DELIVERABLE 175:
REPORT ON THE ADAPTIVE DSS, CONCEPTUAL APPROACH AND APPLICATION IN CASE

Report of the NeWater project -
New Approaches to Adaptive Water Management under Uncertainty

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Title	Report on the adaptive DSS, conceptual approach and application in case
Purpose	Techniques developed in this task are set to assist the transition to adaptive management practices, with uncertainty as a defining characteristic. The approach described here builds on conceptual modelling techniques such as cognitive mapping, causal loop diagrams and Bayesian belief networks to gain insight into possible adverse and unintended consequences of water management policies. In combination with decision methods (optimisation based on genetic algorithm and multiple criteria decision methods) these techniques allow to address uncertainties, uncover discrepancies in decision analysis process (e.g. completeness or redundancy of the model based on utility function) and generate policy options that trade-off between conflicting objectives.
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Policy Summary

Overview

Two principles of adaptive management are explored in this report - robustness to perform reasonable well under not entirely known future conditions, and flexibility - sponsored by the sequential decision making – to undo decisions which turn out badly without loosing all the process up to that point. The focus here is placed on the ability to explore intended and unintended consequences of policy measures, and facilitate participatory model development, from simple qualitative word-and-arrow diagram up to quantitative or semi-quantitative models able to provide insights about policy outcomes. We draw on the generic archetypes developed in system dynamics to explore the ramifications of policy interventions. The research reported here is experimental and exploratory. It complements the 'breath' of other WP17 activities by focusing on policy measures, or in terms of the Management and Transition Framework (MTF) on the action arena and action situations.

Description of the tools

Our system starts with the qualitative description of the policy issues, usually conveying the views of different people with stakes in the sought policy choices. This initial description helps to make out what is the believed cause(s) of the issue at hand or what are the aspects with important implications for the analysis and what solutions have been proposed. The existing conceptual modelling techniques (e.g. causal loop diagrams, cognitive maps and their fuzzy counterparts, qualitative and certainty probabilistic networks, Bayesian belief networks) are similar in scope but differ though in way how they capture essential information (e.g. uncertainty) and how the further semi-quantitative analysis is facilitated. Valuable information can be extracted from these qualitative accounts, such as feedbacks and unintended consequences of policy interventions, or recognition of critical system's components. Enriched description of the nodes and the nature of the relations between them can facilitate further insights about the system's behaviour, based on the analytical concepts of the graph theory and inferred from the supported analytical method (e.g. qualitative or probabilistic inference).

The research described here aimed at exploring how the initial qualitative accounts of the systems (cognitive maps) can be translated into a form more apt to assessment of unintended feedback loops (e.g. causal loop diagrams CLD) and how the knowledge consisted in these accounts can be further developed. Particularly, we have focussed on the transformation of cognitive maps into CLD and further into BBN which are further analysed by genetic optimisation techniques (based on genetic algorithm) and multiple criteria decision methods. The combination of these techniques allows to model decision making process in complex environmental problems, addressing uncertainties, uncovering discrepancies in decision analysis process (e.g. completeness or redundancy of the model based on utility function) and generating policy options that trade-off between conflicting objectives.

However, there are important methodological obstacles. The CLD main strength is to analyse the feedbacks loops but these feedbacks are not allowed in the BBN and similar networks which are basically a-cyclic directed graphs. The task team devised options to go about this issue by incorporating multiple snapshots of Bayesian networks. The belief networks will be used to generate snap shots of the model each representing a possible scenario. This will be followed by grouping the actions based on the different scenarios.

Demonstration examples

We refer to two demonstrative cases in this report, one situated in Upper Tisza and the other in Guadiana river basins. The Tisza demonstration example focuses on floods and waterlogging issues. As in many other places, the Tisza river had been streamlined in the past to prevent floods and to gain new agriculture land in landscapes where wetlands and marshes dominated before. Here we have analysed existing legislation, policies and subsidy schemes with potential effects on farmers' decisions, eventually affecting the damages from waterlogging and floods. The policies we looked into include compulsory rules and financial or material incentives realized in the context of the European Agricultural and Rural Development Operational Programmes; national programmes for rural development, environmental protection and spatial development; diverse compensation and insurance schemes, and legislations referring to land use and water management in general.

In Guadiana the demonstration examples refer to groundwater management issues, particularly the overexploitation of the resources as the climate becomes drier and the Guadiana river is insufficient to satisfy all conflicting water uses.

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1 Introduction

1.1 Initial note

The task 175 mandated assistance for and in transition to adaptive management. We recognise that adaptive management draws on many and many different principles[1] and can be realized in different ways. A decision support system (DSS)[2] can inform the choices and help to navigate on the path to adaptive management, but no single DSS can be ample enough to trade-off all the necessary institutional, operational and strategic choices. The focus here is placed on the ability to explore intended and unintended consequences of policy measures, and facilitate participatory model development, from simple qualitative word-and-arrow diagram up to quantitative or semi-quantitative models able to provide insights about policy outcomes.

The research reported here is thus experimental and exploratory. It draws on different tools, conceptual and computerised ones, and suggests how these different tools can be used in combination, exploiting their reciprocal synergies. For explanation of the advantages of these tools we use examples from Tisza and Guadiana case studies.

The adaptive management has been defined elsewhere in the project (Medema *et al.* 2005; Pahl-Wostl *et al.* 2005), thus we discuss the principles of adaptive management only to the extent necessary to explain the choices which guided the research described here. Two of these principles are most important for the purposes of this report: *robustness* to perform reasonable well under not entirely known future conditions, and *flexibility* - sponsored by the sequential decision making – to undo decisions which turn out badly without loosing all the process up to that point.

In adaptive management, policy interventions are provisional and subject to subsequent revisions in response to new learning and new insights collected. The policies thus need to be designed to perform well under a range of anticipated circumstances (IISD 2006). This robustness is not free of costs, the outcomes of policies designed in this way are usually not the best obtainable. To keep these costs low, in some cases the decisions can be split into several subsequent commitments made as new knowledge comes in, which gradually narrow down the range of policy options available. Sequential decision making is a well developed field and suitable to provide aid in similar situations.

Learning and adaptation eventually takes places even if the policy making processes are not designed to encourage them. After the Wenchuan earthquake disaster (China) earlier this year the responsible authorities learned a tragic lesson that many schools buildings were not built to endure long enough to allow people to evacuate (Stone 2008). Similarly, research conducted by Criss and Shock (2001) and earlier by Belt (1975) suggested that the flood protection by increasing levees and other engineering works eventually increase the flood stages for the same discharges, thus increasing risk of flood all other factors being equal. This 'ex-post' or hindsight learning is obtained at considerable costs, in terms of fatalities and

[1] A good overview is given in IISD (2006)

[2] For the purpose of this report, we consider *decision support system* as a collection of tools designed to aid in problem solving, by means of improving the problem structuring, exploration of the result of and aiding informed choices. Not all these tools have to be computerised devices, see Giupponi et al. (2007) for more detail.

damage caused. In an recent Op-Ed[3], Secretary General Ban Ki-moon lauded Bangladesh for adopting disaster risk reduction policies which prevented larger fatalities from the 2007 cyclone Sidr. These policies, Ban Ki-moon stressed, are costly lessons learned from 1970 cyclone Bhola which claimed half a million lives, and other later cyclones. In this report we focus on adaptation explicit at the outset of regulatory policies.

The approach pursued here is not the only possible way how to assist implementation of adaptive management principles. Chuang and Yadav (1998) for example outlined adaptive DSS as a system able to their structure, functionality or interface so as to better meet the different needs of their users. In Fazlollahi et al. (1997) and elsewhere, the adaptivity refer to the ability to support different cognitive styles. In Giupponi et al. (2007), we have addressed the issues of the limited DSS uptake for practical decision making, arguing that more attention needs to be paid to early stages of the decision analysis. Still others have preferred to focus on identifying vulnerable zone and population segments, so as to increase their ability to cope with unexpected or unpredictable events (Alessa *et al.* 2008; Moser *et al.* 2008). Our research is in many aspects complementary to these approaches.

Many examples used in this report relate to climate change. This is because water management is a key area for climate adaptation strategies to focus on. Water is both bone and bane; a life-sustaining resource and one of the deadliest and costliest hazards. Water vapour is also an important greenhouse gas, but clouds, mountain snow-packs and ice sheets reflect the most energy and cool the Earth. In this way, “water acts as the venetian blind of our planet, as its central heating system and as the fridge, all at the same time” (Langenberg 2002). In this report, to avoid confusion of adaptive management policies and climate adaptation policies, we use the adjective "adaptive" synonymously to ‘flexible’ or ‘robust’. When using the substantive ‘adaptation’ or ‘adaptation strategies’, we mean policies aimed to increases preparedness to climate conditions. Although the usage of these both terms is different, they are to a large extent related.

1.2 Task 175 in the context of the project

The task 175 is formally part of WP17 (Methods for the transition to adaptive Management) whose main aim is to design management and transition framework (MTF) for adaptive water management. MTF is a conceptual framework helping to understand contemporary management regimes and facilitating the transition to AWM (Pahl-Wostl *et al.* 2007). A part of this framework is activity diagram or Double Loop Diagram (DLD), in which the conventional management processes are complemented with opportunities for "reframing" or restructuring the management regimes to make them more introspective. Another aim of the WP17 is to explore how explicit uncertainty management and inclusive governance practices can help to set stage for implementation of adaptive measures.

The task 175 contributes in this 'breath' of activities by focusing on policy measures (their robustness and flexibility). The system described here is useful for an in-depth analysis of the action arena and action situations (both are parts of the MTF). This research ties in also with the activities of WB2 related to assessment of vulnerability and adaptive capacity; WB3 case driven research in Tisza and Guadiana, and WB4 research on tool enhancement and users' training.

[3] Accessible in New York Times ‘Dot Earth’ blog http://dotearth.blogs.nytimes.com/2008/07/30/un-chief-seeks-action-to-cut-disaster-losses-before-the-fact/

1.3 Credits and acknowledgments

The research described here has involved collaborative efforts of FEEM (Jaroslav Mysiak and Zsuzsanna Nagy), UNEXE (Raziyeh Farmani) and IRSA (Raffaele Giordano), referred hereafter as task team. In the context drawn in this report, FEEM conducted analysis of water, agricultural and rural development policies with impact on waterlogging in Upper Tisza Basin; UNEXE led efforts towards development of the management and transition framework based on idealised policy stages (problem structuring, model building and using the model to inform and challenge thinking); and IRSA concentrated on the quantitative insights which can be obtained from the qualitative models. All partners share the credits for the development of the core design of the system in which cognitive maps, causal loop diagrams, Bayesian belief network, evolutionary algorithms and other decision analysis tools are employed to advise transition to adaptive management practices, with uncertainty as a defining characteristic.

The above research bases on literature survey, desk analysis and review, interviews with people knowledgeable about analysed practical issues, and on group deliberations. In addition, the task team co-organised a conference session and workshop dedicated to conceptual and participatory modelling during the International Environmental Modelling and Software congress in Barcelona, July 7-10, 2008. The session and workshop aimed to stimulate discussion about greater use of conceptual models to capture uncertainty and facilitating stakeholders' involvement in model development for regulatory purposes.

Other Newater partners and associated researchers contributed to analysis reported here with valuable advise, informed opinion, knowledge and local assistance: Zsuzsanna Flachner, Dagmar Haase, Carsten Bohn, Jan Sendzimir, Piotr Magnusewski, Sukaina Bharwani and many others.

The task team members contributed to this report as following: FEEM drafted the chapters and sections 0 (executive summary), 1, 2, 3 and 6; IRSA has written the section 4.1 and 5; UNEXE the section 4.2 and 4.3.

1.4 Structure of this report

The chapter 2 describes the concepts of feedback loops, unintended consequences and robustness of policy measures. The chapter 3 provides a concise overview of the system and explains motivation behind and methodological issues to be resolved. The chapter 4 explains the system in detail. Chapter 5 gives an overview of computerised tools used and practical guidance and recommendations.

2 Unintended consequences and feedback looks

There are many examples of policy interventions whose outcomes were different from those expected. As in the cases of drugs successfully healing some diseases but triggering side effects as bad as the original plagues or sometimes worse, it may not surprise if policies intervening on a complex system interrelated causes and effects provoke non-desirable system responses.

For instance, although hydropower is generally hailed as a renewable and "clean" energy source, tropical reservoirs such as the Balbina dam in Brazil are known to release greenhouse gas (GHG) many times more powerful than carbon dioxide in stimulating warming effect, the methane (Giles, 2006). Methane is created as a product of the organic matter decay, stimulated by warm water. Under the bottom line, the effect of released methane can outweigh the impact of fossil-fuel power stations. Other well-known example is the case of DDT, powerful pesticide which secured its inventor the Nobel Prize, but which was later banned for damaging side-effects on environment.

The side-effects as those above may be suspected but not precisely known, and to learn more about them may require years of research and substantial resources. In other cases the unexpected outcomes may become visible only after substantial delay or many steps down the cause-interaction path. In these situations the negative effect may be observed without knowing its original cause. The recent food crises for example is suspected to be triggered by the incentives to produce biofuel which is by itself a laudable goal. However, the food price raised as many farmers sell their crops to biodiesel or ethanol refineries, instead as foods. This has created incentives to turn additional forests into agricultural land, or to plant on marginal agricultural lands and land previously set aside for environmental reasons. At the same time the food price is determined by large scale droughts (e.g. by the eight-year-in-a-row drought in Australia) or floods (such as 2008 Midwestern United States floods). Under such complex interconnection the extent to which the biofuel incentives contributed to price increase is difficult to assess and provides potential for disagreement and conflict.

In situation such as that above the final results of a chain of cause-effect relations may in the end turn back to its starting point and by doing so close the loop. The biofuel is "carbon neutral", meaning that by its burning only the carbon dioxide is released which has been previously captured in the plants and thus no additional greenhouse gas is released into the atmosphere. However, the deforestation encouraged by the high prices of food and energy crops may indeed increase the net CO2 emissions. This example is used here only for illustration of how initial interventions with certain aim can set of a chain of responses which counteract the original aim, or which make the original issue even worse. Hereafter we will refer to these "backfired" interventions as feedback loops.

Feedback denote a situation in which a system replies to original perturbation in a way which further increases (positive feedback +) or decreases (negative feedbacks –) these perturbation. For example, the albedo (degree of light reflection) of the polar ice caps influences the earth's radiation balance and thus co-determines the Earth temperature. Any change of the temperature due to higher concentration of the greenhouse gasses (GHG) reduces the extent of polar ice cover which in turns leads to higher absorption of incoming radiation energy and thus further warming. Other example of feedbacks on radiative forcing are water vapour (+), clouds (–), aerosols (+/–), and ocean heat uptake (+). In many cases the magnitude of the feedback is not sufficiently known, but in some cases even the direction of the net effect is uncertain. This is for example the case of the soil capacity to sink carbon which according to some may turn into a source as the temperature increases.

Lack of knowledge about the feedbacks is pervasive in many environmental fields, climate change science being the most prominent example. Feedbacks are also responsible for the typical shape of probability distributions long-term increases in global mean temperature expected from the doubling of atmospheric carbon dioxide: long tails with small but finite probabilities of very large increases (Roe and Baker, 2007). The probabilities of these extreme changes remain quite stable even if the understanding of climate processes improves. The main reason for this are feedbacks which at as magnifier which translate small uncertainty in physical processes into large uncertainties in the climate response.

Feedbacks can and have been studied to realize the volatile ramifications of system interventions (Gordon 2007; Bonan 2008; Heimann *et al.* 2008). It has been shown that the qualitative scrutiny of the feedback can yield relevant information about system behaviours and what's more, the different systems' responses can be reduced to a set of generic archetypes (Wolstenholme 2003; Wolstenholme 2004). These archetypes are important for realising how well-intentioned policy interventions may turn out to have different outcomes than those expected. These four archetypes are described in Figure 1 and 2. All four share the same configuration: interventions (*action* in Figure 1) are design to produce certain *outcomes* under explicitly considered system's components. The causal relations left outside of consideration initially however may transform the outcomes, often unfavourably.

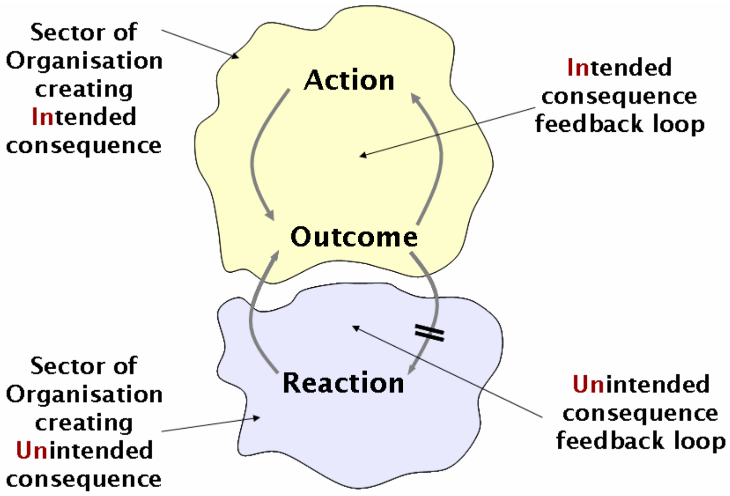
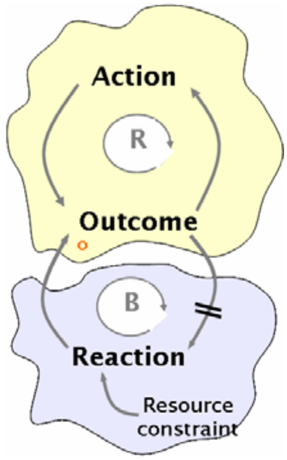
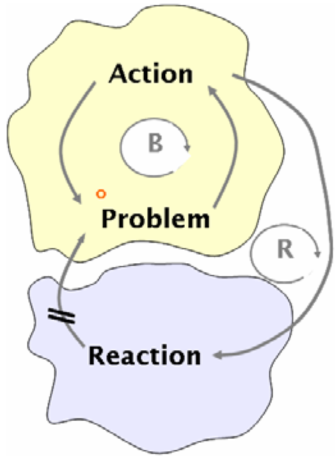


Figure 1: Generic archetype (Source: Wolstenholme 2004)

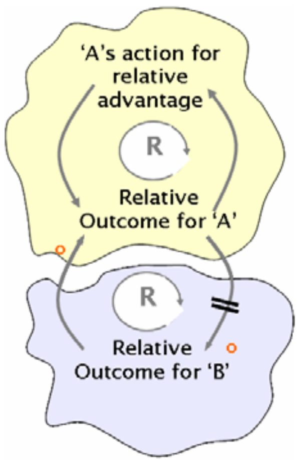
The *underachievement* archetype describes a situation in which the intended feedback is reinforcing loop (the sign of the causal relation from action to outcome is the same as the causal relation from outcome to action) and the unintended feedback is balancing loop (the signs of the causal relation from action to outcome is opposite).



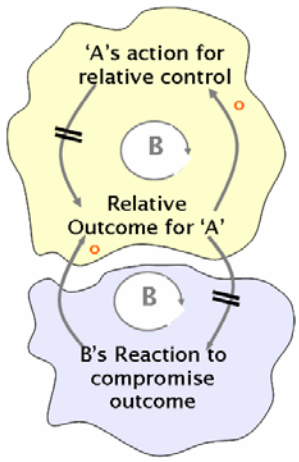
‘Underachievement’



‘Out of Control’



‘Relative Achievement’



‘Relative Control’

Figure 2: A set of generic archetypes (Source: Wolstenholme 2004)

For example the flood protection works (action) meant to reduce flood damages (outcomes) in the long term create incentives to build up the former floodplains, so that in cases of levees or dam failure (reaction) the damage is much higher than it would have been without the river engineering work.

The *out-of-control* archetype describe situations in which attempts to control some problem spurs unintended responses which make the problem worse. The biofuel incentives for example were meant to hold back greenhouse emissions but the rising food prices set of processes which actually increased the rate at which the GHG are emitted. In this archetype the intended loop is balancing and the unintended loop is reinforcing.

In "relative achievement" and "relative control" archetypes both intended and unintended loops are of the same kind (reinforcing in the former and balancing in the latter) but both work in opposite direction. Another example from the international climate change policy can make the point clear: the UNFCCC proposed strategy to control deforestation foresees allocation of avoided deforestation credits, which in turns create incentives in countries in which the deforestation is not major issue to moderate their own policies to benefit from these credits. Or more generally, a deadlock on international climate talks is related to "free rider" problem, i.e. fears that a tight climate mitigation policy in one part of the world can dissuade others to seriously tackle the issue.

These generic archetypes are useful to anticipate situations under which adaptive policy interventions have to operate. To this end we introduce a generic representation of transition as shift from current somehow unsatisfactory situation to more desirable state. The original situation can be one of high vulnerability to e.g. regular river flooding, and policy interventions are meant to reduce this vulnerability. The transition is influenced by intended interventions meant to control (speed up or limit) the rate of change, and by system responses which are out of control of the policy maker whose discretion to intervene is being considered (Figure 3 left). The unintended feedback loops (Figure 3 right) can be result of the effect policy interventions may have on the other interventions, system responses and original state. Examples for such unintended responses are given elsewhere in the document.

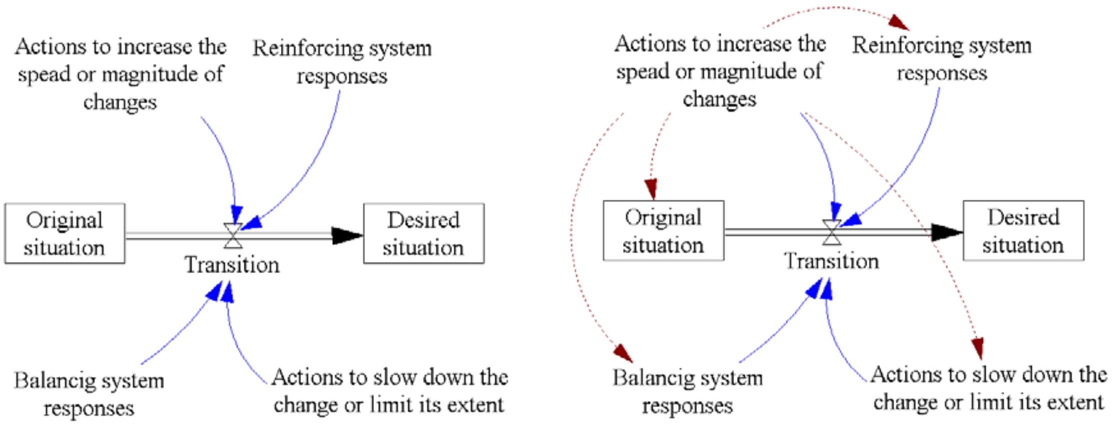


Figure 3: Transition framework (left) with possible feedback loops

Summering, the climate-carbon feedbacks are important sources of uncertainty in climate predictions (SRM, 2007) and the existing models differ in their strength. The thoughtfulness of policy analysis thus relate to the ability to identify possible side-effects and unintended consequences. Robust policy interventions (Wong *et al.* 2000; Rosenhead 2002) need to be designed so that defensive actions and policy re-assessment are carried out when the original intents seems slipping away. In situations in which deep uncertainty pervades, the policy interventions need to be design in a way to prevent unexpected, slow or run-away system responses with potentially disastrous effects. Recognition of the critical thresholds and most sensitive system components (Lenton *et al.* 2007; Lenton *et al.* 2008) is critical in this context.

3 A brief outline of the system

3.1 Conceptual design

1. Qualitative, conceptual modelling techniques: Our system starts with the qualitative description of the policy issues, usually conveying the views of different people with stakes in the sought policy choices. This initial description helps to make out what is the believed cause(s) of the issue at hand or what are the aspects with important implications for the analysis and what solutions have been proposed. A number of conceptual modelling techniques have been developed facilitate transparent development of models and bolster these models' potential to promote consensus and cooperation: causal loop diagrams, cognitive maps and their fuzzy counterparts, qualitative and certainty probabilistic networks, value and decision trees, Bayesian belief networks, and reasoning map. These techniques are similar in scope as they all capture views and concerns of non-scientists and help to incorporate them in models. They differ though in way how they capture essential information (e.g. uncertainty) and how the further semi-quantitative analysis is facilitated.

2. Initial insights from the qualitative models: As shown earlier, these early qualitative accounts are not only useful for the further, more quantitative analysis, they are useful on their own (Wolstenholme 1999). Examples of these insights can be exploration of feedbacks and unintended consequences as discussed in previous chapter, or recognition of critical system's components. The latter are often based on the analytical concepts of the graph theory such as measures of centrality masses, betweens, and in-out degree.

3. The transition from the early qualitative accounts into more rigorous analytical schemes: The initially qualitative models - whether being merely networks of ideas or more elaborated variables and interventions - can be further enriched to describe the nature of the represented relations and probabilities. Fuzzy cognitive maps for example allow to include value of the interconnected variables, and nature of the interaction and its weight. Probabilistic networks such as Bayesian Belief Networks (BBN) employ conditional probabilities instead of weights and states of the variables instead of a single value. *Qualitative probabilistic networks* (Wellman, 1990) employ qualitative probabilistic relationships. Qualitative influence ('+', '−', '0', and '?') between two nodes means that parent node influence the likelihood of the value of child's node, positive (negative) influence means that higher parent's value makes more probable that the child's value is higher (lesser). Additive synergy describes how the values of two nodes *jointly* influence the probabilities of the values of a third node a. A product synergy expresses how the value of one node influences the probabilities of the values of another node upon knowing the value for a common child in the network's digraph. And finally the certainty networks (Person) employ another way of capturing the available knowledge: certainty value is a numerical measure of uncertainty, whatsoever the nature of that measure is (probability, possibility or belief).

4. The various the issue on terms of terms of causes and other factors: Our research was thus directed in exploring how the initial qualitative accounts of the systems (cognitive maps) can be translated into a form more apt to assessment of unintended feedback loops (e.g. causal loop diagrams CLD) and how the knowledge consisted in these accounts can be further developed. Particularly, we have focussed on the transformation of cognitive maps into CLD and further into BBN which are further analysed by genetic optimisation techniques (based on genetic algorithm) and multiple criteria decision methods.

The combination of these techniques allows to model decision making process in complex environmental problems, addressing uncertainties, uncovering discrepancies in decision analysis process (e.g. completeness or redundancy of the model based on utility function) and generating policy options that trade-off between conflicting objectives.

However, there are important methodological obstacles. The CLD main strength is to analyse the feedbacks loops but these feedbacks are not allowed in the BBN and similar networks which are basically a-cyclic directed graphs. Under the lead of UNEXE the task team devised options to go about this issue by incorporating multiple snapshots of Bayesian networks. In this methodology, first different management strategies are identified. This is followed by identification of future states of the system based on scenarios, which has been done by introduction of new nodes. Scenarios represent possible consequences and effects of each action solution on other aspects of the system through feedback loops. A Bayesian belief network is set up for each time step. The developed Bayesian belief networks are considered simultaneously in identification of robust decision paths. The outcomes of each time step are the inputs of the following time step Evolutionary multiobjective optimisation tool (here we use GANetXL) is used to examine the Bayesian belief networks and inspect for inconsistencies and to generate optimal trade-offs between conflicting objectives considering alternative management scenarios simultaneously. The detail of these steps are described in detail in (Farmani *et al.* 2008; Farmani and Savic 2008a), (Giordano *et al.* 2005; Giordano *et al.* in press) and elsewhere.

3.2 Application cases

In this report we refer to two demonstrative cases, situated in Tisza and Guadiana river basins. Detail description of the geophysical and socioeconomic characteristics of both these river basins can be found in (Horvath 2002; Vari *et al.* 2003; Haase *et al.* 2006; Sendzimir *et al.* 2007).

Tisza river basin (here we focussed on the upper stream up to the border between Ukraine and Hungary, Bereg region[4]) is extensively described in (Haase *et al.* 2006). Here we focussed on floods and waterlogging issues. In the past, the Tisza river had been streamlined to prevent floods and to gain new agriculture land in landscapes where wetlands and marshes dominated before; the same development which is so characteristic for many other river basins. This has further amplified the vulnerability to flood and draughts, the latter being the consequence of low water retention to bridge the meagre summer periods. The floods in 2001, 2005 and 2006 affected several hundred thousands hectares and caused damages costing billions. At the time of writing this report, the Upper Tisza is experiencing flood again, albeit not as severe as other places in the region. FEEM conducted an extensive bibliographic survey to existing legislation, recent policies and subsidy schemes with potential effects on farmers decisions, eventually affecting the damages from waterlogging and floods. Similar to other studies employing qualitative, conceptual models to examine the behaviour of the systems before getting hold of quantitative data, the aim was to analyse obligations and incentives encouraging farmers to employ management practices which ultimately reduce their vulnerability to flood and waterlogging damages. The policies we look into include compulsory rules and financial or material incentives realized in the context of the European Agricultural and Rural Development Operational Programmes; national programmes for rural development, environmental protection and spatial development; diverse compensation and insurance schemes, and legislations referring to land use and water management in general. Particular attention was paid to single area payments

[4] Szabolcs-Szatmar-Bereg county in the north east of Hungary, home of 590,000 and covering about 6000 square kilometres

(SAP) and the cross-compliance obligations the farmers have to meet, and the agri-environmental schemes reducing the vulnerability to floods and waterlogging (e.g. afforestation, planting of autochthonous plants more resistant to high water tables, flood plain restoration and establishments of environmental set-aside areas). We considered policies currently in practice, as well as measures realised in the past and newly planned interventions. When possible, the policies were analysed quantitatively in terms of financial resources allocated, number of actors who adhered to the policy schemes, and the tangible impacts. When such information is not accessible, the policies are delved into qualitatively, in terms of compliance criteria and revealed preferences of the intended beneficiaries. For this scope a series of semi-structured interviews had been conducted, involving farmers, representatives of agricultural water boars, water authority, nature protection agencies and others relevant actors.

The upper Guadiana basin presents a paradigmatic case of a semiarid region where intensive groundwater use for irrigation has helped transform a largely poor rural region into a prosperous agricultural and industrial centre. However, some problems have arisen as a result of uncontrolled groundwater development. These refer to the conflict between farmers' social and economic development and the environmental value of groundwater-dependent ecosystems (Guadiana baseline report, 2005). The main aim in this work was to examine the trade off between agricultural and environmental aspects and their response to the different water management actions on the possible recuperation of the aquifer in farm and aquifer scale. Main factors to be considered are socio-economic welfare (e.g. farm income, regional agriculture income) and state of water systems (e.g. groundwater level).

4 Detailed description of the design

4.1 Cognitive maps and causal diagrams

A cognitive model can be defined as a representation of thought process for how something works in the real world. Most of the techniques for Cognitive Modelling may be viewed as composed by three main phases: identify concepts, refine concepts and identify links. A common characteristic of these approaches is a focus on obtaining the views of people in the problem environment.

Two different interpretations seem to emerge concerning what a Cognitive Model represents. On one hand, it can be seen as a model as close as possible to the cognitive representation made by decision makers. Thus the model can be considered as a "mirror" of the causes and effects that are inside the mind of decision makers (Montibeller et al., 2001). On the other hand, the constructivist view of knowledge assumes that knowledge is considered to change dynamically, in order to understand the reality. According to the constructivist approach, the model is a construct that can be useful to generate reflections on the decision maker. The decision makers are involved in the iterative psychological construction of the real world, rather than the perception of an objective world (Eden and Ackermann, 2001).

These two different perspectives originate two general approaches for knowledge elicitation and structuring:

- Cognitive Model as a qualitative model of the decision environment (see for example, Axelrod, 1976; Ozesmi and Ozesmi, 2004): the nodes represent variables and the arcs represent causal assertions. The variables can be physical quantities that can be measured, or complex aggregate and abstract concepts.
- The Cognitive Model as a network of ideas connected by arrows: the arrows indicate the way in which one idea may lead to, or have implication for, another.

In the first case, CM are often defined also as Causal Map or Influence Diagram, and are used to simulate the effects of possible actions taking into account the perceived influences between the elements of the considered system. From now onward, this kind of CM will be called Influence Diagram (ID). Adopting the second approach, CMs are not taken as models of cognition but rather tools for reflective thinking and problem solving. The adopted approach influences the way in which CMs are developed and analyzed.

An important differences between these two approaches regards the nature of the links. In ID, there are two different kind of links, i.e. positive and negative. A positive arc from variable a to b means that an increase of a will cause an increase of b. A negative arc from variable “a” to “b” means that an increase of “a” will cause a decrease of “b” (Marchant, 1999). In the second approach, a link between two concepts indicates the existence of a logical implication between concepts. In this kind of CM, the meaning of a concept is derived from its implication and explanation through an action orientation; not by any dictionary definition (Eden and Ackermann, 2001). A link in CM does not imply cause-impacts relations. Thus, causal inference to assess impacts of policy options is not possible using CM as defined by Eden. Therefore CM cannot support decision making by modelling the impacts of possible action in different scenarios. The analysis of CM can support reflective thinking in problem solving by providing information about the characteristics of the issues to be addressed, which are often difficult to be identified.

Influence Diagram (ID) can be defined as a directed graph that represents the cause-effects relations embedded in participants’ thinking (Nadkarni and Shenoy, 2004). ID expresses the judgement that certain events or actions will lead to particular outcomes. There are three main components in an ID: causal concepts, causal connections and causal values. Each concept represents an entity, a state, a variable, or a characteristics of the system (Xirogiannis et al., 2004). A causal connection depicts an antecedent-consequent relation between two concepts. A causal value represents the strength of causal connection (Nadkarni and Shenoy, 2004).

In an ID links are characterized by a positive or negative links. The causal inference is performed along paths, that is a sequence of distinct concepts connected by arrows. A path starts from the first concept (cause) until the last concept (ultimate effect). To assess the effects of each cause on the ultimate effect, it’s fundamental to calculate two indexes (Axelrod, 1976), i.e. the partial effect and the total effect. The partial effect is obtained through multiplying the signs along each path. The total effect between the cause and the ultimate effect is positive if all partial effects between these two concepts are positive; it is negative if all paths have a negative partial effect; and it is undetermined otherwise (Montibeller et al., 2001).

Other authors suggest to use fuzzy weights to express the strength of causal relations between concepts (e.g. Xirogiannis et al., 2004). The sign of the weights indicates whether the relations is positive or negative, while the value indicates how strongly one concept influences the other. The weights can also be expressed using linguistic terms and fuzzy linguistic variables. Mostly the weights are defined asking to the participants to describe the interconnection influence of concepts. Given the partial effects of means variables, the total effect on the end variable is calculated using fuzzy aggregation operators (Montibeller, et al., 2001). The policy alternatives can be evaluated considering their performances in terms of total impacts (Montibeller et al., 2007).

Fuzzy Cognitive Map (FCM). FCM extend traditional Cognitive Map CMs in two important directions: i) identifying which causes generate stronger effects; or ii) assessing the dynamic effects if a given cause happened. To this aim, FCM allows systematic causal propagation, e.g forward and backward chaining.

The FCM inference allows to define the value of one of the variable at time t, considering:

- The value of the linked variables;
- The sign of the links;
- The weight of the links.

A typical formula for calculating the values of concepts of FCM is:

$$A_i^{t+1} = f\left(\sum_{j=1, j\neq i}^{n} W_{ji} A_j^t \right) \quad [1]$$

Where At+1 being the value of the concept Ci at time t+1; Ajt the value of the interconnected concept Cj at step t; Wji is the weighted arc from Cj to Ci; f is a function used to transform the results of vector matrix calculation into the interval [0,1].

Typically, the logistic function is used:

$$f(x) = \frac{1}{(1+e^{-1+x})} \quad [2]$$

Therefore, the running of the FCM starts assigning the value 1 to each variable. Then, the value of x is iteratively changed until the variables reach the steady state. This steady state is assumed as the basis to understand possible changes due to introduction of policies. The first state can named as “no policy steady state”.

The inference is based on the adjacency matrix, which is developed considering the sign and weight of the links among the variables, as in the following table:

	V1	V2	V3	V4
V1	0	W12	W13	W14
V2	W21	0	W23	W24
V3	W31	W32	0	W34
V4	W41	W42	W43	0

The comparison between different steady states allows to assess the impacts of policy introduction on the whole system. Using this approach, it becomes possible to qualitatively compare the impacts of different policies.

The approaches described above are based on the means-ends perspectives, where decisions are based on a perceived gap between desired goal and the actual situation of the system. To deal with complexity of real world, decision process needs not to be linear, open-ended sequence but may manifest as a closed loop feedback system in which the decision outcome may have impacts, after some times, on the original problem, or creates a new problem (Fowler, 2003). Moreover, it becomes important to take into account the time, appreciating delays between actions and responses (Diehl and Sterman, 1995).

System dynamics is a thinking model and a simulation methodology that was specifically developed to support the study of dynamic behaviour in complex system (Hjorth and Bagheri, 2006). System dynamics modelling is about discovering and representing feedback processes. The understanding of these processes is then used to draw causal loop diagram (Hjorth and Bagheri, 2006). Causal Loop Diagram (CLD) is a modelling device which has been developed to better represent the complexity and dynamicity of systems behaviours. CLD presents relationships that are difficult to verbally describe because normal language presents interrelations in linear cause-and-effect chains, while, in a system dynamic approach, leaving aside the circular chains of cause-and-effects can lead to erroneous conclusions. CLD are intended as qualitative models describing how a given system operates. These models can be built up incorporating lags, delays and nonlinearities characterizing the complex systems.

To better represent the system complexity, the links can be represented as a causal loop. Formally, a causal loop is a closed sequence of causes and effects, that is a closed path of action and information. The sign of a loop is the algebraic product of the sign of its links. A positive (reinforcing) loop reinforces changes with even more change. This can lead to rapid growth at an ever increasing rate, according to an exponential growth pattern. In this case, the influence is usually destabilising, leading to explosive behaviour (Fowler, 2003). Therefore, in the beginning of the growth process something that is going to be a major problem can seem minor because it is growing slowly. If this exponential growth is not considered, it could be too late to solve whatever problem this growth is creating. The negative loop tends to balance the value of a variable towards a goal. The value of the variable is pushed up if the current level is below the goal. If the level is above the goal, the negative loop pushes the value down. In positive loop, an output is fed back to activate a balancing or controlling mechanism, guiding the system to some defined equilibrium condition (Fowler, 2003).

The combination of feedbacks, inertia and delays in a CLD ensures that considerably complex dynamic behaviour can be taken into account in system modelling.

The CLD allows the simulation of policy options both in quantitative and qualitative way. Different software packages have been developed to support complex system modelling. Among them Vensim, developed by Ventana System, is one of the most commonly used. It allows to develop and simulate CLD, analyzing the results. Vensim is organized around models, and data or simulation results that relate to those models. This software allows us to use mathematical formulas to describe relationships between variables.
Another interesting software for modelling based on system thinking is Stella, developed by ISEE System. Stella is mainly based on the "Stock and Flow" diagram, which is an extension of CLD. This kind of representation distinguishes between two different types of variables, i.e. stock and flows. A stock represents the accumulation of something, and a flow is the movement of something from one stock to another. The stock variables constitute a memory of past events that condition new decisions (Diehl and Sterman, 1995). The stock and flow diagram contains also information links. The existence of information links between two variables means that the information about the value of one variable influences the value of the other. Furthermore, the absence of the information link means that information about the value of one variable doesn't influence the value of the other.

4.2 From Causal loops to Bayesian Networks

Belief Network

A Bayesian Belief Network (BBN) is a powerful tool for modelling decision-making under uncertainty (Pearl, 1988; Cowell et al., 1999; Jensen, 2002). It consists of nodes, links and conditional probability tables, which are underpinned by a theory of probability using Bayes' rule. This rule describes mathematically how existing beliefs can be modified with the input of new evidence. This may be an observation of the state of a variable, or a scenario or potential action that may take place. Setting the states in this way will result in a chain reaction of impacts on all variables linked to it. The calculation of the a priori probabilities for all the nodes in the network is termed "belief propagation". The belief propagation capability of BBN tools facilitates probabilistic inference. BBNs can be used either in “bottom-up” reasoning to address diagnostic tasks or in “top-down” reasoning for descriptive/explanatory purposes. In the first case, the evidence of an effect is given and the most likely cause is inferred. In the second, the probability of an effect is computed once the evidence for one or more of its causes is provided (Castelletti and Soncini-Sessa, 2007b). Once the full range of management options and/or scenarios has been completed, the final decision can be made by taking into account the various objectives for success and failure of a management strategy or scenario.

In the simplest case, a Bayesian network is specified by an expert and is then used to perform inference. In many cases, it is difficult to identify all the alternative solutions. This is often due to the objectives tending to act against each other, particularly when economic and environmental variables are being evaluated. Also, when the number of possible options is large, it may be worth exploring the entire action space instead of considering only the actions proposed by experts and stakeholders.

The use of BBN, in the form of influence diagram where decision and utility nodes are included, can be of value in supporting the decision making procedure for comparing alternatives, but may not be fully adequate for negotiations. In a negotiation process, it is critical to identify all alternatives, involving multiple stakeholders. The number of actions that compose an alternative is generally significant and thus, due to combinatory effect, the number of alternations to be examined is very high. Therefore, for negotiations, more complex and flexible tools are required, which can be based on mathematical programming or optimal control (Castelletti and Soncini-Sessa, 2007b). One way to do this is to couple the BBNs to an optimization tool. Here, an optimization tool (GANetXL, 2007), which is based on an EMO, is used to generate the state variable values which are fed into the BBNs. Once the probability of all the linked nodes have been updated, the objective function values are returned to the optimization tool and the process is repeated. By this combined approach it is possible to analyze the action space more openly without having to take the position of a single expert or stakeholder (dealing with uncertainty pertaining to human behavior) (Farmani et al. 2008).

Evolutionary multi-objective optimization

Decision making in environmental projects can be complex and seemingly intractable, because of the inherent trade-offs between socio-political, environmental, ecological and economic factors. The selection of appropriate strategies often involves multiple conflicting objectives that should be optimized simultaneously. As a result, there exist multiple Pareto optimal solutions, i.e., solutions for which it is not possible to improve on the attainment of one objective without making at least one of the others worse. Multicriteria decision making (MCDM) methods evaluate the coupling among these objectives (Miettinen, 1999; Wright et al., 2002).

Traditionally all the competing objectives are aggregated to identify the best strategy (a priori preference articulation) in which the decision maker (DM) defines the preferred pay-off among the objectives in advance of the search. This methodology introduces additional uncertainties due to human behavior and also the ability to track conflicting stakeholder preferences may be lost in the process (Kiker et al., 2005). Dorner et al. (2007) illustrated a methodology for creating a multi-objective modeling system using Bayesian probability networks to emulate the behavior of an environmental model. In their work, multi-criteria modeling attempts to work in more than one problem domain through coupling of production and waste systems by aggregating different criteria, to quantify the economic cost of remediation.

EMO algorithms offer a means of finding the optimal Pareto front in a single run (Farmani et al., 2005a) (a posteriori preference articulation, in which the DM is presented with a set of nondominated solutions and then chooses a final design solution from that set). Although the efficiency of these algorithms in solving a number of complicated real-world problems has been illustrated (Farmani et al., 2005b, 2006 and 2007), there have been limited applications in policy analysis of water resources management. In the Optima (optimization for sustainable water resources management) project (Fedra, 2005) a simulation-based water resources planning and an evolutionary based optimization system have been developed and applied to real case studies. The optimization uses heuristics and the concepts of genetic programming (Fedra, 2005). The primary optimization identifies sets of non-dominated Pareto-optimal solutions in heavily constrained scenarios; these then form a basis for an interactive discrete multi-criteria selection with the participation of end users. deVoil et al. (2006) presented a search approach based on a multiobjective evaluation technique, for quantification of attributes of cropping systems that represent Pareto-optimal combinations of economic and environmental objectives. Castelletti and Soncini-Sessa (2006) used a strict multi-attribute value theory for evaluation of the alternatives and generation of a Pareto front. This is followed by identification of compromise solution through negotiations with stakeholders on the set of Pareto efficient solutions. Reed et al. (2007) demonstrated potential of EMO techniques in significantly reducing computational demands for groundwater monitoring by quantifying a sufficient trade-off as a subset of nondominated (Pareto) solutions. Kollat and Reed (2007) presented a framework for visually interactive decision making and design that enables decision makers to explore large solutions sets generated by EMO algorithms in environmental systems.

In this work an evolutionary multi-objective optimization technique based on NSGAII (Deb et al., 2000) is coupled with a BBN and used in the selection of the best compromise management option(s) for participatory decision making. Attempting to achieve the multiple goals simultaneously requires the achievement of a compromise solution in the Pareto optimality sense. This is done by allowing stakeholders to articulate their preferences, values and beliefs related to potential scenarios. Then the EMO technique is used as a tool for eliciting stakeholder preferences. EMO algorithms use a population based search to find many Pareto efficient solutions in a single run. The final task of an EMO algorithm run is to choose, depending on the preference of a decision maker, a group of good solutions for more detailed analysis.

Evolutionary Bayesian Belief Network Methodology for Adaptive Management

In general, there is no single solution for complex and uncertain problems. There are often trade-offs that require choices. Scenario planning is a strategic method that can be used to make flexible long-term plans. Scenarios represent the outcome of the feedback loops with complex interactions and long delays based on a set of assumptions about key driving forces (Farmani and Savic, 2008a). They assist in the assessment of impacts, adaptation and mitigation processes.

To learn effectively in a world of dynamic complexity when evidence cannot be generated through experiments, virtual worlds and simulation become the only reliable way to test hypotheses and evaluate the likely effects of policies. The virtual worlds are models or simulations in which decision makers can conduct experiment, rehearse decision-making and play. They can be physical models, role-plays, or computer simulations (Sterman, 2006). The proposed methodology, which is based on the integration of evolutionary multiobjective optimisation algorithm and Bayesian belief, facilitates design of robust and flexible management strategies through an iterative decision making process. The two tools are linked via Microsoft Excel where all the data exchange takes place.

In this methodology, first different management strategies are identified (Figure 4.a). This is followed by identification of future states of the system based on scenarios, which has been done by introduction of new nodes (nodes A’, B’ and C’, Figure 4.b). Scenarios represent possible consequences and effects of each action solution on other aspects of the system through feedback loops (Figure 4.b). A Bayesian belief network is set up for each time step. In the simplest from, on one hand, this is similar to the temporal extension of BBN which means that the network structure or parameters do not change dynamically, but that a dynamic system is modelled. On the other hand, as it consists of time-slices (or time-steps), with each time-slice containing its own variables that are generated using EMO, it resembles single loop learning where only actions and strategies can be changed. However in complex systems with a large number of feedbacks, not only it models temporal nature of the problem, but also introduces changes to the next time step as they are identified in each time step. Changes here refer to those that will affect structure or parameters of the existing Bayesian belief network. From decision making point of view, the former deals with sequential decision making task while the latter, so called dynamic decision making task, is more concerned with controlling dynamic systems over time (Farmani and Savic 2008b).

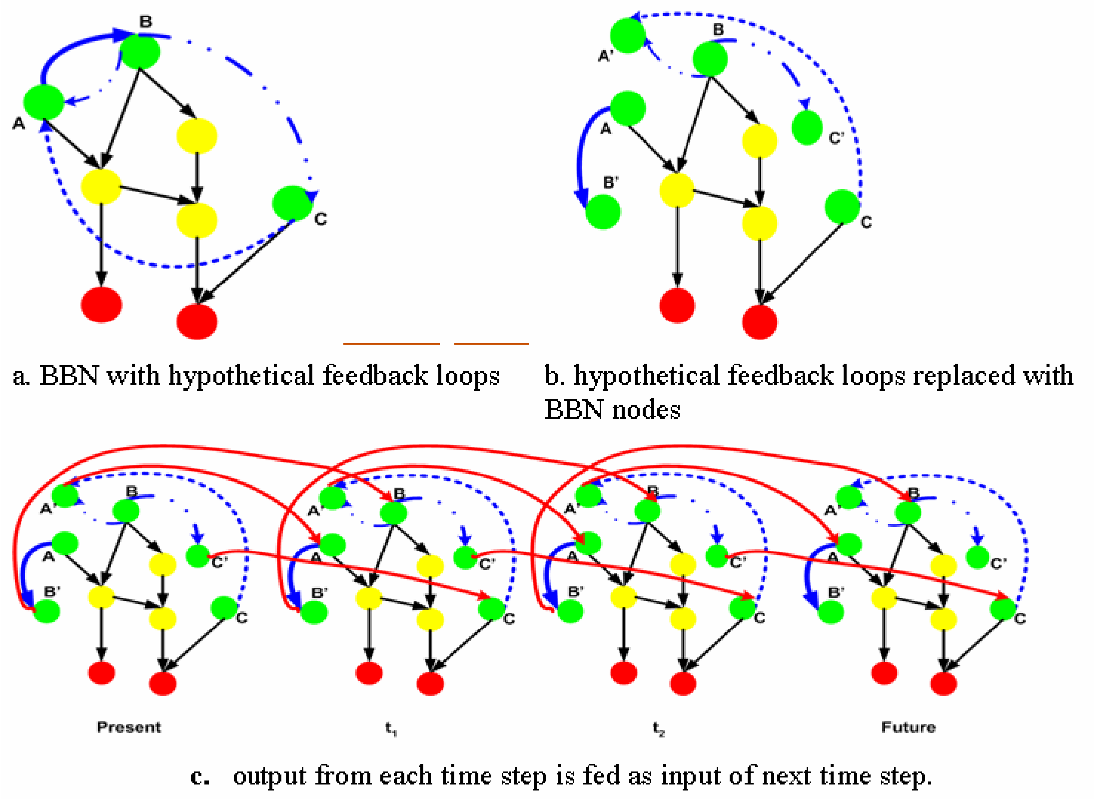


Figure 4: Handling feedback loops in BBN

The developed Bayesian belief networks are considered simultaneously in identification of robust decision paths (Figure 5). The outcomes of each time step are the inputs of the following time step (Figure 4.c). The trade-offs between different objectives are evaluated. The stopping criterion for the algorithm is defined as identification of a management strategy that is reinforced by other strategies enabling its growth and stabilization. The evolutionary based model facilitates this and identifies, based on the concept of survival of the fittest, the robust pathways in a co-evolving environment (Farmani and Savic 2008a). Figure 6 demonstrates the main steps of the proposed methodology. The algorithm starts by initialising action or strategy nodes using randomly generated values from EMO software. This change will then have a knock on effect throughout all those nodes linked to it. In this way the impact on the whole system can be evaluated. The criteria for stopping this part of algorithm are that either several consecutive decisions support similar actions or a predefined large finite time horizon has reached. If the former criterion is not satisfied and depending on the information provided by additional nodes representing the impacts of the feedbacks, two possibilities exist. If additional nodes indicate no need for change in structure or parameters of the system, the next step action plans generated by EMO will be implemented otherwise the changes will be fed back to latest Bayesian network and the process will be continued. This process will be repeated for all the solutions generated by EMO. The evaluated results will be ranked based on their objective function values. The procedure will be repeated until no improvement is made on Pareto optimal front or maximum number of generations is reached (Farmani and Savic, 2008a).

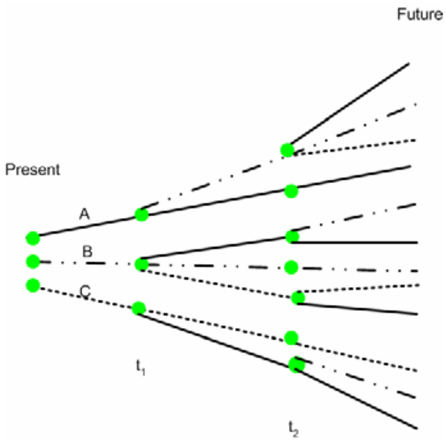


Figure 5: Decision tree

The methodology proposed in this work is not only anticipatory but also exploratory. Anticipatory in a sense that it starts with prescribed vision of the future and then works backwards in time to visualize how this future could emerge (focusing on long term). On the other hand it is exploratory as it starts in the present and explores possible trends into the future. This methodology is similar in a way to transition management (Rotmans et al., 2001) which involves long-term planning process in small and incremental steps. These planning and management methodologies take uncertainty and complexity as starting point rather than as closing entry; they take learning as guide rather than fixed goals and are co-evolutionary. Evolutionary planning and decision making process is aimed at different interventions at different levels in time and space (Rotmans, 2006).

Despite our efforts to present the methodology by application to a flood plain management problem, we were not able to quantify our developed conceptual models due to lack of data.

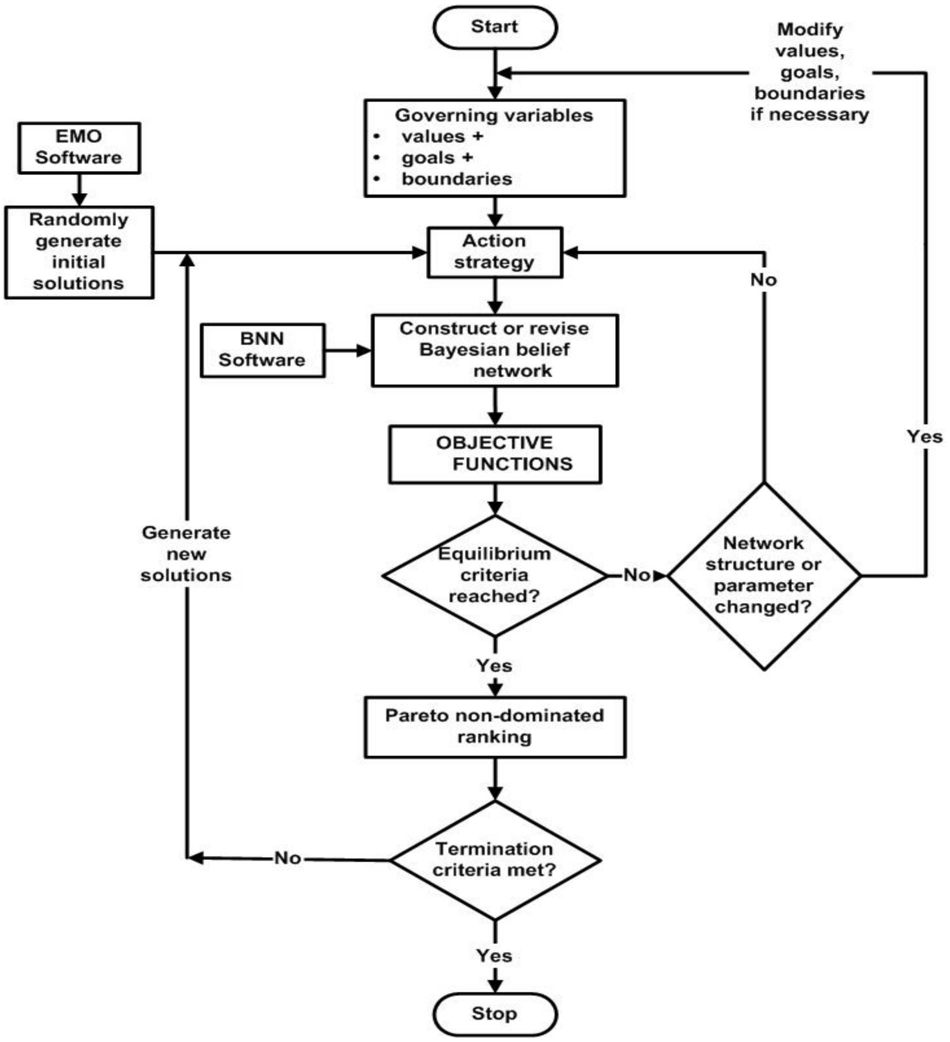


Figure 6: The proposed methodology

Other Advantages of integrated Evolutionary Bayesian Belief Network tool

The proposed integrated methodology addresses some of the shortcomings of the individual tools as described below:

Validation of the Developed BBNs

Systematic validation of a BBN as a tool for decision making under uncertainty is not usually possible because to investigate the future impact of a management decision, data cannot exist for validation until such management changes have been implemented. Instead model and input data for each of the nodes, links and corresponding conditional probability tables are usually validated using existing data for current conditions, in order to check that the model is behaving as expected (Ticehurst et al. 2007). There are two limitations in using manual comparison methods to make decisions on relative attribute importance, or select from competing alternatives and to aggregate individual preferences. First they ignore the true utility functions of a decision maker. Second, when comparing they do not directly account for the relative importance of the attributes. Also the utility is usually calculated from the parameters entered by the user. Therefore, the state of the key variables under the full range of management options can not be easily analyzed. In complex networks of environmental systems, it is necessary to analyze all the variations experienced by each variable and the results produced by a group of intermediate variables (Martin de Santa Olalla et al., 2007)

Consistency is critical to being able to identify a preferred alternative with confidence. The consistency check on conflicting goals (i.e. consistency check on consequences) is followed by consistency check on goals with conflicting context (consistency check on causes). In the proposed method, the first step in consistency check is after the evolutionary algorithm has generated a set of non-dominated policy or management options, to check based on the conflicting objectives if the results reflect coherent preference of the decision maker. If the objectives are not behaving the way it has been expected, the consistency of causes should be checked. The impacts made on any indicator or objective are controlled by two factors, the structure of the network and the values placed in conditional probability tables (CPTs). There are three possibilities for action not having strong response on objective: 1) the structure and influence of intermediate variables 2) the impact of second parent is cancelling out any effect and 3) the values in the CPT are not sufficiently large (Bromley 2005). EMO facilitated the generation of appropriate combinations of interventions. Usually solutions generated by evolutionary algorithm are good indicator of shortcomings of the network, for example, if changes in an action node should have effect on utility function and this has been ignored intentionally or unintentionally in the CPTs. The results generated by EA will exploit this weakness in the network and generate solutions that should have corresponded to higher utility function values but as this information has not been included, increase of the action variable corresponds to zero value in utility function.

Introduction of constraints to eliminate bottom-up reasoning shortcoming in BBNs

The second problem was with the range of the states of the variables. In BBN it is not possible to impose a constraint on state values of the variables. This can potentially be very dangerous in "bottom-up" reasoning to address a diagnostic task, where infeasible causes can be generated. The use of the proposed integrated methodology, by combining BBNs and EMO, allows introduction of the constraints on state values in the problem setting stage of optimization.

Generating a set of efficient management options

After eliminating the sources of inconsistencies in the network, the validated network can be used for generating management options. EMO algorithms use a population based search to find many Pareto efficient solutions in a single run. The final task of an EMO algorithm run is to choose, depending on the preference of a decision maker, a group of good solutions for more detailed analysis.

Further information on the advantages and applications of the integrated evolutionary Bayesian belief network to water resources management can be found in Farmani et al., 2008 and Farmani and Savic 2008b.

5 Toolbox and practical guidance

The potentialities of Decision Explorer (DE) (www.banxia.com), a software package developed by the University of Strathclyde, can be used to support both the development and analysis of CM. Particularly, DE provides useful information concerning the different perspectives on the problem at stake. DE allows identifying central concepts (Eden, 2004). The simplest analysis available for seeking out the “nub of the issue” is generally known as “domain analysis”. It returns the “central degree” of concepts by calculating the total number of in-arrows and out-arrows from each node. Those nodes whose immediate domain is most complex are taken to be those most central. The analysis indicates the richness of meaning of each particular concept. The identification of key concepts is fundamental to understand the stakeholders’ interests. The assumption here is that the higher is the central degree of a concept, the more important is the concept in the stakeholders’ perception of the problem.

The results of this analysis are used to inform the debate about the most important elements of the problem at stake (Giordano et al., 2007).

Moreover, the analysis of CM performed using DE can support the identification of loops in the CM and of all concepts included in these loops. The detection of loop in CM allows to verify whether the existence of loop is due to a coding accident or not. Unintended incorrect coding with respect to loops tend to be common in CMs because of the problematic nature of determining the interviews' view about what is cause and what is effects. The existence of mistaken or unintended loops can lead to erroneous conclusions in modelling actions impacts. Thus, a debate on the detected loops can be supported by CM analysis.

6 Future work and uptake of the result

At the time of writing this report (July 2008) the Bereg region is experiencing another severe flood. A new regulation tackling with waterlogging is being discussed (but not released yet for public consultation). Next year the preliminary River Basin District Plans are due to be released. These plans need to address provisions of the Flood Risk Management Directive and the Groundwater Directive, accepted in 2007 and 2006 respectively. The White paper on climate adaptation, expected to have wide-reaching consequences European programmes[5], is due in autumn his year. The EU target and subsidies for biofuel production have been reconsidered. These changes will have large impact on bringing the flood/waterlogging issues into debate and revise policies to tackle with these issues. These changes provide an excellent opportunity to further analyse the farmers' choices described here. In the remaining months and using spare resources will intend to continue and extend policy analysis briefly described here. Tisza case study has been inserted as a focus area for forthcoming projects Xerochore (started in May 2008) and in proposals yet to be submitted.

The effort to initiate a new conceptual modelling technique, inspired by the Unified Modelling Language (UML) and meant to draw on the best features of the existing techniques will continue in the next months. As next, we plan to initiate a ample collaborative review paper of these techniques, their principles and knowledge generated with their help. This review will involve contribution from a large number of researchers - experts in practical application of these tools. Furthermore, depending on the ability to attract research funding, we intend to organise a exploratory workshop to develop a proposal for the unified conceptual technique.

The proposed evolutionary Bayesian belief network based methodology was presented at iEMSs2008. Based on the feedback received and further discussions with experts in the field, there was a general agreement that the problems addressed using this integrated methodology are common problems with no other methodology to address them. Efforts will be made to further apply the proposed methodology to quantitative water resources management problems or to management problems from other sectors (e.g. manufacturing management) to demonstrate capabilities of the methodology that have not yet been tested by real applications (i.e. addressing feedback loops).

Finally, we intend to further test and demonstration example of the methodology described here, and develop additional training material. These activities will go beyond the Newater project.

[5] Structural, Cohesion and Solidaruty funds, Agriculture and Rural Development Funds, Life+ instrument

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