the interventions under analysis.

TABLE 4.1: Uncertainties evaluated in the original analysis and in this study's RDM analysis

A. Deep Uncertainties	Original Analysis		RDM Analysis	
	B. Projected Value	C. Sensitivity [b] Test Values	D. LHS Range min	max
Wholesale price of electricity (US$/kWh)	0.05	0.04, 0.045	0.04	0.1
Discount Rate[a]	0.1	-	0.01	0.2
Estimated Life of the Plant (years)				
Rehabilitation; New local lignite plant; New gas-fired plant;	20	(10, 16)	5	25
New imported coal plant; New lignite fluidized bed plant	40	-	5	45
Capacity Utilisation				
Rehabilitation; New gas-fired plant; New lignite fluidized bed plants	0.76	(0.6, 0.68)	0.5	0.9
New local lignite plant; New imported coal plant	0.9	-	0.6	0.95
Capital Costs (US$, in millions)[6]				
Rehabilitation	683	(819, 1024.5)	600	1030
New local lignite plant	1998	-	1800	3000
New imported coal plant	586.7	-	500	880
New gas-fired plant	420	-	350	630
New lignite fluidized bed plant	451.84	-	400	670
Length of Construction Time (years)				
Rehabilitation	4	-	2	6
New local lignite plant	6	-	3	9
New imported coal plant; New gas-fired plant; New lignite fluidized bed plant	3	-	1.5	4.5
Cost of energy inputs				
Local lignite (US$/ton, for the rehabilitated and the new plant	6.05	(7.06, 9.08)	3	12
Imported coal (US$/ton)	60	-	30	120
Gas (US$/tcm, for the new gas-fired plant)	220	-	110	440
Improved coal[7] for the new lignite fluidized bed plant (US$/ton)	21	-	10	42

[a] Only the wholesale price of electricity and the discount rate have the same ranges across all options' cost effectiveness models, both in the original and in the RDM analyses.
[b] The original analysis conducted sensitivity tests only for the IRR of rehabilitating the existing plant.

are possible. Hence, we considered a range of capital costs from a lower bound of just below each option's stated cost, to an upper bound of 150% of the stated cost. We also added two new uncertainties: the length of construction time and discount rate. The length of construction time is an uncertain and important parameter. Most projects experience delays in implementation (Ahsan and Gunawan, 2010). Indeed, the original analysis identified possible delays in rehabilitation and construction as plausible risks. Moreover, decision makers were concerned with how quickly each option could be implemented and would begin producing electricity.

The discount rate is also deeply uncertain. It is a political choice and often highly-contested (Arrow et al., 2013). It shapes how we allocate resources between the present and the future (Gollier, 2011). A higher discount rate signifies an urgency to satisfy present needs, whereas a lower discount rate expresses concerns for the long-term impacts of an investment. Although the World Bank typically uses discount rates of 10% to 12%, no single discount rate is appropriate for all projects and it may be difficult for stakeholders to come to consensus (Hoekstra, 1985, Oxera, 2011). After consultation with World Bank experts, we use a range from 1 to 20% to explore both the longer-term considerations of contributing to the country's growth and the short-term objectives of avoiding an energy crisis.

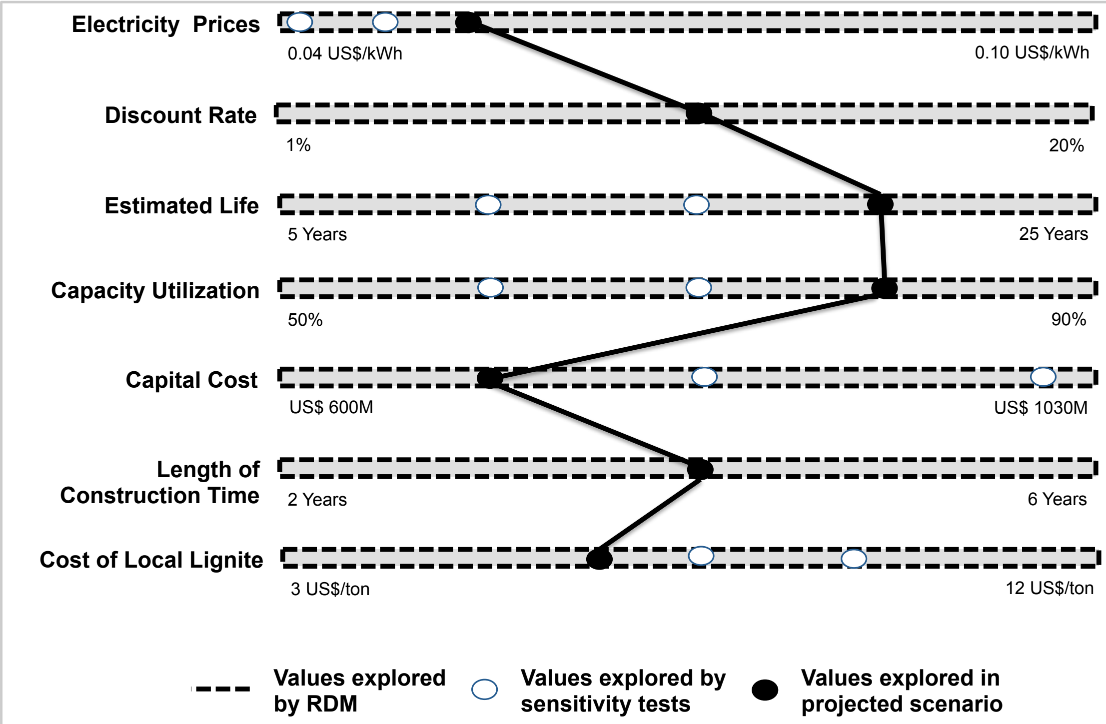

FIGURE 4.1: Uncertainty space assessed by the projection, sensitivity analysis, and RDM analysis of rehabilitating the existing plant.

The original sensitivity tests were only carried out for the cost-benefit metric of rehabilitating the existing plant and variables were made to vary one at a time. In contrast, we conduct the RDM analysis for all options and for both the cost-benefit and cost-minimization metrics. Note that we are not assigning any likelihood to values in this range. We use the ranges to answer the question, "What *could* the future bring and how would it affect our investment?" rather than "What *will* the future bring?"

Generating Futures

We then statistically generate 500 futures, each a combination of one value for each uncertainty.[8] Again, these futures are not predictions, and we do not assign any likelihood to their occurrence. We use them to better understand the behavior of our investment options. We evaluate the cost per kWh of energy (the cost-minimization criterion) and the IRR (the cost-benefit criterion) of each of the five options in each of these 500 futures.[9] The result is a table of 2,500 model runs, four rows of which are shown in Table 4.2. This table of results helps us answer our key questions.

[8]In this study, we use Latin Hypercube Sampling, which is similar to but more efficient than Monte Carlo sampling. It examines the behaviour of our options over the full range of uncertainties with the fewest number of samples.

[9]To easily repeat the analysis, we re-implemented the economic analysis equations from Excel into the Analytica risk modeling environment. Analytica is a visual modeling platform for quantitative risk and uncertainty analysis. It allows analysts to create influence diagrams that define how factors in analysis relate to each other and to quickly add or modify elements of the model during the course of the analysis and in response to input from stakeholders. Analytica is well suited for managing uncertainty because, unlike spreadsheets, it can be easily configured to run over many futures and save the results to a table. See www.lumina.com.

TABLE 4.2: Sample from the database with the 500 futures

		Inputs				Outputs	
Future ID	Option	Wholesale Price of Electricity	Capital Cost	Length of Construction Time	Other Four Uncertainties*	Discounted Cost per KWh	IRR
1	Rehabilitation	5.15	824.89	2.85	[...]	6.39	0.05
2	Rehabilitation	8.79	945.29	4.14	[...]	7.11	0.35
3	Gas-fired plant	5.15	526.68	4.01	[...]	4.29	0.27
4	Gas-fired plant	8.79	514.92	4.38	[...]	8.91	0.15

*Other uncertainties are the discount rates, cost of inputs, lifetime of the plants, and capacity utilization rates.

How do our options perform across a wide range of potential future conditions?

Figure 4.2 shows the performance of the investment options in 500 plausible futures. Rehabilitating the existing local-lignite plant meets the cost-minimization and cost-benefit targets in most futures. However, there are many in which constructing a new gas-fired plant would be more cost effective. There are also some futures in which the rehabilitation option has an IRR of less than12%. The other three options meet performance goals in far fewer futures. This indicates that rehabilitation meets our goals under a wider range of assumptions about the future than do other options.

Up to this point, our analysis resembles the steps in traditional Monte Carlo analyses used for project evaluation:[10] both approaches run many simulations over randomly generated cases. However, the approaches diverge significantly in how they use such simulations. A Monte Carlo analysis uses the sampled cases to represent the likelihood of future conditions (e.g. probabilities of future energy prices, construction time, etc.). It further uses the results of the simulations to make inferences about the likely performance of the project, e.g. that rehabilitation is more likely to meet decision makers' goals than other interventions because it outperforms other interventions in most cases. This approach works well and the inferences are credible when we have reliable probability distributions.

However, in many investment decisions such as this one, we do not have defensible probability distributions of our deep uncertainties and therefore we cannot infer the relative success or failure of our options from these results. For example, although rehabilitation produces energy at lowest cost in 269 of 500 futures, this does not mean that the probability of doing so is 54% (269/500). Similarly, although rehabilitation falls short of a 12% IRR in 99 of 500 futures, this does not mean that the probability of failing to meet this threshold is 20% (99/500).

[10]Monte Carlo analysis describes a useful approach to numerically generating a probability distribution of an outcome by repeatedly and randomly sampling input parameters from probability distributions of their values (Belli, 2001). For project evaluation, analysts first assign probability distributions to inputs such as future energy prices, length of project implementation, climate change impacts. The resulting distribution of outcomes (e.g., IRR) is interpreted as a statement of the project's likelihood of success or failure.

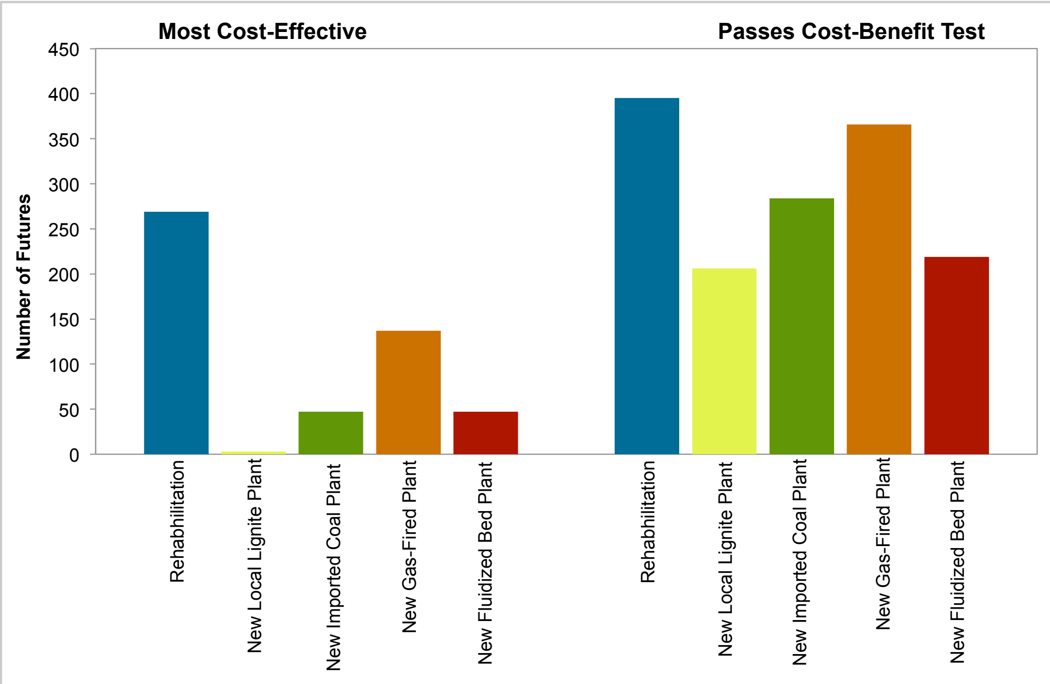

FIGURE 4.2: The cost-effectiveness and cost-benefit performances of the five investment options in 500 futures.

Instead, in an RDM analysis, we sample uniformly across the range of plausible values of our deep uncertainties to ensure that we represent all viewpoints about the future in our analysis. This does not mean that we believe that each case is equally likely. Indeed, we are making no statements about likelihood at all. Rather, we use the cases to stress test the performance of a project over the widest range of possible conditions. Then, in the next step, we mine the database of simulation results to identify the specific set of underlying conditions that lead each option to fail to meet our goals. Finally, we assess the relative plausibility of these threatening conditions to determine which option is more robust and to present trade-offs to decision makers.

Under what specific conditions does the leading option fail to meet our goals?

We next used statistical "scenario discovery", running data-mining algorithms on the table of results.[11] This step identifies the combinations of uncertain future conditions that most reliably distinguish those futures in which rehabilitation of the existing plant does not satisfy the cost-minimization or cost-benefit targets, from those futures where it does. This step, typically performed by analysts and modelers, identifies the key drivers of the decision and focuses attention on those future conditions that would matter given the investment options available.

Scenario discovery reveals that a gas-fired plant is more cost effective than rehabilitating the existing plant if:

[11] We used the Patient Rule Induction Method, which is available as a free software package in the R programming environment. http://cran.r-project.org/web/packages/sdtoolkit/sdtoolkit.pdf

1. The cost of local lignite (US$/ton) is more than 4.5% of the cost of gas (US$/tcm).[12]

Scenario discovery also reveals that rehabilitating the existing plant fails our cost-benefit test, i.e. has an IRR below 12%, if two conditions hold simultaneously:

1. The wholesale price of electricity is below 0.059 US$/kWh;
2. Local lignite costs more than 6.3 US$/ton.[13]

The discount rate, estimated life of the plant, capacity utilization, length of construction time, and capital costs - though highly uncertain and potentially a source of disagreement among stakeholders - are less important in determining whether or not investing in rehabilitating the plant is economically sound. We could invest significant time discussing what these values should be, when indeed they are not key drivers of the economic performance of our investment.

Are those conditions sufficiently likely that we should choose a different energy investment option?

So far we have sought to better understand the merits and drawbacks of our options under a wide range of conditions, and to identify the conditions that may lead them to fall short of our goals. We have said little about what the future may actually hold. We now turn to the evidence to assess whether those conditions are sufficiently likely that we should choose a different energy investment option. We begin by examining the vulnerabilities to cost-minimization and then to cost-benefit goals.

Recall that rehabilitating the existing power plant is less cost effective than building a new gas-fired plant if the cost of local lignite (US$/ton) is more than 4.5% of the cost of gas (US$/tcm). The original cost-benefit analysis assumed that with an upgrade, the mine would sell local lignite at an average of 6.05 US$/ton, 2.8% of the 2006 gas price of 220 US$/tcm and well below the 4.5% threshold.[14]

However current and historical trends do not guarantee or bound future outcomes, and we should not use them to predict what will be. Instead, we should use them to answer a more useful question, *"Is there evidence that the conditions that threaten the success of our investment could occur?"*

The answer is yes. The cost of local lignite depends substantially on the efficiency and output of the mine. Let us turn briefly to the main drivers of local lignite costs. The cost of local

[12]This condition is a statistically strong predictor of when building a new gas-fired plant is more cost-effective than rehabilitating the existing plant. Of the 97 futures with this condition, building a new gas-fired plant is more cost effective in 92 of them (95%). However, it is not a complete predictor: this condition exists in 92 of the 153 futures (60%) in which the new gas-fired plant is more cost effective. Further scenario discovery analysis, beyond the scope of this demonstration, would reveal additional sets of conditions that explain the remaining 40%, which policy makers could weigh against additional evidence. Nevertheless, this single condition offers useful information for a policy dialogue on the potential vulnerabilities of the rehabilitation option.

[13]This condition is also a statistically strong predictor of when rehabilitating the existing plant fails the cost-benefit test. Of the 92 futures with these conditions, rehabilitation fails the cost-benefit test in 73 (79%). Of the 99 cases in which rehabilitation fails the cost-benefit test, this condition occurs in 73 (74%).

[14]In the time series utilized by the project, the ratio maintains an average of 3.1% and never exceeds the 3.5% thresholds (The World Bank, 2006).

lignite is at least partially under decision makers' control. It depends on the efficiency of the mine that supplies lignite to the plant, i.e. how many millions of tons of lignite are extracted annually. Most of the mine's costs, including labor, electricity, and materials, are fixed and when production is down, prices are high. At low production in 2004, just before the project's preparation phase, the mine produced only 6.7M tons, about 30% of the mine's annual capacity of 18.6M tons, which were sold at 11.46 US$/ton (The World Bank, 2006). As part of this project, however, this mine would have been expanded and upgraded to ensure a cheaper and more stable lignite supply. Hence, policy makers have options to reduce the cost of lignite, for instance by improving the mine's maintenance and operation.

From 2002 until 2008, gas prices increased sharply in Turkey, reaching over 300 US$/tcm (Ozen, 2012), but have since declined and stabilized at around 220 US$/tmc (Energy, 2012, Lomsadze, 2013). Hence, the highest ratio based on recent historical trends, when lignite cost is high (11.46 US$/ton) and gas price is low (220 US$/tmc), would be 5.2%. This exceeds the threshold of 4.5%. Indeed, if current trends continue to hold and the price of gas remains low, the cost of local lignite would have to be below 9.9 US$/ton (i.e. produce at least at about half of its capacity) to be under the 4.5% threshold (9.90/220).

It thus appears that rehabilitating the existing plant may not be the most cost-effective option under all plausible future conditions, though policy makers have options to influence those conditions.

We can more fully understand the relative merits of the two investments by also comparing their cost-benefit performance. Recall that rehabilitating the existing plant fails our cost-benefit test in 99 of 500 futures, i.e. has an IRR below 12%, when two conditions hold:

1. The wholesale price of electricity is below 0.059 US$/kWh
2. Local lignite costs more than 6.3 US$/ton[15]

Building a new gas-fired plant fails our cost-benefit test in 128 of our 500 scenarios, which occurs when:

1. The wholesale price of electricity is below 0.073 US$/kWh
2. Gas costs more than 220 US$/tcm[16]

Rehabilitating the existing plant would be more robust to decreases in the price of electricity than would the gas-fired plant. In 2009, the Government of Turkey guaranteed a minimum price of 0.068 US$/kWh for the following 10 years (Turkey, 2009). This price is above the vulnerable threshold for rehabilitating the existing plant, but below the threshold for the gas-fired plant. Nevertheless, in 2009, Turkish electricity's wholesale prices were approximately 0.10-0.11 US$/kWh and were not likely to decrease for years to come until excess capacity was in the marketplace.

[15]This condition is also a statistically strong predictor of when rehabilitating the existing plant fails the cost-benefit test. Of the 92 futures with these conditions, rehabilitation fails the cost-benefit test in 73 (79%). Of the 99 cases in which rehabilitation fails the cost-benefit test, this condition occurs in 73 (74%).

[16]This condition is also a statistically strong predictor of when building a new gas-fired power plant fails the cost-benefit test. Of the 125 futures with these conditions, rehabilitation fails the cost-benefit test in 100 (80%). Of the 128 cases in which rehabilitation fails the cost-benefit test, this condition occurs in 100 (78%).

As noted above, policy makers have options to reduce the cost of lignite. In particular, operating the mine at about 13 million tons per year – roughly two-thirds capacity – would keep the lignite cost below 6 US$/ton (The World Bank, 2006). Simultaneously, the cost of gas has remained above 220 US$/tcm since 2006. In combination, the conditions that would lead the gas-fired plant to fail the cost effectiveness test seem more plausible than the conditions that would lead rehabilitation to fail the cost-benefit test.

In sum, this analysis leads to several important insights about the merits of our options:

- Rehabilitating the existing lignite plant fails to meet decision makers' cost-minimization goals under plausible future conditions. If gas costs remain low while local lignite costs increase, a new gas-fired plant would be more cost effective.
- Yet, the cost of local lignite is at least partially under decision makers' control, suggesting that decision makers can take action to avoid those threatening conditions.
- Moreover, building a new gas-fired plant fails to pass the cost-benefit test under conditions that are less constraining and more plausible than the conditions in which the rehabilitation fails a cost-benefit test.

These observations could reasonably lead decision makers to conclude that rehabilitating the existing plant is an economically sound choice: it performs well under a wide range of potential future conditions and is less vulnerable than other options. However, other factors may also influence their decision. The relative importance of cost-benefit versus cost-effectiveness metrics, decision makers' risk aversion, and other concerns may shape their choice. Nevertheless, a more complete and more transparent understanding of the merits of decision makers" options helps inform these deliberations and keeps the decision in the hands of decision makers.

4.5 Key Findings and Recommendations

Faced with pervasive deep uncertainties about the future, decision makers struggle to choose near-term decisions that make long-term sense. In this paper, we sought to answer three key questions:

1. How are deep uncertainties currently managed in World Bank projects?
2. Can new approaches help projects better manage those uncertainties?
3. Are they practical and applicable, and what challenges do they pose?

To help answer these questions, we reviewed prior project analyses and then applied RDM to the economic analysis of a long-term energy investment in Turkey. Our goal is not to reevaluate the earlier decision, which today would be very different and for example, include climate change concerns. Rather, we show the type of questions decision makers and analysts should ask about the robustness of their investments, and how they can answer them. Through this demonstration, we also hope to motivate and equip analysts to better manage uncertainty in investment lending decisions.

Current World Bank Project Analyses Struggle to Manage Deep Uncertainty

Our review of prior project analyses suggests that analysts typically use traditional Predict-then-Act methods to assess project performance, and do not explore the full range of deep uncertainty. In particular:

- Project documents contain efforts to manage uncertainties.
- However, even though project narratives may identify several deep uncertainties, the economic analyses address only a few.
- There is a disconnect between risk and economic analysis. For instance, analyses typically assume that project costs and implementation will occur as planned, even though implementation issues are often cited as potential risks to the project.
- Projects often carry out sensitivity analyses only for the already-preferred investment option or for the option shown to perform best under a single prediction of future conditions.
- Most project managers we contacted during this study are aware of the potential for improving economic analysis.

In sum, project analyses can be improved to help make projects more robust.

Methods Like RDM Can Help Make Better-Informed Investment Decisions

The findings from the Turkey project suggest that methods like RDM can improve our understanding of the vulnerabilities and strengths of our investment options, despite deep uncertainty and a potentially surprising future. In particular, this analysis demonstrates how RDM can help analysts and decision makers

- Identify and make explicit the many deep uncertainties that may affect the performance of investment options;
- Analyze the performance of investment options across a full range of plausible futures, without needing to assign controversial likelihoods to those futures;
- Identify and focus attention on the specific combinations of conditions that determine whether an investment meets or fails to meet decision makers' goals; and
- Use historical and scientific evidence credibly, to assess whether threatening conditions are plausible, rather than to make predictions about what will be.

Such knowledge informs rather than replaces decision makers' deliberations. It helps them systematically, rigorously, and transparently compare their options and select one that is robust - meeting their needs in the widest range of possible futures. Decision makers can have confidence in a robust decision, even if they cannot have confidence about the future.

These Methods Can Be Readily Applied, Though They Pose Some Challenges

In this study, we used the same economic models and data that analysts used in the original analysis; we just used them differently. Rather than using the data and models to assess performance in a single best estimate of the future, we used them to stress test our options in hundreds of possible futures. This approach was more forgiving of data gaps: where a quantity was unknown, we could use a wide range of plausible values, rather than tenuously choosing a single value. This also enabled us to include uncertainties that may not have been feasible in the original analysis.

Nevertheless, methods like RDM may have a steep learning curve - from understanding how to structure a robustness analysis, to learning software that aids in scenario discovery, to interpreting the results of scenario discovery, to communicating the findings to stakeholders. However, prior applications of RDM with other organizations and agencies suggest that these challenges can be readily overcome with time and training.

Managing Uncertainty Requires Rethinking "Good" Decision Making

Analysts and decision makers routinely face pressures to demonstrate that a decision is risk-free. Political and cultural expediency press them to ignore rather than acknowledge uncertainty and present their decision as advantageous and certain. Such thinking keeps us in the dark about the real threats to our decision, and may lead us to brittle decisions that fail when the future surprises us.

To manage uncertainty, we may need to revisit our beliefs about what makes a decision "good". Instead of ignoring uncertainty, we should seek more fully to understand the threats it may pose to our choices. This will enable us to make decisions that are robust to an unpredictable future.

Such a change requires a cultural shift as much as it requires an analytical shift. Yet methodological innovations like RDM can help. By motivating and equipping analysts to manage uncertainty, they can shape how we think, discuss, and ultimately make decisions.

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Final Thoughts And Next Steps

This thesis explores the value of decision support tools. Sustainable development is a long-term process. Limited inclusion of stakeholders, disagreement among decision makers, and deep uncertainties about the future pose daunting challenges to decision making for sustainable development. Sustainable development is also a political, more than a technical process (Kersten et al., 2000). The communities need to determine sustainable development goals and the choice of planning options. Whilst technology can assist decision-makers in making the decision, it cannot substitute for the decision making process.

Many methods have been recommended for planning sustainable development, but they are not widely used in practice. Althuizen et al. (2012) identify a disconnect between how users perceive decision support systems and how these systems actually perform. One reason may be that they do not understand well the extent to which deep uncertainties affect decisions, or know the usefulness and practicality of these methods for designing policies and/or planning investments. Moreover, decision support tools developers often come from the academic world. Academics have their own research agenda and various projects and publication pressures; and they do not necessarily taylor the analysis to maximise the replicability of the approach (Schuff et al., 2010). The result is that the adoption of decision support tools remains limited (Giupponi and Sgobbi, 2013).

This thesis sought to help bridge the gap between available and utilised decision tools and methods, as explored in the previous chapters. Two questions emerge:

- Can our tools facilitate planning?
- Can we motivate and equip analysts and decision makers to better manage the decision process for sustainable development?

This thesis explores the value of existing decision support tools and approaches via three possible decision products:

- To stimulate learning and promote higher levels of creativity in decision making processes.
- To help coordinate top down policy design with transformations and preferences from the ground.
- To disseminate and help mainstream tools for the support of good planning, which address complexity, conflicts, and uncertainties.

This thesis tests innovative combinations of heuristic and quantitative methodologies for supporting choices on sustainability and CCA. It shows that decisions are not taken in isolation. It identifies solutions and conditions for their application via case studies and tools. By mainstreaming these approaches, I believe decision-makers can make better decisions in which benefits are appropriately valued and educated choices are made.

This Thesis Shows That Good Planning Is Possible

The main empirical and specific methodological findings are chapter specific and were summarized within the respective chapters (see Chapter 1 to Chapter 4). This section will synthesize the empirical findings to answer the study's two research questions.

Can our tools facilitate planning?

This thesis applies a set of tools for decision support. It is not the first work on applications of decision making tools, nor it will be the last. It does neither develop new algorithms, nor new techniques for stakeholders engagement. Surely, other tools are available than those chosen here and they could be as effectively utilised in supporting the decisions described. Yet, the combinations proposed in the previous chapters demonstrate that the three decision objectives that this thesis set out to address can be achieved. If appropriately tailored to the context, these tools are conducive to good planning.

Our tools only facilitate planning insofar as they are integrated into decision processes. Decision makers need to feel the ownership of the process, buy into the methods that leads to the analytical results. This is fundamental for the outputs of the quantitative analysis to influence the decision. Similarly, if involved in the policy design, beneficiaries are more likely to adopt the policy decisions. Planning alone is an empty box. Thanks to the inclusive processes we implemented, we improved the dialogue between decision-makers and beneficiaries.

There exist several attempts to identify strengths and differences of various tools for decision support. In my opinion, these "decision trees" are often biased by the direct experience and expertise of the authors. In the end, a decision analyst will apply the tools he/she feels more confident with - and the tools' level of complexity will depend on the time and resources available. However, the experience I gained during my thesis work helps me conclude:

- Everywhere people act, are taught to do things better, interact to influence each other's behaviour, and are making decisions about tools and technology in use. For a decision process to instill durable change, it if fundamental to understand **what drives their choices**.
- **The process, rather than tools per se, is the key**. For this, the NetSyMoD framework provides an excellent, comprehensive, useful, and clear structure to the analysis. The approaches described can make our planning processes more evidence-based and participatory, and robust to uncertainties about future changes.
- Decision makers need numbers to make choices. Participatory processes without models and technical analysis are also "a bag of wind". A transparent, well-communicated **technical analysis is crucial for a choice gain legitimacy**.

- Even if tools are complex, analysts need to **develop a simpler interface for interacting with decision makers**. One analyst can develop a very efficient but extremely complex tool, which is difficult for decision makers to understand. In this case, the chances that decision makers may buy into the decision outcomes is more limited than in those cases where decision makers can understand how the analysts arrived at certain conclusions. This is crucial also for mainstreaming certain concepts (i.e. climate change) in policy debates.

- For long term decisions, it is critical to **move away from predict-then-act approaches**, i.e. from decisions designed upon certain expectations of future changes. Even scenario analysis, i.e. testing the behaviour of a system under a small number of scenarios, may miss critical vulnerabilities of the options. The RDM method described in this thesis is one of a selection of approaches that describe alternative ways of addressing the vulnerability of available options under hundreds of futures, without relying on predictions. Behavioural science can help us devise a strategy for mainstreaming these new methods.

- Decisions depend on **considerations of tradeoffs** between the various decision parameters (i.e. cost, vulnerability, feasibility, social impact, and so forth). MCA methods are a crucial added value to any vulnerability assessment. Not only do they help integrate decision makers' priorities, but they also help move away from a (unnatural) monetisation of non monetary parameters. As other methods, however, MCA should refrain from presenting an index and should instead maintain transparency - Chapter 2 and 1.6 describe ways analysts can apply MCA without hiding information.

However, hopefully this is not a final conclusion, as I hope to continue doing this work where in each project, I learn something new.

Can we motivate and equip analysts and decision makers to better manage the decision process for sustainable development?

This thesis tests and demonstrates the practicality and value added of different methods to support planning decisions. Even in situations with limited resources, high conflict, and/or high uncertainties, these tools helped the decision makers reach an informed decision.

This thesis could not follow projects to their implementation. Yet, all the decision makers contacted during the thesis and involved in these decision processes were grateful for the involvement and appreciated the lessons learnt. At least within the four case studies, we succeeded in involving decision makers into examining more alternatives, introducing quantitative analysis which maximised the data available. At the end, decision makers claimed to have a better understanding of the problem and felt that the combination between sound analysis and improved communication provided them with more confidence in the decision (to be made). This confirms that the decision analysts can provide decision makers with good evidence to make informed decisions.

In all cases, policy makers realised during our engagement that the premises, upon which they were designing the new policy or lending investments, were often not accurate. In Chapter 2, local decision makers had not considered the impact of external factors such as climate change and competitiveness of neighbouring resorts. In Chapter 1.6 and Chapter 2.6, policy makers realised that they had a limited (and in some cases, biased) knowledge of the preferences and priorities of the beneficiaries. Finally, in Chapter 3.5, our analysis confirmed the original choice, but added useful information about the specific vulnerabilities of the projects, and tradeoffs between performance metrics. Most importantly, all stakeholders involved realised that solutions exist to overcome these knowledge gaps.

Despite the fact that the majority of these analysis were carried out within research projects, this work can claim some impact. In these four projects, I engaged with local municipalities, regional offices, policy and research centres, national ministries, and World Bank lenders' operation teams. After our project, the policy makers we engaged with in Chapter 1.6 designed a similar online platform for the collection of preferences and feedback on their policy design. The tools developed in Chapter 2.6 will support the design of the next phase of a World Bank project that promotes no tillage agriculture in Morocco. And Chapter 3.5 contributes to the World Bank's efforts to improve decision making within the Bank and among client countries. After the publication of the paper, project managers are beginning to seek advice on how to introduce a better management of uncertainties in their project analysis. Moreover, whenever now project managers raise concerns over the complexity of decision processes, the chapter provides a useful example of the contrary.

Then, at least within the limited sample of decision processes described in my thesis and based on the work I have been involved in in these past few years, I can successfully conclude that we can motivate decision makers to utilise support tools to make informed decision for sustainable development.

The Road Is Still Long

However, the question is not if a specific decision support tool/method is right or wrong. I tailored my choice of tools to the priorities of the policy makers and to the specific context they needed support with. In all instances, I cared to remark that the intended beneficiaries should also be involved in the process. Yet, the measure for the effectiveness of decision processes needs to be related to quantitative and qualitative changes in the outcomes of decision making, better understanding of the problem, improved communication, and confidence in the decision.

In this regard, whilst the application of the suggested tools and inclusive processed has improved the dialogue between decision makers and beneficiaries and it has raised critical questions in the policy makers' minds, the main limitation of this thesis is that it does not follow any of the decision processes through to the implementation phase.

On the one hand, the information we provided in the four projects is only a small part of the total information input of decision makers. In the "real" world, analysis seldom informs decisions. The world moves into the future as a result of decisions, not as a result of plans (Boulding, 1975). This means that the planning outputs described in this thesis will become significant only in so far as they affect decisions.

On the other hand, there is "no certainty that its impact is positive for producing better decision, rather than worse" (Boulding, 1975). Following the process through to implementation would disclose the real value of a decision support analysis. This limitation is common to the vast majority of decision support projects. However, works like this thesis provide solutions and hopefully promote a different awareness in the decision bodies.

For these two reasons, it would be recommendable to monitor the final decision and its long term impact on the intended beneficiaries. Until now, the study of the effects of the products of decision analysts has been much neglected and is indeed a stimulating field of research. Did decision makers implement the choice, which emerged from the decision process? What was the impact? Did they apply similar approaches to subsequent decision problems? This study would provide useful insights into what should be changed in the decision support practice. It would help reducing the uncertainty which surrounds the long-term impacts of our work.

Final Thoughts

This work hopes to illustrate the advantages and the criticality of joining qualitative and quantitative analysis. It strived to adapt established methods to the decision contexts, in order to maximise the potential of adoption of the outcome of the process. The message is, the simpler the better, without losing scientific soundness. Thus, by presenting a portfolio of applications that provide answers to three decision objectives, this thesis contributes to the body of knowledge on good decision making.

We must seek local solutions tailored to specific problems. But, the combinations tested are replicable in similar contexts, depending on the data and resource availability. Therefore, in spite of what is often reported about the limitations of decision support processes in theoretical and policy debates, this thesis suggests that decision analysis, if properly applied, may contribute to successful sustainable development and climate change adaptation.

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Appendix A

Additional Publications

Bojovic, D., Bonzanigo, L., Giupponi, C., Maziotis, A. (in press). Online participation in climate change adaptation: case study of agricultural sector adapting agriculture in Northern Italy water management. Journal of Environmental Management.

Bonzanigo, L., Bojovic, D., Maziotis, A. Giupponi, C. (under review). The informative role of farmers' perceptions of change for the development of robust climate change adaptation policies. A case study from Italy. Journal of Sustainability. Preliminary version published in the conference proceedings, Italian Society for Climate Science, September 2013.

Bonzanigo, L. Sinnona, G. (2014). Present challenges for future water sustainable cities in Northern Italy. Drinking Water Engineering Science, 7, 35-40, 2014. doi:10.5194/dwes-7-35-2014.

Appendix B

Chapter 1 - Supplementary Material

B.1 Outputs Of The Social Network Analysis

As the outcome of the social network analysis, the various institutions are represented as nodes, whereas the edges that unite the nodes indicate the existence of institutional interaction. The size of the nodes represents the overall scores that each received from the other interviewees. The thinner is the edge between two nodes, the worst the frequency of the actors' interaction. The frequency of the social network analysis (SNA) is graphically represented below, if simplified (Figure B.1). For sake of simplification, reciprocity was assumed. As it appears in (Figure B.1), the social network that emerges from this preliminary analysis is very compacted. Although to different extents, the interviewees are inter-related. No sub-groups operate independently from the others. The network density of 0.52 indicates that 52% of the relationships that could occur indeed materialise. Nevertheless, there emerges some difference in the number of actors to which each institution is connected: from a minimum of 2 of 'Civil Protection' to a maximum of 20 of the 'Tourism Board' and the Municipality's 'Technical Office'. Strong interactions occur also within and amongst actors involved in outdoor activities (alpine guides, ski instructors, and so forth).

TABLE B.1: Characteristics of Auronzo's social network

Node	Degree	Relative Degree*	Node	Degree	Relative Degree*
Public administration	10	0.45	**Construction companies**	**6**	**0.27**
Technical office	**19**	**0.86**	MisurinaNeve	9	0.40
Regole Villapiccola	9	0.40	Tourist office	15	0.68
Hotels/Restaurants Auronzo	15	0.68	Civil protection body	2	0.09
Chalets	13	0.59	**Alpine rescue**	**5**	**0.22**
Agrotourism	15	0.68	Ski resort	12	0.55
Estate-agents	10	0.45	**Estate-less tourist**	**16**	**0.73**
Italian Alpine Club (CAI)	13	0.59	**Second-home tourist**	**16**	**0.73**
Ski school Auronzo	14	0.63	Hotel Misurina	16	0.73
Alpine guides	15	0.68	Ski school Misurina	12	0.55
Tourism board	**18**	**0.81**	Regole Villagrande	11	0.50
Businesses	13	0.59			

(* relative to number of all other nodes (self excluded))

TABLE B.2: Quality of interactions' average scores (1-6)

Institution	Score	Institution	Score
Public administration	4.1	Construction companies	3.5
Technical office	4.7	**MisurinaNeve**	**5.7**
Regole Villapiccola	3.7	Tourist office	5.6
Hotels/Restaurants Auronzo	5.2	Civil protection body	4.3
Chalets	4.3	Alpine rescue	5.2
Agrotourism	4.6	Ski resort	5.4
Estate-agents	3.4	Estate-less tourist	4.7
Italian Alpine Club (CAI)	5.2	Second-home tourist	5.3
Ski school Auronzo	5.2	Hotels Misurina	4.1
Alpine guides	4.7	Ski school Misurina	4.3
Tourism board	**5.8**	**Regole Villagrande**	**2.1**
Businesses	4.8		

Table B.1 summarises the number of relations of each institution considered. It appears that both "estate-les" and "second-home" tourists have direct contact with 73% of the other actors. Not only social interactions vary in frequency, but also their quality fluctuates significantly (see Figure B.1). Thus, respondents were asked to indicate the quality of interaction with the other nodes. "1" stood for "appalling", "6" for "optimal". Table B.2 reports instead the average mark that each institution received from the others in terms of quality of relationship. Although the average remains quite positive, with an average score of 4.5 out of 6, Villagrande land authority seems to score the worst result, with an average of 2.1 (scarce quality). Conversely, the Tourism Board remains at the top, together with MisurinaNeve, the company that owns the lifts in Misurina. Alpine rescue, which in terms of frequency was one of the lowest, is however recognised as offering a good service by those who interact with the body.

B.2 Cognitive and spatial mapping of adaptation strategies considered

Figure B.3B.4B.5 illustrate the results of brainstorming over the strategies, during the first workshop.

B.3 mDSS and its interfaces

Figure B.6B.7B.8B.9B.10B.11 illustrate the various interfaces of the decision support tool mDSS.

B.4 Results of the SWOT analysis

Table B.3 synthesises the SWOT analysis of the three adaptation strategies.

B.5 Quantification of the indicators for the MCA evaluation

Table B.4 describes how we quantified the different indicators.

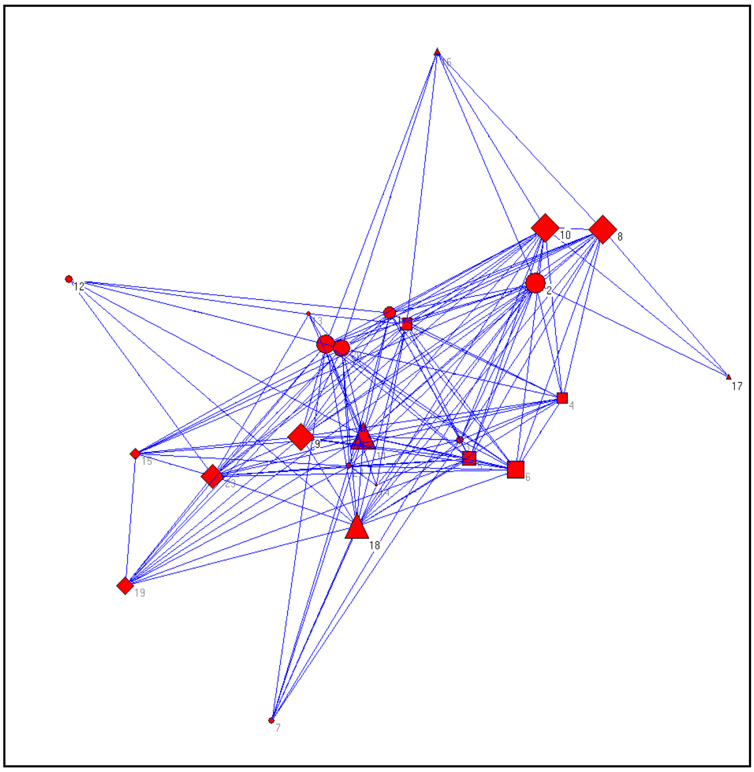


FIGURE B.1: Emerging social network. The different shapes represent the categories, which individuals belong to: Triangle = municipal administration and other institutions both for tourists and for residents; Circle = public tourist management organism; Square= Hoteling facility, including restaurants; Rhombus= outdoor entertainment.

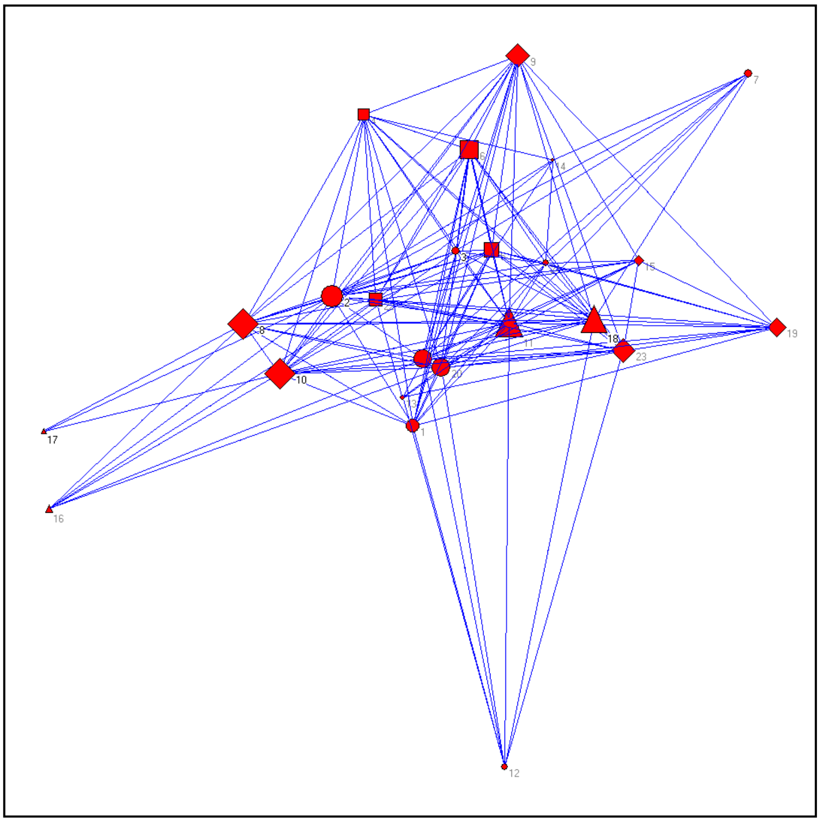


FIGURE B.2: The quality of interactions between actors

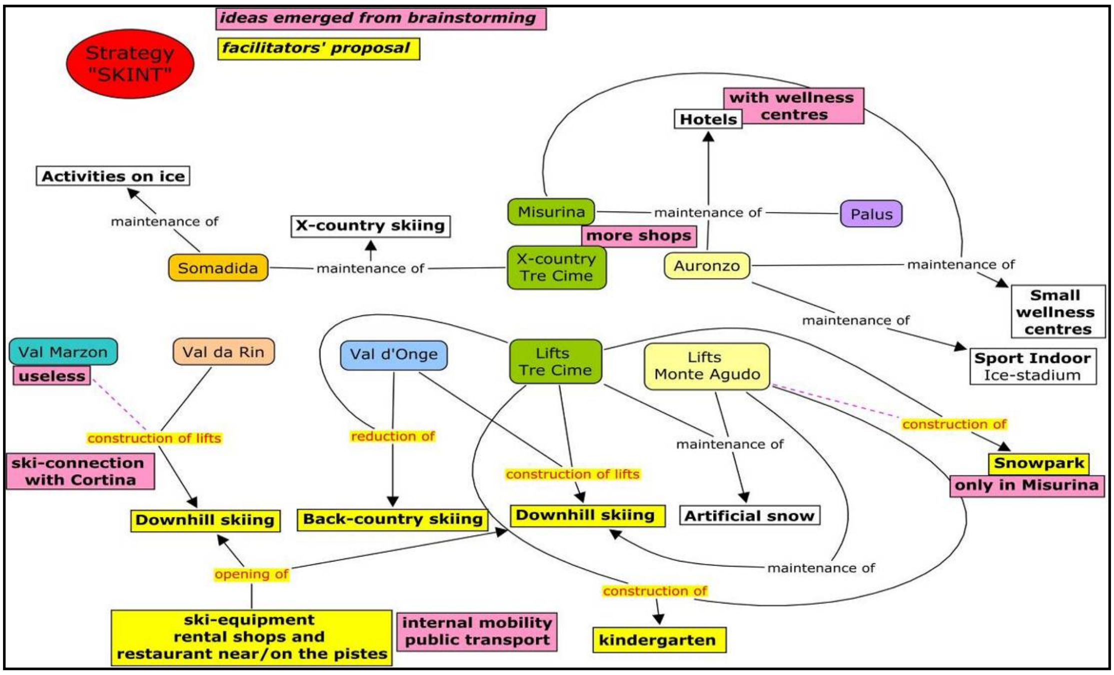


FIGURE B.3: Strategy SKINT after brainstorming

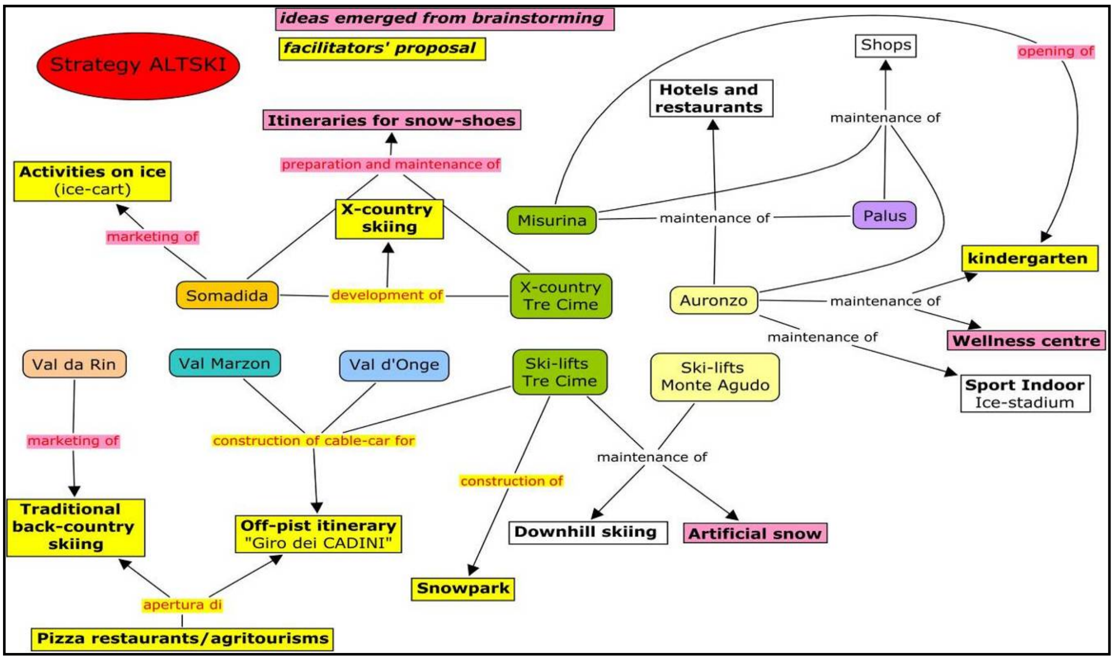


FIGURE B.4: Strategy ALTSKI after brainstorming

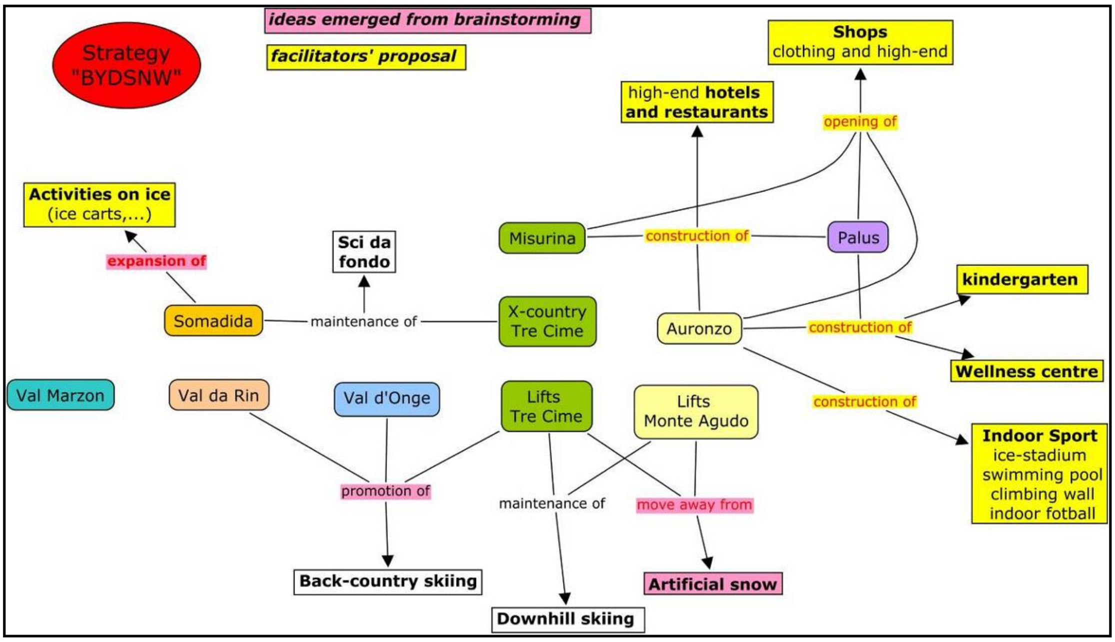


Figure B.5: Strategy BYDSNW after brainstorming

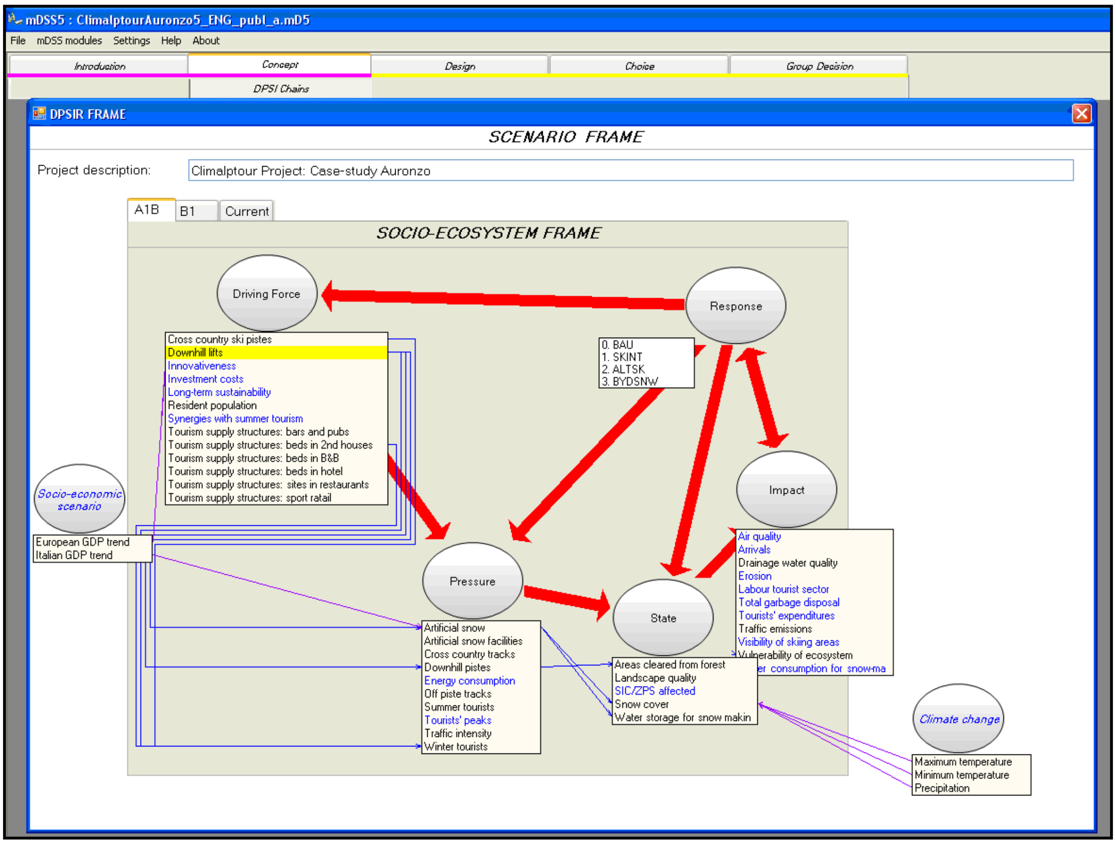


Figure B.6: ClimAlpTour mDSS5, the DPSIR interface

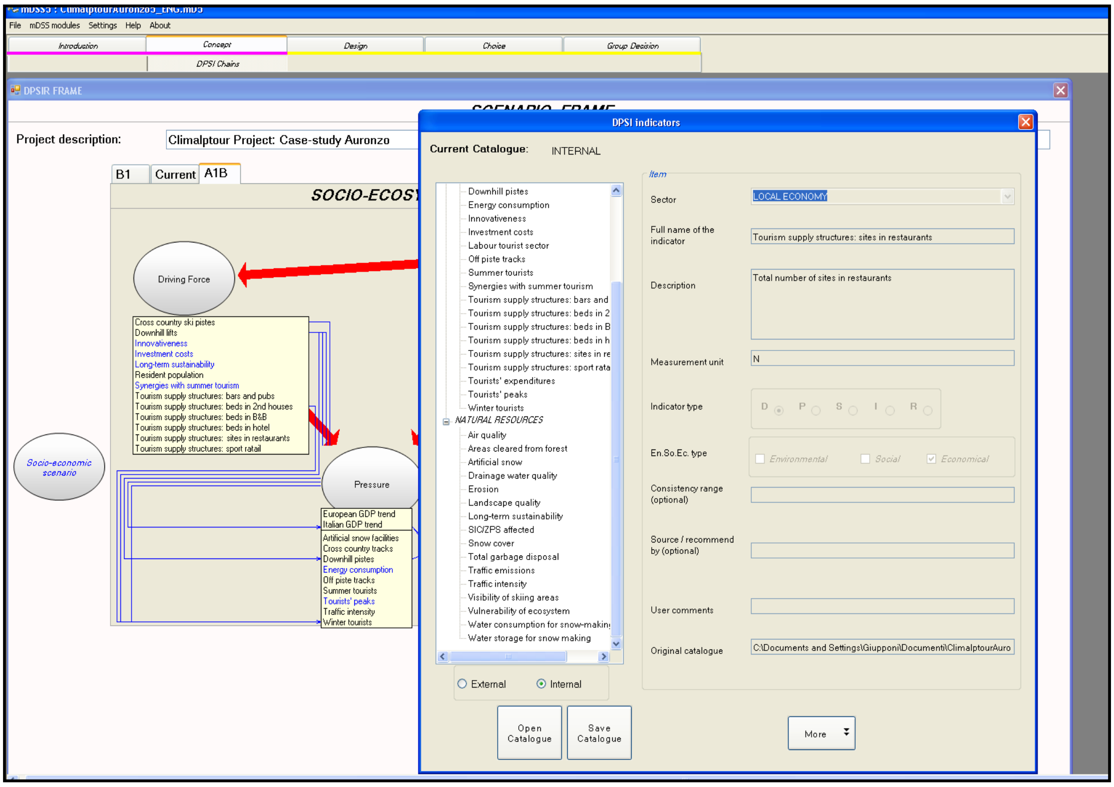
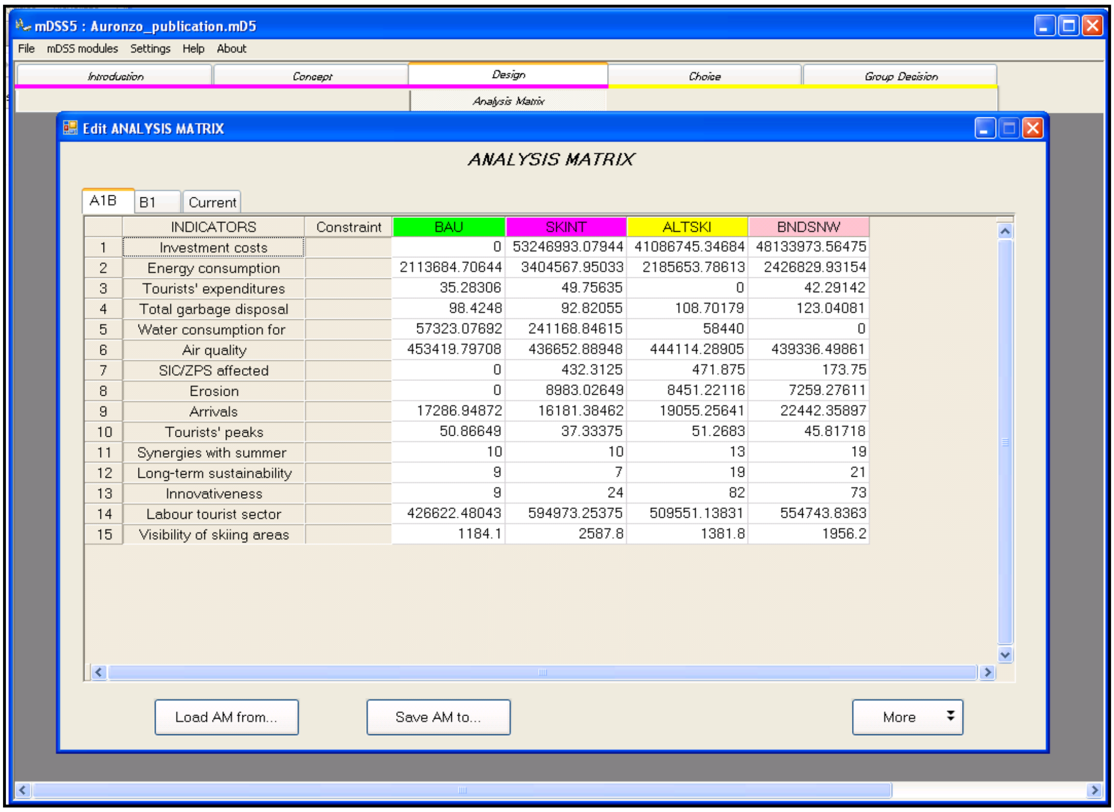


Figure B.7: ClimAlpTour mDSS5, uploading the indicators



	INDICATORS	Constraint	BAU	SKINT	ALTSKI	BNDSNW
1	Investment costs		0	53246993.07944	41086745.34684	48133973.56475
2	Energy consumption		2113684.70644	3404567.95033	2185653.78613	2426829.93154
3	Tourists' expenditures		35.28306	49.75635	0	42.29142
4	Total garbage disposal		98.4248	92.82055	108.70179	123.04081
5	Water consumption for		57323.07692	241168.84615	58440	0
6	Air quality		453419.79708	436652.88948	444114.28905	439336.49861
7	SIC/ZPS affected		0	432.3125	471.875	173.75
8	Erosion		0	8983.02649	8451.22116	7259.27611
9	Arrivals		17286.94872	16181.38462	19055.25641	22442.35897
10	Tourists' peaks		50.86649	37.33375	51.2683	45.81718
11	Synergies with summer		10	10	13	19
12	Long-term sustainability		9	7	19	21
13	Innovativeness		9	24	82	73
14	Labour tourist sector		426622.48043	594973.25375	509551.13831	554743.8363
15	Visibility of skiing areas		1184.1	2587.8	1381.8	1956.2

Figure B.8: ClimAlpTour mDSS5, the Analysis Matrix

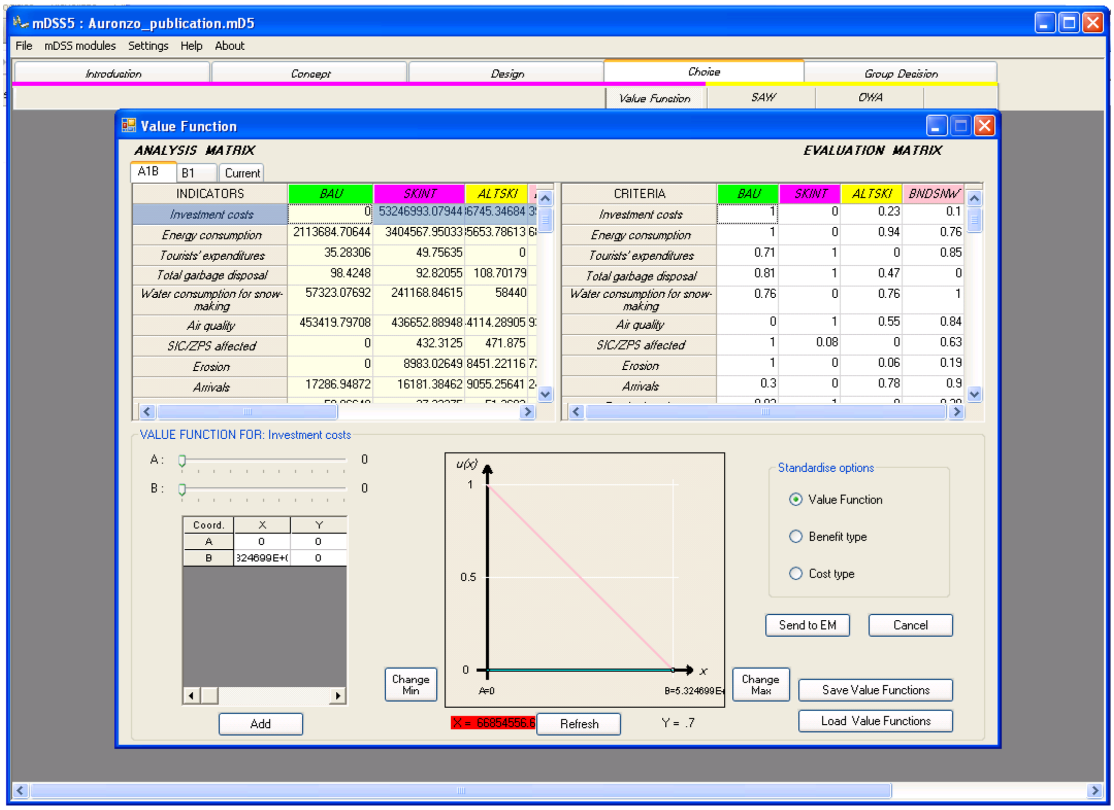


Figure B.9: ClimAlpTour mDSS5, From the Analysis Matrix to the Evaluation Matrix, via normalisation

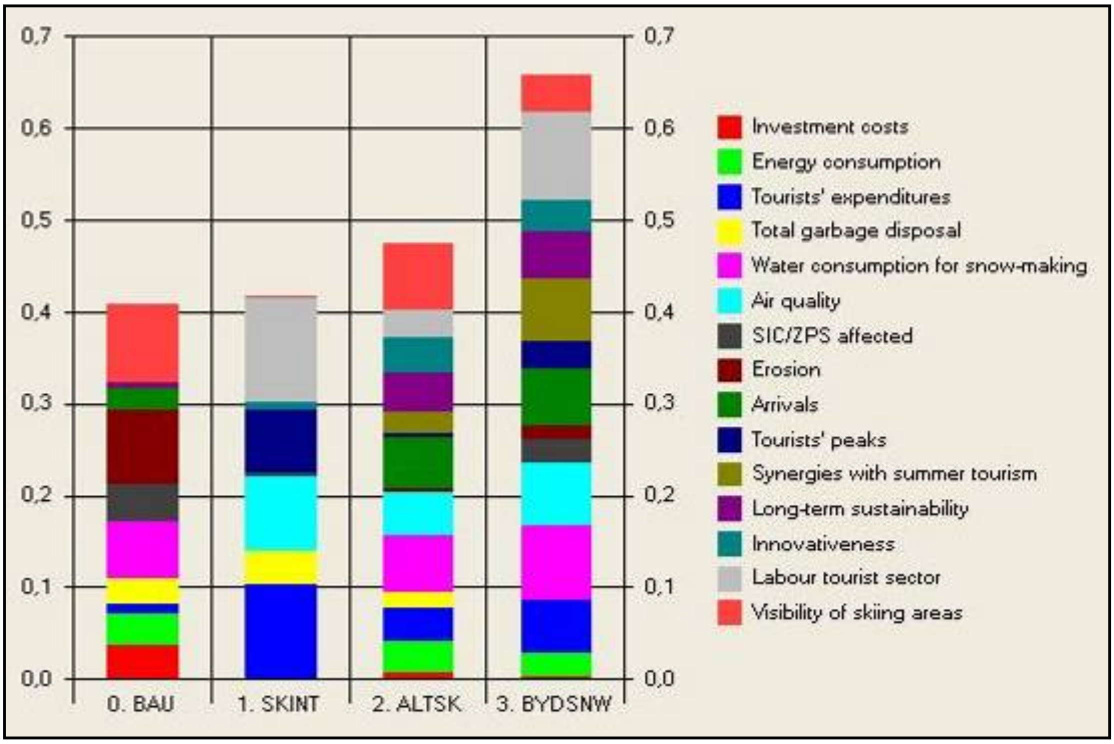


Figure B.10: Strategies ranking after weights' elicitation (under scenario B1)

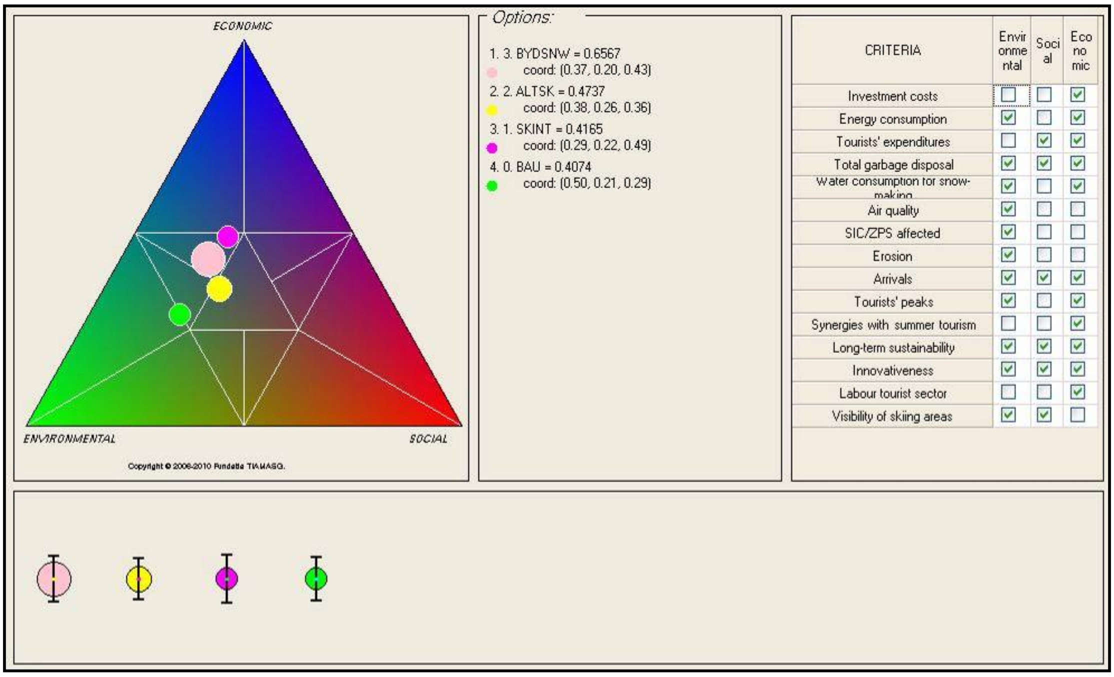


FIGURE B.11: Sustainability triangle of the strategies evaluated (under scenario B1)

TABLE B.3: Synthesis of the SWOT analysis

	S	W	O	T
SKINT	Uniqueness of the Municipality's landscape	Transport connections; UNESCO regulations	Potential links with neighbouring resorts	Competition with neighbouring resorts
ALTSKI	Uniqueness of the Municipality's landscape	Public transport system	Less competition with neighbouring resorts	Scarce natural snow around Auronzo di Cadore
BYDSNW	Uniqueness of the Municipality's landscape	Local people's attitude	Different offer from neighbouring resorts	Competition with neighbouring resorts

TABLE B.4: Quantification of the indicators for the MCA evaluation

	Indicators	Sustainability Pillar(s)*	Description	Unit	DPSIR	Calculated with:
1	Erosion	Env	Delta tons of average soil loss after each strategy's implementation	ton	I	RUSLE (Simile), GIS (Idrisi), Google Earth
2	Air quality	Env	CO2 captured by forest - (C02transport + CO2hotels + CO2ski-lifts)	ton/y	I	AWS1.0 for n. of tourists and their displacement, IDRISI for ha deforested, lit. review for average CO2 emissions
3	SCI affected	Eco/Env	Site of Community Importance altered by interventions	ha	S	GIS (Idrisi) /maps Region
4	Visibility of skiing areas	Env/Soc	Associates to each cell of the urban landscape the percentage of a given ski area that is visible from there, as a function of terrain topography and land cover	ha	I	GIS (Idrisi)
5	Water consumption for snow-making	Eco/ Env	Water use for artificial snow	m3/y	I	AWS1.0
6	Total garbage disposal	Eco/Env/Soc	Garbage disposal per winter season per number of tourist nights	ton	I	AWS1.0 (tourist nights), lit. review
7	Energy consumption	Eco/Env	Average cost of energy of a season	euros	P	AWS1.0
8	Tourists' expenditures	Eco/Soc	Average daily expenditures per visitor	euros/day	I	AWS1.0
9	Labour tourist sector	Eco	Approximated with variable cost of running tourist facilities	euros	I	AWS1.0
10	Tourists' peaks	Eco/ Env	Standard deviation of total daily visitors over 40 seasons	CV%	P	AWS1.0
11	Arrivals	Eco/Env/Soc	N. of arrivals, Existing data on guest structure	N.	I	AWS1.0
12	Synergies with summer tourism	Eco	Sum of contribution of each strategy to summer tourism	0-4	D	Experts' judgment
13	Investment costs	Eco	Sum of costs per sector per strategy	euros	D	AWS1.0
14	Long-term sustainability	Eco/Env/Soc	The strategy seems appropriate from a long-term-sustainability perspective	0-4	D	Experts' judgment
15	Innovativeness	Eco/ Env	Innovativeness of strategy in terms of green-initiatives, new activities proposed, type of tourism, niche offer etc	0-4	D	Experts' judgment

(* Eco= Economic; Env= Environmental; Soc= Social;

A1B | B1 | Current — tab: **A1B**

OPTIONS:	Score:	% (relative to 1st position)
3. BYDSNW	0.6422	100%
2. ALTSK	0.4729	73%
1. SKINT	0.4245	66%
0. BAU	0.3974	61%

A1B | B1 | Current — tab: **B1**

OPTIONS:	Score:	% (relative to 1st position)
3. BYDSNW	0.6567	100%
2. ALTSK	0.4737	72%
1. SKINT	0.4165	63%
0. BAU	0.4074	62%

A1B | B1 | Current — tab: **Current**

OPTIONS:	Score:	% (relative to 1st position)
3. BYDSNW	0.6313	100%
2. ALTSK	0.4648	73%
1. SKINT	0.4165	65%
0. BAU	0.4053	64%

FIGURE B.12: Results of the mDSS runs

B.6 Ranking of adaptation strategies in the three scenarios

Finally, Figure B.12 reports the output of the MCDM analysis with the mDSS5 tool. For sake of transparency, we recommended always to accompany this figure with Figure B.10. An index means little to a decision maker and hides all the information that lead to a specific ranking.

Appendix C

Chapter 3 - Supplementary Material

C.1 The Multi Criteria Analysis Questionnaire

Figure C.1 reports the questionnaire participants compiled during the first workshop. It is divided into three phases. First, they had to evaluate the performance of different indicators under CA and conventional agriculture. Then, if they had quantitative data about the indicators, they could add them in. Finally, we asked them to weight the relative importance of the indicators for a farm's long term performance.

C.2 The Questionnaire For The Elicitation Of The Conditional Probability Tables

The following pages report the questionnaire we distributed to various experts to compile the Conditional Probability Tables (CPTs).

NAME:	FARM MANAGEMENT	NO-TILL: ha.	TILL: ha.

1. How will the single criterion perform in no-till and till soil management practices?

In the matrix below cross the appropriate value to express the validity of each management practice (columns) with respect to each of the criteria (rows), according to the scale of ratings on the right

THEME	CRITERIA	NO-TILL	TILL	RATINGS
Management of natural resources	Soil Erosion	1 2 3 4 5	1 2 3 4 5	1=very poorly
	Water Consumption	1 2 3 4 5	1 2 3 4 5	2=negatively
	Agrochemicals Consumption	1 2 3 4 5	1 2 3 4 5	3=neutral
	Diesel Consumption	1 2 3 4 5	1 2 3 4 5	4=positively
Viability of rural life	Straw availability	1 2 3 4 5	1 2 3 4 5	5=very positively
	Contribution to Household Food Security	1 2 3 4 5	1 2 3 4 5	
	Feasibility	1 2 3 4 5	1 2 3 4 5	
Competitiveness of agricultural sector	Yield Stability	1 2 3 4 5	1 2 3 4 5	
	Production Costs	1 2 3 4 5	1 2 3 4 5	
	Farm Income	1 2 3 4 5	1 2 3 4 5	
	Labour Demand	1 2 3 4 5	1 2 3 4 5	

3. Quantitative data from fields

		2012		2013		2014	
THEME	CRITERIA	NO-TILL	TILL	NO-TILL	TILL	NO-TILL	TILL
Management of natural resources	Soil Erosion						
	Water Consumption						
	Agrochemicals Consumption						
	Diesel Consumption						
Viability of rural life	Straw availability						
	Contribution to Household Food Security						
	Feasibility						
Competitiveness of agricultural sector	Yield Stability						
	Production Costs						
	Farm Income						
	Labour Demand						

2. Which is the relative importance of each criterion when trying to increase farm productivity in the long term?

Read carefully the criteria's list. You have 100 points to distribute among the criteria The most important criteria receive the highest score. The total score must add up to 100.

THEME	CRITERIA	WEIGHTS
Management of natural resources	Soil Erosion	
	Water Consumption	
	Agrochemicals Consumption	
	Diesel Consumption	
Viability of rural life	Straw availability	
	Contribution to Household Food Security	
	Feasibility	
Competitiveness of agricultural sector	Yield Stability	
	Production Costs	
	Farm Income	
	Labour Demand	
		SUM=100

4. Had you already tried no-till before ACLIMAS? Yes ☐ No ☐

FIGURE C.1: The Questionnaire For The MCA Evaluation: Performance, Eventual Field Data, And Weighting.

23-08-2014

Questionnaire pour la calibration d'un network bayésien consacré à l'exploration du potentiel d'adoption de l'agriculture de conservation dans une région agricole pluviale. Application à la région semi-aride du Maroc central.[1]

Durée estimée: 45 min

<table>
<tr><td>Nom*</td><td></td></tr>
<tr><td>Prénom*</td><td></td></tr>
<tr><td>Affiliation*</td><td></td></tr>
<tr><td>Email*</td><td></td></tr>
<tr><td colspan="2">Est ce que vous dérangera d'être recontacté par les auteurs? [Oui] [No]</td></tr>
<tr><td>Compétence sur l'agriculture de conservation dans les régions semi-arides</td><td>1. Compétence général? [Oui] [No] [Autre] (Spécifié)
____
2. Années d'expérience dans le domaine?
[<5] [de 5 à 10] [>10]
3. Avez-vous déjà travaillé sur l'adoption de nouvelles pratiques agricoles? [Oui (Spécifié)] [No]
____
4. Êtes-vous familier avec le cas d'étude? [Oui] [No] [Autre] (Spécifié)
____
______________________________</td></tr>
<tr><td>Pourriez-vous suggérer d'autres experts que nous pourrions contacter pour ce questionnaire?</td><td>Nom, prénom et email :
(1) ______________________________
(2) ______________________________
(3) ______________________________</td></tr>
</table>

* L'analyse des données préservera l'anonymat de la source.

[1] Ce travail fait partie de la thèse de Laura Bonzanigo en Sciences et Gestion du Changement Climatique, à l' Université Ca' Foscari de Venise. Le superviseur de ce travail est le professeur Carlo Giupponi.

1. Raisons

L'agriculture de conservation (AdC) est basée sur trois principes:

1. la réduction du travail du sol, ou semis direct;
2. l'utilisation de couverts améliorants permanents (composées d'une culture ou un paillis des résidus de récolte);
3. les rotations culturales[2].

La recherche dans la région semi-aride du Maroc Central démontre que dans des conditions optimales, l'AdC augmente et stabilise les rendements, réduit les besoins du main-d'œuvre, limite l'érosion et améliore la fertilité du sol.

Ce dépendant, après deux décennies de démonstration et de sensibilisation, l'adoption de l'AdC dans la région est encore limitée.

Les chercheurs mentionnent l'absence des semoirs adaptés comme une contrainte importante. Les agriculteurs mentionnent aussi le manque de connaissances, la disponibilité des engrais, des pesticides et des incitations suffisants pour les rotations. Les petits exploitants en particulier, mais pas seulement eux, ajoutent la gestion des résidus comme une contrainte sévère.

Ce travail étudie les **conditions pour l'adoption** de l'AdC dans la région par 3 différentes typologies des agriculteurs locales (petites, moyennes, grandes). L'hypothèse est que la gestion de la ferme et la disponibilité des intrants varient considérablement en fonction de la taille de l'exploitation. Au même temps, quelques contraints, comme les incitations pour le légumineuses et la disponibilité de main-d'œuvre, affectent tous les agriculteurs également.

A notre connaissance, il n'existe aucune étude qui tente de quantifier les contraintes rencontrées par les agriculteurs et de proposer des solutions. Nous mesurons les voies possibles pour l'adoption via un Réseau Bayésien de Décision (Bayesian Decision Network, ou BDN). Nous utilisons BDN pour l'évaluation probabiliste de l'influence que les différents critères ont vers la décision d'adopté l'AdC.

Le questionnaire sera utilisé pour calibrer le BDN, afin qu'il puisse refléter les opinions d'experts que vous même et les autres fournirez.

2. Explication du modèle

Un réseau bayésien (BDN) est un système représentant la connaissance et permettant de calculer des probabilités conditionnelles apportant des solutions à différentes sortes de problématiques[3]. Il est un modèle graphique probabiliste représentant des variables aléatoires sous la forme d'un graphe orienté acyclique.

La structure de ce type de réseau est simple: un graphe dans lequel les *nœuds* représentent des variables aléatoires, et les *arcs* (le graphe est donc orienté) reliant ces dernières sont rattachées à des probabilités conditionnelles.

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[2] Ken E. Giller et al., "Conservation Agriculture and Smallholder Farming in Africa: The Heretics' View," *Field Crops Research* 114, no. 1 (October 1, 2009): 23–34, doi:10.1016/j.fcr.2009.06.017.

[3] Parent and Eustache, (2007). Les Réseaux Bayésiens. A la recherche de la vérité. http://liris.cnrs.fr/amille/enseignements/master_ia/rapports_2006/Reseau%20Bayesien%20SYNTHESE%20ECRITE.pdf

L'intérêt particulier des réseaux bayésiens est de tenir compte simultanément de connaissances a priori d'experts (dans le graphe) et de l'expérience contenue dans les données. Construire un réseau bayésien, c'est donc :

1. définir le graphe du modèle;
2. définir les tables de probabilité de chaque variable, conditionnellement à ses causes.

Le graphe est aussi appelé la « structure » du modèle, et les tables de probabilités ses « paramètres ». La structure est fournie par des experts, et les paramètres sont fournis par eux ou calculés à partir de données.

1. Définition du graphe du modèle
Nous avons construit une carte conceptuelle des éléments qui influencent la décision d'adopté l'AdC et nous avons l'affiné dans un atelier à Settat en mars 2014 avec des agriculteurs et des chercheurs de l'INRA Settat.

Ensuite nous avons traduit le point de vue des participants sur les contraintes et les opportunités pour l'adoption dans un BDN, en soulignant leurs priorités et préoccupations (Figure 1). Le BDN résultant contient critères *physiques* (p.e. sol et climat), *techniques* (p.e. disponibilité des intrants), et *macro* (p.e. les subventions et les conditions du marché), ainsi que des variables de *gestion agricole* (p.e. les rotations culturels).

Le BDN Pour La Simulation De La Décision Stratégique D'Adopté Semis Directe

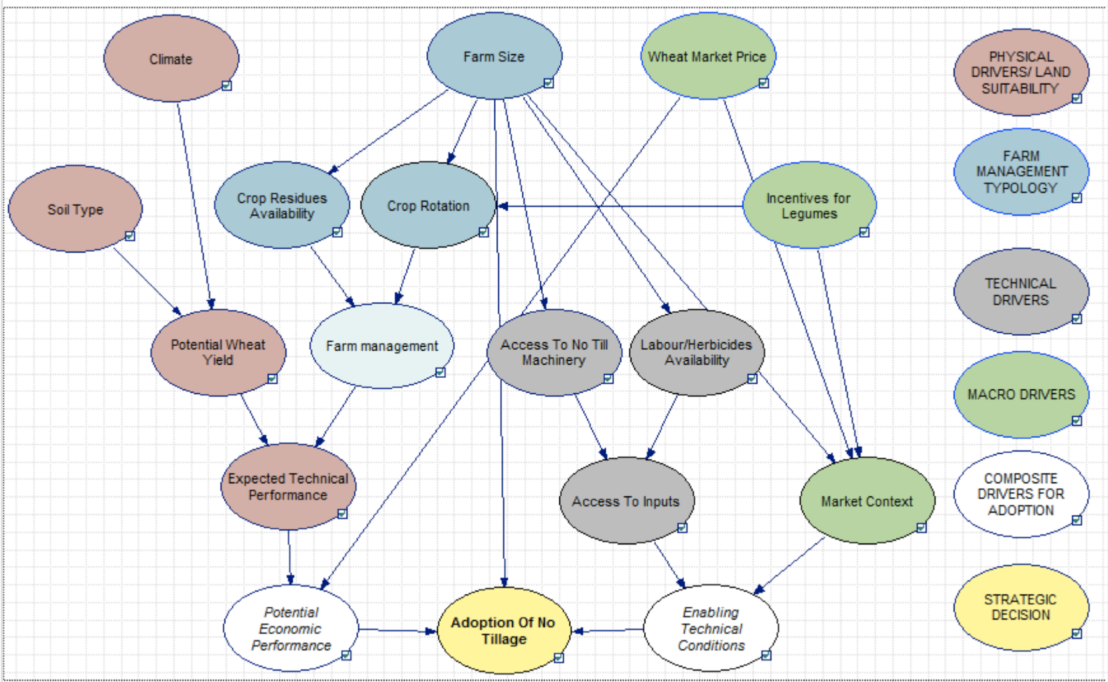

Figure 1 Le BDN proposé pour la simulation de la décision d'adopter l'AdC dans la région semi-aride du Maroc Central

2. *Définition des tables de probabilité*
Pour chaque variable, nous avons identifié des catégories possibles des données. Avec ce questionnaire, nous aimerons collecter la connaissance des experts, pour définir les tabes de probabilité de chaque variable.

N.B.: Cette BDN est probablement pas exhaustive de tous les éléments qui influencent la décision d'adopter semis directe. Cependant, nous avons tenté de inclure les éléments principaux qui sont émergé à Settat avec les acteurs locaux. Aussi, la typologie de décision que nous explorons est *stratégique* (au long-term), et pas *tactique* (de un ans à l'autre). C'est pour ça que nous n'avons pas inclus par exemple le commun délai de 2 à 5 ans, pour retrouver un sol vivant normal et une productivité plus stabile que dans l'agriculture avec labour.

3. Récolte de données

Nous vous demandons de nous aider en 2 façons:

1. Pour définir les tables de probabilité de chaque variable, conditionnellement à ses causes.
2. Pour exprimer votre point de vue sur certaines définitions.

Les réponses, pour quelles nous aimerions votre opinion, concernent:

1. La probabilité de rendements potentiels du blé en utilisant l'AdC.
2. La probabilité de l'aptitude de la ferme en utilisant l'AdC.
3. La probabilité de productivité potentielle en utilisant l'AdC.
4. La probabilité de conditions de marché adéquates pour l'AdC.
5. La probabilité de l'accès aux intrants pour faire l'AdC.
6. La probabilité de l'adoption de l'AdC.

Instructions

***Exemple de question* : Comment évaluez-vous les rendements potentiels d'une ferme en utilisant l'AdC, en considération des différentes combinaisons de climat et de sol?** *S'il vous plaît remplir dans les zones grises du tableau ci-dessous avec les valeurs de 0 à 100 (faible à forte probabilité). Pour chaque colonne, la somme devrait être de 100.*

Exemple de reposte :

<table>
<tr><td>SOL</td><td>Sablonneux</td><td rowspan="6">Ici, selon ma connaissance de la question et de la région, j'estime que les rendements d'une ferme que pratique l'AdC où les sols sont sablonneux et le climat est négatif, il' y aura une probabilité de 60% d'être inférieurs à 2 tonnes/ha, une probabilité de 30% d'être entre 2 et 3 tonnes/ha, et une probabilité de 10% d'être plus de 3 tonnes/ha.</td></tr>
<tr><td>CLIMAT</td><td>Négatif</td></tr>
<tr><td>Rendements <2 ton/ha</td><td>60</td></tr>
<tr><td>Rendements de 2 à 3 ton/ha</td><td>30</td></tr>
<tr><td>Rendements >3 ton/ha</td><td>10</td></tr>
<tr><td></td><td>=100</td></tr>
</table>

4. Questions

4.1 Probabilité des rendements potentiels du blé qui utilise l'AdC.

La variable «rendements potentiels du blé» indique les rendements qui on pourrait obtenir avec l'AdC, en dépendent du sol et climat qui varient. On assume ici une disponibilité optimale de tous les intrants nécessaires, incluant une rotation et des couverts appropriés.

Comme indicateur du **climat**, nous avons utilisé l'indice ombrothermique (OI), qui est la moyenne des précipitations mensuelles (mm) divisée par la température moyenne (°C). L'OI est utilisé pour identifier les mois secs et humides pendant la saison[4]. Chaque fois que le rapport est inférieur ou égal à 2, le mois est considéré trop sec pour les cultures. Les mois où l'indice est supérieur à 2, sont considérés comme assez humide et propice à la croissance des cultures[5].

Nous définissons ainsi un climat *positif* celui avec un OI supérieur à 2 dans au moins l'80% des mois de la saison agricole (de Novembre à Juin au Maroc). Cela correspond à environ 6 mois, qui est le climat moyen actuel dans la région semi-aride du Maroc central. Dans le climat positif nous incluions aussi que il-y a assez d'eau pendant le 30 jours de floraison du blé[6].

Nous définissons comme un climat *moyen*, celui avec un OI supérieur à 2 dans au moins le 70% de la saison agricole - ce qui équivaut à la 40e percentile de 33 ans de données (par INRA Settat). Enfin, un climat *négatif* est celui qui a moins de 70% des mois de la saison agricole avec un OI supérieur ou égal à 2.

Normalement, il y a 4 Groups Du **Sols** Hydrologiques, de A ou sols sablonneux à D ou sols argileux. Nous considérons les 3 typologies principales de la région du Maroc Central. Ils sont les sols *argileux noirs profonds* (deep black clay), D; les *sols salés rouges et les sols profonde douces calcaires* (Shallower soft chalky soils and salty red soils), B; et les *sols sablonneux* (sandy soils), A.

Comment évaluez-vous les rendements potentiels d'une ferme qui utilise l'AdC, en considération des différentes combinaisons de climat et de sol? *S'il vous plaît remplir dans les zones grises des tableaux ci-dessous avec les valeurs de 0 à 100 (faible à forte probabilité). Pour chaque colonne, la somme devrait être de 100.*

SOLS	*Sablonneux*			*Salés Rouges*			*Argileux Noirs*		
CLIMAT	*N**	*M*	*P*	*N*	*M*	*P*	*N*	*M*	*P*
Rendements <2 ton/ha									
Rendements de 2 à 3 ton/ha									
Rendements >3 ton/ha									
	=100	=100	=100	=100	=100	=100	=100	=100	=100

*Climat : N=Négatif ; M=Moyenne ; P=Positive

[4] F. Bagnouls and H. Gaussen, "Saison Sèche et Indice Xérothermique," *Bull. Soc. Rist. Nat. Toulouse* 88, no. 3.4 (1953): 193–239.
[5] Riad Balaghi et al., *Agrometeorological Cereal Yield Forecasting in Morocco* (Morocco: National Institute for Agronomic Research, 2013).
[6] Beáta Barnabás, Katalin Jäger, and Attila Fehér, "The Effect of Drought and Heat Stress on Reproductive Processes in Cereals," *Plant, Cell & Environment* 31, no. 1 (January 1, 2008): 11–38, doi:10.1111/j.1365-3040.2007.01727.x.

4.2 Probabilité de aptitude d'une ferme à l'AdC.
Nous définissons l' « aptitude de la ferme » à l'AdC comme résultat des les *rotations culturales* et de la *disponibilité de couverts améliorants*. En d'autres termes, l'aptitude de la ferme se réfère à une certaine façon de gérer la ferme sur une base *pluriannuelle*.

(a) La rotation culturale

Pour l'AdC, il est important d'alterner les familles de plantes, afin d'aider à contrôler les mauvaises herbes et augmenter les nutriments dans le sol. Au Maroc, les cultures le plus appropriées/communes après de céréales sont les légumineuses alimentaires. En faisant tourner les céréales et les légumineuses sur un cycle pluriannuel, les parasites et les maladies diminuent. Cependant ça, de plus en plus, les agriculteurs préfèrent faire des céréales/céréales, à cause pour exemple des haut couts de production des légumineuses.

En conséquence, nous définissons les **rotations culturales** comme résultat de la combinaison de la taille de la ferme (il y a des différents attitudes sur les rotations entre grands, moyennes, et petits) et aussi des incitations pour les légumineuses – ça ils peuvent être soif des subventionnes pour les herbicides, soif des hauts pris au marché.

Pour chaque typologie d'agriculteur, **quelle est la probabilité que il/elle puisse introduire la rotation céréales-céréales, céréales-légumineuses alimentaires, ou céréales-fourrage**, en considérations de l'introduction ou pas des incitations pour les légumineuses**?** *S'il vous plaît remplir dans les zones grises de la table ci-dessous avec des valeurs de 0 à 100 (de faible à forte probabilité). Pour chaque colonne, la somme devrait être de 100.*

TYPOLOGIE DE FERME	*Petites Exploitations (<5ha)*		*Moyennes Exploitations (de 5 à 20 ha)*		*De Grandes Fermes (>20 ha)*	
INCITATIONS POUR LE LEGUMINEUSES	*Oui*	*Non*	*Oui*	*Non*	*Oui*	*Non*
Céréales - Céréales						
Céréales – Légumineuses Alimentaire						
Céréales – Fourrage						
	=100	=100	=100	=100	=100	=100

(b) Les couverts améliorants

Alors que nous pouvons attribuer de nombreux avantages de l'AdC aux **couverts du sol**, la disponibilité limitée des résidus culturels, qui sont utilisé comment fourrage ou pour la vende, surtouts dans les années sèches, est souvent une contrainte importante pour sa adoption[7].

Pour chaque typologie d'agriculteur et de climat, **quelle est la probabilité que les agriculteurs puissent laisser sur la parcelle des résidus suffisants pour les niveaux de couverts suivants**? *S'il vous plaît remplir dans les zones grises de la table ci-dessous avec des valeurs de 0 à 100 (de faible à forte probabilité). Pour chaque colonne, la somme devrait être de 100.*

TYPOLOGIE DE FERME	*Petites Exploitations (<5ha)*			*Moyennes Exploitations (de 5 à 20 ha)*			*Grandes Fermes (>20 ha)*		
CLIMAT	*P**	*M*	*N*	*P*	*M*	*N*	*P*	*M*	*N*
Couverts améliorants 0-20%									
Couverts améliorants 20-40%									
Couverts améliorants >40%									
	=100	=100	=100	=100	=100	=100	=100	=100	=100

* P= Positif, M= Moyenne, N=Negatif

(c) L'aptitude d'une ferme à l'AdC

Finalement, **quelle est la probabilité que l'aptitude de la ferme à l'AdC,** comme résultat des combinassions des différents rotations culturales et disponibilité de résidus, puisse être

- *Faible* – la gestion actuelle de la ferme n'est pas appropriée pour l'adoption de AdC.
- *Moyenne* – la gestion actuelle de la ferme présente des limitations pour l'adoption de l'AdC. Les limitations réduiront la productivité potentielle où augmenteront les intrants requis.
- *Elevée* – la ferme n'a pas des limites de gestions importantes à l'adoption de l'AdC.

Marquez le quadrant le plus approprié avec une « X ». Chaque colonne doit contenir q'une « X ».

ROTATIONS CULTURALES	*Céréales- Fourrage*			*Céréales-Légumineuses*		
DISPONIBILITE DE COUVERTS AMELIORANTS (%)	*0-20*	*20-40*	*>40*	*0-20*	*20-40*	*>40*
Aptitude FAIBLE de la ferme						
Aptitude MOYENNE de la ferme						
Aptitude ELEVEE de la ferme						

[7] Giller et al., "Conservation Agriculture and Smallholder Farming in Africa."

4.3 Probabilité de productivité potentielle a niveau de la ferme, en utilisant l'AdC, en dépendent des rendements potentiels du blé et de l'aptitude de la ferme.
La «productivité potentielle» d'un ferme dépende des *rendements potentiels de blé* et des l'*aptitude de la ferme à l'AdC*. En autres mots, c'est le rendement atteignable du blé. Ici nous n'avons pas encore considéré la disponibilité de les intrants nécessaire pout obtenir cette productivité. Ça réfère à la performance théorique que un agriculteur peux obtenir en utilisant l'AdC dans sa ferme, avec le système de gestion actuelle.

Rappelons-nous que l'aptitude de la ferme indique si l'agriculteur pratique (ou pas) les rotations appropriées pour l'AdC et se il' y a (ou pas) assez de résidus pour la couverture du sol. Les rendements de blé atteignable par une ferme indique ces rendements qui on pourrait obtenir avec l'AdC, en dépendent du sol, de climat et de la disponibilité de tous les intrants nécessaires, en incluant une rotation et des couverts appropriés. Donc pour exemple, sans une gestion appropriée de la ferme, je peux aggraver les rendements potentiels.

Comme définiriez-vous la productivité potentielle a niveau de la ferme, en utilisant l'AdC, comme résultat des différents combinassions des rendements potentiels du blé et de l'aptitude de la ferme :

- *Faible* – la productivité potentielle de la ferme avec l'AdC n'est pas de tous optimale,
- *Moyenne* – la productivité potentielle de la ferme peux être amélioré
- *Elevée* – la productivité potentielle de la ferme est très compétitive (i.e. plus de 3.5 ton/ha[8])

Marquez le quadrant le plus approprié avec une « X ». Chaque colonne doit contenir qu'une « X ».

RENDEMENTS POTENTIELS DU BLE	*<2 ton/ha*			*2< ton/ha <3*			*>3 ton/ha*		
APTITUDE DE LA FERME	*E**	*M**	*F**	*E**	*M**	*F**	*E**	*M**	*F**
Productivité potentielle FAIBLE									
Productivité potentielle MOYENNE									
Productivité potentielle ELEVEE									

*Aptitude de la ferme: *E = Elevée*; *M = Moyen*; *F = Faible*

[8] Boughala and Dahan, *An Economic Comparison between Conventional and No-Tillage Farming Systems in Morocco*. INRA estimates that with no-tillage, under optimal conditions wheat yields should range around 3.5 ton/ha, regardless of farm size

4.4 Probabilité des conditions de marché adéquates pour l'AdC.
Dans le modèle, les « conditions du marché » dépendent du *prix du blé* et des *incitations pour les légumineuses* (soit via des subventionnes ou des prix de marché fixe, comme pour le blé).

(a) Les prix du blé

Maintenant, les prix actuel du blé sont réglementés en 2500 DH/t, mais les prix internationaux changent de façon significative. **Quelle est la probabilité que les prix du BLE DE MARCHE au Maroc dans les années à venir seront:**
S'il vous plaît, remplissez les zones grises du tableau ci-dessous avec les valeurs de 0 à 100 (de faible à forte probabilité). La somme de la ligne devrait être de 100.

LES PRIX DU BLÉ AU MARCHÉ (DH/ton)	*< 2000?*	*2,000 à 3,000?*	*> 3,000?*	
Probabilité				=100

(b) Les incitations pour les légumineuses

Quelle est la probabilité que les *incitations* pour les légumineuses seront introduites dans les 5 prochaines années?	*Marquez un valeur entre 1 a 100 (de faible a faible à forte probabilité)*
Quel douvrait être le *prix minimum (DH/ton) des légumineuses* parce les agriculteurs les introduisissent dans leur rotations?	………….DH/ton

(c) Les conditions du marché

Plusieurs agriculteurs mentionnent que les conditions du marché ne sont pas adéquates pour cultiver les légumineuses, à cause de bons prix de céréales e des prix trop bas - ou trop variables - des légumineuses. Mais **comment définiriez-vous les CONDITIONS DU MARCHÉ appropriées pour l'adoption de l'AdC, pour différentes typologies d'agriculteurs?**

Marquez le quadrant approprié avec un « X ».

PRIX DU BLÉ	<2,000 DH/ton		De 2,000 à 3,000 DH/ton		>3,000 DH/ton	
INCITATIONS POUR LES LÉGUMINEUSES	*Oui*	*No*	*Oui*	*No*	*Oui*	*No*
*Conditions de marché **adéquates** pour les PETITS agriculteurs*						
*Conditions de marché **adéquates** pour les agriculteurs MOYENNES*						
*Conditions de marché **adéquates** pour les GRANDES agriculteurs*						

4.5 Probabilité de l'accès aux intrants pour l'AdC.
La variable «accès aux intrants» est la conséquence de *l'accès à des semoirs adaptés* (qui sont très rare dans la région), à *les engrais et les pesticides*, et à la *main-d'œuvre aux temps de pointe* (c'est a dire pendant le semis, le désherbage).

Comment estimez-vous le pourcentage de fois que les différents agriculteurs ont accès aux intrants nécessaires?

Remplissez les zones grises du tableau ci-dessous avec les valeurs de 0 à 100 (de faible à forte probabilité). La somme de chaque ligne doit être de 100.

SEMOIRS ADAPTES	Accès Ponctuel	Accès tardif	Aucune accès	
Petits agriculteurs (<5ha)				=100
Agriculteurs moyennes (5-20ha)				=100
Grands exploitants (>20ha)				=100

ENGRAIS ET PESTICIDES	Abordable et disponible	Abordable et Indisponible*	Inabordable et Disponible**	
Petits agriculteurs (<5ha)				=100
Agriculteurs moyennes (5-20ha)				=100
Grands exploitants (>20ha)				=100

MAIN-D'ŒUVRE AUX TEMPS DE POINTE	Abordable et disponible	Abordable et Indisponible	Inabordable et Disponible	
Petits agriculteurs (<5ha)				=100
Agriculteurs moyennes (5-20ha)				=100
Grands exploitants (>20ha)				=100

INFORMATION	Aucun accès	Moyen accès	Bon accès	
Petits agriculteurs (<5ha)				=100
Agriculteurs moyennes (5-20ha)				=100
Grands exploitants (>20ha)				=100

* Abordable et indisponible= l'agriculteur a des moyennes que il peut utilisé pour payer la main d'œuvre

** Inabordable er disponible= l'agriculteur n'a pas assez de recours pour les intrants nécessaires à le semi-direct

4.6 Probabilité de l'adoption du semis direct.
Comme nous avons déjà décrit, la recherche montre le grand potentiel économique de l'AdC, étant donné la disponibilité de touts les intrants nécessaires. Toutefois, ces intrants ne sont pas toujours facilement disponibles et ils sont essentielles pour la décision des agriculteurs comme la perspective de gains économiques, si non plus. Et il y a aussi de limitations dans la performance de l'AdC à cause de la gestion de la ferme, qui n'est pas toujours appropriée pour cette technique agricole.

Dans le modèle, nous avons considéré que l'adoption dépende de la <u>performance économique potentielle</u> et des <u>conditions externes</u>. La variable «conditions externes appropriées » combine le contexte du marché et l'accès aux intrants nécessaires. La variable «performance économique potentielle » combine la performance technique – le rendement atteignable en ton/ha - et les prix du blé au marché.

L'hypothèse est qu'un agriculteur peut être convaincu des avantages économiques de l'Adc mais, si il n'a pas accès aux intrants nécessaires par son implémentation, il ne peut pas l'adopter. Au même temps, il pourrait avoir un accès optimal aux intrants mais la performance économique potentielle ne soit pas suffisant a le convaincre à convertir sa ferme a l'AdC.

Quelle est la PROBABILITE D'ADOPTION de l'AdC en dépendant des différentes combinaisons de la performance économique potentielle et des conditions externes?

Remplissez les zones grises du tableau ci-dessous avec les valeurs de 0 à 100 (de faible à forte probabilité). Come référence, INRA a calculé que le rendement moyen après les cout sur le semis conventionnel est du 4,000 DH/ha pour les grands agriculteurs et du 1,700 DH/ha pour les petits.

CONDITIONS EXTERNES	*Appropriées*		
PERFORMANCE ECONOMIQUE POTENTIELLE (DH/HA)	*<3,500*	*3,500 à 5,000*	*>5,000*
Probabilité qu'un PETIT agriculteur adopterait l'AdC			
Probabilité qu'un MOYEN agriculteur adopterait l'AdC			
Probabilité qu'un GRAND agriculteur adopterait l'AdC			

CONDITIONS EXTERNES	*Modérément appropriées*		
PERFORMANCE ECONOMIQUE POTENTIELLE (DH/HA)	*<3,500*	*3,500 à 5,000*	*>5,000*
Probabilité qu'un PETIT agriculteur adopterait l'AdC			
Probabilité qu'un MOYEN agriculteur adopterait l'AdC			
Probabilité qu'un GRAND agriculteur adopterait l'AdC			

CONDITIONS EXTERNES	*Pas appropriées*		
PERFORMANCE ECONOMIQUE POTENTIELLE (DH/HA)	*<3,500*	*3,500 à 5,000*	*>5,000*
Probabilité qu'un PETIT agriculteur adopterait l'AdC			
Probabilité qu'un MOYEN agriculteur adopterait l'AdC			
Probabilité qu'un GRAND agriculteur adopterait l'AdC			

Politiques agricoles pour l'adoption de l'AdC

(a) Pourriez-vous expliquer quelles sont actuellement les contraints majeurs pour l'adoption de l'AdC? (100 mots max.)?

(b) Choisi 3 options de politiques pour faciliter l'adoption de l'AdC

1. ____

2. ____

3. ____

Le questionnaire est terminé!

S'il vous plaît ajouter vos commentaires et notes ci-dessous. Les votre suggestions sont les bienvenues.

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MERCI BEAUCOUP!

CA' FOSCARI UNIVERSITY OF VENICE

Abstract

Department Of Economics

Doctor of Philosophy In Science And Management Of Climate Change
XXVII Cycle

Four Essays On Decision Support Processes For Climate Change Adaptation

by Laura Bonzanigo

Abstract This dissertation is a collection of four essays. Each essay describes a different decision support process in a different context and with different decision makers. However, all decision problems try to answer the same question: how can we make good decisions for the sustainable development of ...? This thesis thus explores different and innovative combinations of tools and methods that may support these decisions. The focus lays on providing sound and transparent technical information to decision makers via engagement processes. It concludes that despite different interests, uncertainties about the future, and complex institutional, political, social, and environmental settings, a sound decision support process can influence the choice of a robust option. Specifically, this thesis proves that decision support can (i) stimulate learning and promote higher levels of creativity in decision making processes; (ii) help coordinate top down policy design with transformations and preferences from the ground; and (iii) help mainstream tools for the support of good planning, which address complexity, conflicts, and uncertainties. And that these results hold even when it is not possible to follow the decision process through to the implementation phase.

Estratto Questa tesi è composta da quattro saggi. Ognuno descrive un processo decisionale specifico, caratterizzato da contesti ed attori differenti. I quattro processi affrontano però tutti la stessa: qual è la migliore decisione da prendere per il futuro sostenibile di ...? Questa tesi studia la combinazione di strumenti e metodi innovativi per il supporto alle decisioni, fornendo risposte scientificamente solide e sviluppate attraverso un processo partecipativo di coinvolgimento dei decisori. La tesi evidenzia che, nonostante divergenze di opinioni e di interessi, incertezze sul futuro e complessi sistemi istituzionali, politici, sociali ed ambientali, un processo decisionale appropriato aiuta ad arrivare ad una decisione solida e condivisa. In particolare, questa tesi dimostra che un processo adeguato di supporto alle decisioni può: (i) promuovere livelli di creatività nel processo decisionale; (ii) contribuire al coordinamento delle politiche gestionali con le dinamiche di trasformazione e preferenza dei beneficiari; e (iii) favorire e promuovere l'utilizzo di strumenti per la pianificazione che considerino la complessità, i conflitti e le incertezze.. Questi risultati possono essere raggiunti anche quando non è possibile seguire il processo decisionale fino all'implementazione della decisione presa.