TRANS

Transformation de l'élevage et dynamique des espaces

LITERATURE REVIEW OF SCENARIO METHODS

W.P. 5-W.P. 4 D.3 final (version 1)

Réalisé par C. Simon, sous la direction d'A. Gibon

avec la participation de G. Bigot, P. Bommel,

E. Josien et O. Thérond

2006

TABLE DES MATIÈRES

Abstract

This document is a literature review of scenario methods elaborated in the frame of ADD TRANS project (2005-2009) . Within this project, WP4 is aimed at the assessment of land use change at the farm level and its impacts on the territory and WP5 is aimed at the elaboration of an integrated approach of land-use changes in livestock farming, natural resources and ecosystems at the landscape level. Both intend to contribute to the renewal of approaches and tools of changes in livestock farming and their environmental consequences from prospective assessments based on modelling and scenarios, to support the policy decision-making process and local governance.

When taking an interest in scenario methods and, by the way, in papers that address the theoretical and fundamentals in use in scenarios studies, one faces what Marien (2002) has called a 'very fuzzy multi-field'. But, when structuring future approaches into three modes of thinking: probable (related to predictive mode of thinking), possible (related to eventualities mode of thinking) and preferable (related to visionary mode of thinking), it seems that the great majority of futurists think in only one, or at most two of these three categories (Marien, 2002). Thus, we tackle and depict the wide diversity of scenario methods within the frame of "classical" modes of thinking whilst addressing evolutions of approaches, concerns and objectives. Our literature review of scenario methods highlight the increased interests, when exploring the future, into integrated approaches based on system thinking and participatory approaches, and stress the resulting methodological changes in scenario studies addressing "classical" modes of thinking.

In the last part of the review, we address the recent development of new scenario methods in the environmental field. In close reference to sustainability concerns, environmental scenario studies focus more and more on improving the assessment of the links between societal change and ecosystem change from a global to a micro-scale perspective. These scenario methods appear as adaptive combinations of earlier and new approaches, methods, techniques and tools to better address both decision-making and governance processes. We focus on local scale, where interactions between ecosystem functioning and decisions of stakeholders can be concretely modelled, to illustrate such evolution by means of scenario studies combining the use of multi-agent systems and scenario methods encapsulated within a "companion modelling approach".

TABLE DES ILLUSTRATIONS

Tables

Figures

Figure n°12: Multiscale Design of the Sub-global Assessments in Southern Africa and Portugal (Alcamo et al., 2005)

Boxes

Box 1: Steps in a tradeoff analysis - an illustration (Crissman, 1998; Stoorvogel & Antle, 2000)

Box 2: General steps to scenario planning method (Chermack et al., 2006a)

Box 3: Suggested steps for building explorative scenarios in the context of local development (Wollenberg et al., 2000)

Box 4: The USTED method for conducting a strategic scenario study (Stoorvogel, 1995)

Box 5: Suggested steps for building strategic scenarios (Lancker & Nijkamp, 1999)

Box 6: Suggested steps for participatory backcasting exercise in the context of community-based forest management (Wollenberg et al., 2000)

Box 7: MA Procedure for Developing Scenarios (Alcamo et al, 2005)

Box 8: Research sequence of the step-by-step method (Etienne et al., 2003)

Box 9: Research sequence of self-design process method (D'Aquino et al., 2003)

Introduction

This document is a literature review of scenario methods elaborated in the frame of ADD TRANS project (2005-2009). This project aims at developing a coordinated whole of multi-field research aiming at developing knowledge, to renew the framework of analysis and modelling of change in livestock farming and their impact on natural resources dynamics at the territory scale (WP4-WP5). From an operational viewpoint, WP4 is aimed at the assessment of land use change at the farm level and its impacts on the territory and WP5 is aimed at the elaboration of an integrated approach of land-use changes in livestock farming, natural resources and ecosystems at the landscape level. Both intend to contribute to the renewal of approaches and tools of changes in livestock farming and their environmental consequences from prospective assessments based on scenarios, to support the policy decision-making process and local governance.

When taking an interest in scenario methods and, by the way, in papers that address the theoretical and fundamentals in use in scenarios studies, one faces what Marien (2002) has called a ‘very fuzzy multi-field’. That is, numerous scenario approaches and methods have been developed since the 1950s. The wide development of scenario methods comes within the scope of an evolution of social concerns and views. Moreover, it responds to an increase of sectors (military, business, industry, government…) in which they are used, to a variety of disciplines involved in future studies (management, social sciences, natural sciences or policy science), to a large and diverse group of decision-makers, consultants and researchers that develop and use scenarios, and to an increase of available and suitable tools (Ringland, 1998; Greeuw *et al.*, 2000; Dreborg, 2004).

With the spreading awareness of sustainability and uncertainty challenges emerging from ecological and societal complexities of environmental issues, comes the recognition of the necessity of an integrated assessment of systems under study, and the important role of decisions of the stakeholders in the dynamics of change (Caswill & Shove, 2000; Toth, 2001; van Asselt & Rijkens-Klomp, 2002; ComMod, 2005; Bousset *et al.*, 2005; Quist & Vergragt, 2006). Consequently, scenario methods are adapted to better address these new challenges.

This literature review of scenario methods has several purposes. The first purpose is to provide a general theoretical frame of scenario methods by addressing the wide (and sometimes confusing) diversity of approaches, application fields, concepts and definitions related to scenarios and scenario methods. The second purpose is to replace scenario method within an evolutionary and adaptive frame according to the kind of future approaches and application fields considered, and the targeted goal(s). The third purpose is to provide an operational overview by depicting, within the previous frame, the most widespread scenario methods. The fourth purpose is to replace the specific way of developing scenarios adopted for ADD TRANS project within the course of scenario methods development, and depict the diversity of integrated scenario methods dealing with interactions between natural and social dynamics from the global to the micro-scale perspective.

This literature review of scenario methods was necessary because literature reviews of scenarios or scenario method found in the literature (Ducot & Lubben, 1980; Heugens & van Oosterhout, 2001; van Notten *et al.*, 2003; Henrichs, 2003; Schroth & Wissen, 2004; van der Heijden, 2004; Dreborg, 2004; Shearer, 2005; Börjeson *et al.*, 2006) do not address -or just briefly- the use of scenario methods at the micro-scale perspective. That is, most of the reflection about the principles and concepts of scenarios studies was produced in strong reference to corporate enterprises and political decision making at macro-scales. Fundamentals of the use of scenario studies within a more limited geographical or under social focusses have been given fewer consideration in literature until now.

For reaching our purposes, Deliverable 3 has been set up upon three sections. Section 1 replaces scenario methods within archetypal future approaches encountered in the literature and introduces current evolution of scenario method. We also provide guidance to disentangle and structure the wide diversity of scenarios concepts and definition found in the literature. Section 2 first develops, for each archetypal future approach, the related concepts and provides a general description of the scenario development process and main application fields. Then, the focus is on scenario methods: we provide an historic and general overview of applied scenario methods with related techniques, before providing illustrations and guidance by means of detailed case scenario studies. Section 3 develops the evolution of scenario methods within the frame of (participatory) integrated assessment, and converges on the combined use of scenarios and multi-agent systems within a participatory process of scenario building. The second part provides examples of methodological sequences.

This paper has been written in English for reasons of simplicity. Indeed, most of the literature consulted for this paper is published in English. Moreover, translation of English concepts and terms –widespread in papers related to scenario methods and studies- could have been even meaningless.

Chapter 1

SCENARIOS STUDIES: A MULTIFACETED AREA

Since the 1950s, concern for or interest into exploring the future developed within an increasing number of sectors (military, business, industry, government …), and a variety of disciplines involved in future studies (management, social sciences such as economics, natural sciences such as environmental sciences, or policy science). A large and diverse group of decision-makers, consultants, and researchers developed and used scenarios in a variety of ways (Ringland, 1998; Greeuw *et al.*, 2000). Future studies nowadays consist of a vast array of studies and approaches and the area appears as a 'very fuzzy multi-field' (Marien, 2002). One of the most basic concepts in the field, the 'scenario' concept itself, is contested (Börjeson *et al.*, 2006). The large variety in scenario methods currently available and conceptions on which they are built makes it difficult to establish a clear overview of their respective specificities and interests and limitations and areas of application. In this section of the paper we make use of typologies and criteria used in previous literature reviews for establishing an overview of approaches to scenarios currently used in studies of the future. We concentrate on eliciting the principles of the methods developed and the differences in the conception and the use of scenarios in relation to the objectives they have been built for. Indeed, there is a strong connection between the project goal of a scenario study, the resulting process design and the scenario content: the project goal influences the process design that, in turn, influences the scenario content (van Notten *et al.,* 2003).

This review relies for a large part on papers addressing the theoretical and methodological fundamentals in use in scenario studies: it must be noticed that most of the reflection about the principles and concepts of scenarios studies was produced in strong reference to corporate enterprises and political decision making at macro-scales. A large part of recent literature in the field has global environmental change as a main focus. Fundamentals of the use of scenario studies within a more limited geographical or under social focuses have been given few consideration in literature until now. Interest into the application of scenarios at smaller geographical is nevertheless under progress within the "downscaling" process increasingly included in global assessments (Kok *et al.*, 2006; Verburg *et al.*, 2006). But for now the address of principles of scenarios studies at such scales is mainly restricted to adaptative management of natural resources and ecosystems (see Part 3 of the paper).

Modes of thinking into the future and fields of application of scenario studies

The variety in approaches used in future studies follows firstly from the basic attitude adopted with respect to the exploration of the future. According to numerous authors (Amara, 1981; Dreborg, 2004; Börjeson *et al.*, 2006), studies of the future basically range into three categories (i) those that explore **probable** future, (ii) those that explore **possible** future and (iii) those that explore **preferable** future. These three different future approaches respond respectively to three questions a stakeholder may ask about the future: '**What will happen**?', '**What can happen**?' and '**How can a specific target be reached**?' (Börjeson *et al.*, 2006). Three corresponding classical or even archetypal 'modes of thinking' have been developed: **the predictive, the eventualities, and the visionary modes of thinking** (Dreborg, 2004).

- **The predictive mode of thinking** is a long tradition, dating back at least to antiquity. The idea is to realise or at least get an indication of what will happen by trying to find the most likely development in the future, in order to be better prepared. Scientists understand a prediction as a best possible estimate for future conditions, the less sensistive the prediction being to drivers the better (Peterson et al. 2003). In that view, predictions are conditional probabilistic statements. But non-scientists often understand them as things that will happen not matter what they do. It must be stressed that considering the predictive mode of thinking within the fundamentals of scenarios studies to explore the future is subject to some discussion in literature. Pioneer scenario developers such as Kahn and Wiener reject the use of scenario term in the case of predictive approaches (Kahn & Wiener, 1967). However the fact that many practitioners use this term in a predictive sense leads most of authors to consider scenario methods as also covering predictive approaches with sensitivity testing (Börjeson *et al.*, 2006).
- **The eventualities mode of thinking** is characterised by the openness to several different developments. Again, the idea is to be better prepared to handle emerging situations with the idea that nobody can say what will actually happen.
- **The visionary mode of thinking** means to envisage how society at large, some sector of it or some activity could be designed in a better way than its present mode of functioning. This way of thinking intends to suggest solutions to a fundamental societal problem by taking visionary goals into account and exploring the paths leading to these goals.

The mode of thinking applied in future studies is tightly related to the nature of the scenario project. For each of the three modes of thinking, several scenario methods have been defined and developed, depending on the characteristics of the **systems considered**, the degree of **involvement of the stakeholders**, or the **focus** of the scenario exercise and first of all their specific **purpose** (Westhoek *et al.*, 2006). From the literature, scenario methods can be considered as used and applied to support six main kinds of purpose:

1. The scenario studies that are meant to support **policy optimisation** by answering the question on the best way to reach a particular objective, e.g. the fastest, most cost-effective, fairest or more secure. These studies look typically 15 years or less ahead (Westhoek *et al.*, 2006).
2. The scenario studies that are meant to support **vision building** by answering "What is the future that we want to fight for, or alternatively, want to avoid by all means"? The time horizon is not limited but is usually one beyond 25 years (Westhoek *et al.*, 2006).
3. The scenario studies that are meant to support **strategic orientation** by answering questions such as what alternative worlds do we, in our specific roles, need to prepare ourselves for; what to do if our overall direction is wrong or too risky. The time horizon for this type of scenario often reaches into future decades (Westhoek *et al.*, 2006).
4. The scenario studies that are meant to support a **social learning**[1] **and communication process**. They intend to raise awareness, increase knowledge of the business environment, initiate learning processes and/or widen the perception of possible future events (Henrichs, 2003; Schroth & Wissen, 2004). This kind of scenarios studies

[1] In this paper, we refer to the definition given by Woodhill and Röling (2000) that stats that 'social learning approach' represents an "action-oriented philosophy" focusing on participatory processes of social change underpinned by a theoretical framework in which social processes are defined as non-linear and non-deterministic. Social learning-based inititiatives are essentially non-coercive and their contents are open to collective agreement (In Rist and al. 2006).

sometimes refer to project goal of exploration (van Notten *et al.*, 2003). These studies often look beyond 25 years ahead.

5. The scenario studies that are meant to support **(policy) impact assessment** by describing a range of possible consequences of strategic decisions (Börjeson *et al.*, 2006).
6. The scenario studies that are meant to support **research and scientific processes**. They try to integrate information from different fields and explore possible developments (Henrichs, 2003).

➢ The predictive approach has been applied mainly for the **fifth and the sixth categories,** i.e. impact assessment and research. It leads to the building of so called '**predictive scenarios**'. Predictive scenarios are primarily drawn up to make it possible to plan and adapt to situations that are expected to occur. The predictive approach assumes that the laws governing the system's development under study will prevail during the relevant time period. Therefore historical data often play an important role. As a result of these inherent characteristics, the predictive approach is most suited to the short term when the uncertainty in the development of external factors is not too great. Predictive scenarios are classically used by planners and investors to deal with foreseeable challenges and take advantage of foreseeable opportunities. Predictions are also used nowadays on a more general basis to make decision-makers aware of problems that are likely to arise if some condition on the development is fulfilled (Stoorvogel & Antle, 2000; Börjeson *et al.*, 2006).

➢ The explorative approach is currently applied to support the **fourth last categories of purpose**, i.e., strategic orientation, social learning and communication, impact assessment and research. The eventualities mode of thinking leads to the building of so called '**explorative scenarios**'. The American think-tanks RAND during the 50s, and the Hudson Institute during the 60s (with Herman Kahn as the leading personality) largely contributed to the development of related methodologies (Dreborg, 2004). RAND was an independent research institute with close ties to the U.S. military. The explicit aim of first scenario exercises in the area was to widen the thinking about the future with policy makers as targeted users and to provide a set of scenarios. In the 70s, the Royal Dutch/Shell initiated the integration of scenario development and the use of scenario into strategic planning at business enterprises (van der Heijden, 2004). The application of such a scenario approach for strategic planning is nowadays considered as relevant in a wide array of realms.

➢ The visionary mode of thinking was initially developed in reference to the **first and second categories of purpose**, i.e. policy optimisation and vision building. It is also increasingly used for supporting social learning and communication and in research. Its use leads to the building of so called '**normative scenarios**', i.e. scenarios that take explicitly values and interests into account (Greeuw et al., 2001). This approach finds its roots in the 60s when some people like Polak (Polak, 1973), one of the Dutch founding fathers of future studies, argued for the importance of visionary images of the future to inspire coordination and action. Corresponding methodologies have been then developed since the 70s and typically address perceived societal problems with the aim of finding a real solution (Robinson, 1982). More recently, there has been a clear tendency to involve stakeholders into the process of building the normative scenarios towards a participatory visionary mode of thinking (Robinson, 2003).

Due to the application of future studies to a continuously growing number of areas and societal concerns, scenario methods diversified tremendously over the last decades, by either developing specifically new methods or adapting existing ones for application to other purposes. The array of scenario method and their applications currently available can however be considered as consisting of “classical approaches” that rely on one of the three main modes of thinking described above and a large set of “hybrid approaches”, that make use and combine principles of the classical approaches under a variety of perspectives (Greeuw *et al.*, 2000; van Notten *et al.*, 2003; Dreborg, 2004; Börjeson *et al.*, 2006). In spite of the apparent variety of the modes of thinking currently used in scenario method, Marien (2002) considers that the great majority of futurists still think in only one, or at most two of the categories probable, possible or preferable (Marien, 2002). Furthermore, Dreborg (2004) argues that “typically one of the(se) modes of thinking and a related method are dominant and give the future study its character”.

Hybrid approaches

The methodologies applied and the techniques utilized have been rapidly and notably evolving since the first scenarios studies, in relation to changes in societal concerns and views, and technological evolution of utilized tools for future studies (Ringland, 1998; Greeuw *et al.*, 2000). Evolution in scenario studies follows firstly from the spreading awareness of sustainability and uncertainty challenges emerging from ecological and societal complexities of environmental issues. During the last decade the crucial role of uncertainty has been increasingly recognised. This has led to the understanding that scenario-building should not be a deterministic scientific activity (Greeuw et al 2000). The increased recognition of the importance of the relationships between sectors and society and the environment led also to invest into integrated approaches based on system thinking (Holling, 1978; Kruseman & Bade, 1998; Lambin & Geist, 2002; Walker *et al.*, 2002; Carpenter, 2002; Walker *et al.*, 2004; Wittmer *et al.*, 2006). Additionally, with the recognition of the incompletude of information requested and the important role of decisions of the stakeholders in the dynamics of change, a growing interest was put into participatory approaches (Caswill & Shove, 2000; Toth, 2001; van Asselt & Rijkens-Klomp, 2002; ComMod, 2005; Bousset *et al.*, 2005; Quist & Vergragt, 2006). A general consequence of these changes is hybridation between scenario methods, which is considered in literature under a variety of perspectives. It can refer to the techniques used. For instance, Greeuw and al. (2000) classify the scenario method between modelling, narrative and participatory methods corresponding respectively to quantitative, qualitative and **hybrid scenarios** types. It can also refer to the point of view adopted with respect to the future. If the great majority of scenarios developers follows one of the three modes of thinking and applies one of its related scenario methods, several authors stress that combined of approaches and/or methodologies are also encountered (Greeuw *et al.*, 2000; van Notten *et al.*, 2003; Dreborg, 2004; Börjeson *et al.*, 2006). Two kinds of combination are evocated in the literature:

➢ The first one concerns a methodological evolution within each of the three modes of thinking. The historical and disciplinary methodological gap between them is tending to blur. Thus, some developers use one dominant approach completed by analytical technique rooted in another mode of thinking, e.g. eventualities mode of thinking using a complementary predictive method, or backcasting studies that use predictive modelling techniques in order to assess the likely consequences of a trend-like development as a part of a problem setting phase (Höjer & Mattsson, 2000). As a result of which, some authors note a use of more and more complex methodologies that integrate both qualitative and quantitative data and combine qualitative and computer techniques (Robinson, 2003).

- The second one concerns a combination of two modes of thinking (Dreborg, 2004). For instance one of the first and prominent mixed approaches, the French school ‘La Prospective’ that finds its roots in the 60s, evolved into ‘La Prospective Stratégique’ in the 80s (Godet & Roubelat, 1996; Godet, 1997; Godet, 2001). The second method combines an exploratory mode if thinking for anticipation and a visionary mode of thinking for action. The most common trend in recent scenario studies is to drive an exploratory process to raise awareness, to stimulate creativity, and finally to empower the users of scenarios before engaging, on the basis of the broad range of the resulting exploratory scenarios, a second phase of identifying the relevant and desired goal -or set of goals- and then building the paths to reach them (Godet & Roubelat, 1996; van der Heijden, 2004). Therefore, by supporting successively a social learning and a goal-oriented project, scenario method becomes both a process as a means and a process a goal (van Notten *et al.*, 2003).

In Part 2 of the paper we will consider scenario method and their evolution in reference to each of the three basic modes of thinking.

Scenario definitions

A widely quoted definition of scenarios in literature is the one initially proposed by Kahn and Wiener (1967): *“Scenarios are hypothetical sequences of events constructed for the purpose of focussing attention on causal processes and decision points”*. However, there is obviously not any definition comprehensive enough to cover the various conceptions underpinning studies of the future. A variety of terms are used for qualifying these differences. Many literature reviews address the major factors in the orientations of studies of the future that condition the scenario conception (Ducot & Lubben, 1980; Greeuw *et al.*, 2000; Rotmans *et al.*, 2000; van Asselt, 2000; Heugens & van Oosterhout, 2001; van Notten *et al.*, 2003; Shearer, 2005). Each of them stress out important aspects that ground the variety in the approaches to scenarios, while at the same time suggesting baselines and terminologies for categorisation partly transversal to the other ones. Current difficulty for establishing a common understanding of the typical features of contemporary scenario development and of the relevant terminology associated with it is regarded as following from a relative segmentation in their applications: business-oriented classifications hardly acknowledge the fundamentally different macro-economic and environmental scenarios, and vice versa (van Notten et al., 2003).
In this section, we investigate the diversity of scenarios types and scenarios content towards three overarching themes: i) Categorisation of scenarios as a component of a scenario space, ii) categorisation of scenarios in reference to modes of thinking and study purposes, and iii) categorisation of scenarios as a correlate of the objectives and development method of scenario study. Then, we identify from the literature common features of scenario concepts before suggesting several diverse scenario definitions for each scenario category.

Categorisation of scenarios as a component of a scenario space

In close reference to the three different modes of thinking in use in studies of the future (predictive, exploratory and visionary modes of thinking) , which respectively explore probable, possible and preferable future, Godet and Roubelat (1996) proposed a categorisation of scenarios in reference to their overlaps whithin the scenario space (Fig. 1). They distinguish between **possible scenarios**, i.e. everything that can be imagined, **realisable scenarios**, i.e. all that remain possible when taking account of constraints, and **desirable scenarios**, i.e. meeting interests and values considered. The later, which obviously fall into the possible category, are not all necessarily realisable.

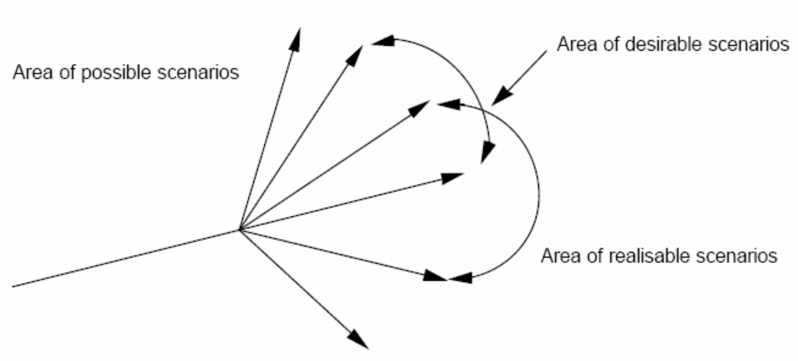


Fig. 1 : Modes of thinking for scenario studies. Source: (Godet & Roubelat, 1996)

Such a conception serves as a framework in many types of scenarios studies. Stoorvogel and Antle (2000) for instance define the **'opportunity space'** as the range of all possible viable future options, and the 'decision space' as the options which are considered to be relevant and potentially viable by the actors (Fig. 2). They consider predictive studies as intending to predict either where do we likely go within the opportunity space or where will we go within the opportunity space after implementing different near foreseeable events or changes (e.g. agricultural or technological changes).

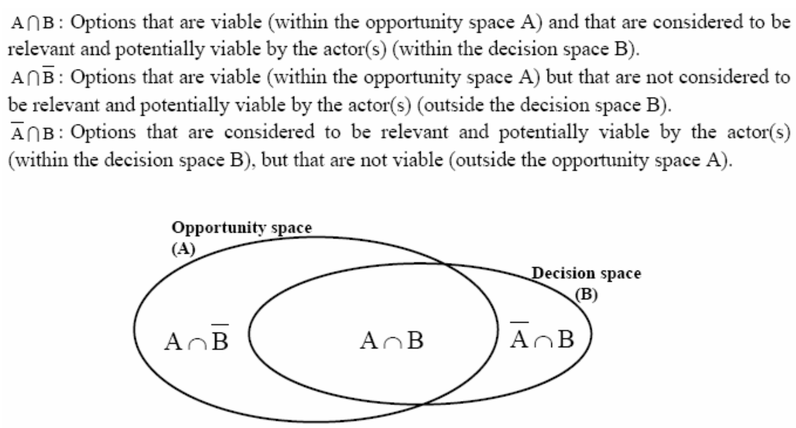


Fig. 2: Schematic representation of the overlapping opportunity space and decision space. Source: (Stoorvogel & Antle, 2000)

It is noticeable that most of the scenario methods concentrate on the domain of realisable or desirable scenarios. Many examples of scenario exercises claim to develop alternative scenarios whereas in fact they are at best only marginally unconventional (van Notten *et al.*, 2003), also called 'perturbations' of a single business as usual future (Robinson, 2003).

Categorisation of scenarios in reference to modes of thinking and study purposes

In the previous section of the paper, we pointed out that there is a relatively large common agreement about categorisation of scenarios into three broad categories (**predictive**, **explorative** and **normative** scenarios) associated with the modes of thinking. Considering there remains an internal diversity resulting from the different targeted purposes of studies, Börjeson and al. (2006) subdivide each broad category into two types (Fig. 3).

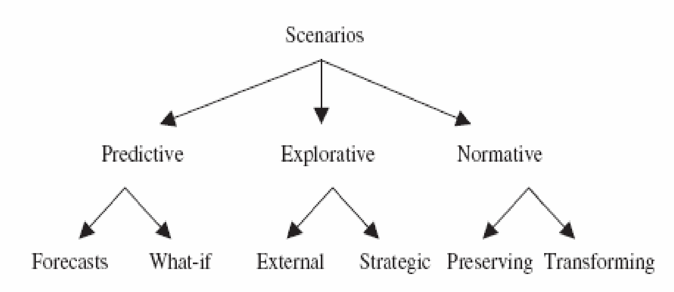


Fig. 3: Scenario typology with three categories and six types.
Source: (Börjeson *et al.*, 2006)

1. Within the predictive mode of thinking, **forecasts** respond to the question 'What will happen, on the condition that the likely development unfolds?', while **What-if scenarios** respond to the question 'What will happen, on the condition of some specified events?' The term 'what if' is used to reflect potential effect under different assumptions (Greeuw et al., 2000).

   - **Forecasts** are conditioned by what will happen if the most likely development unfolds, i.e. when making a forecast the basic supposition is that the resulting scenario is the most likely development. Forecasts can be used as an aid for planning in, for example, the business environment. In such cases, forecasts are made of external factors. These can be economic events, natural phenomena and organisational statistics. Those forecasts are most suited to the short term, when the uncertainty in the development of the external factors is not too great (Börjeson *et al.*, 2006).
   - **What-if scenarios** investigate what will happen on the condition of some specified near future events of great importance for future development. The specified events can be external events, internal decisions or both external events and internal decisions. What-if scenarios can be said to consist of a group of forecasts, where the difference between the forecasts is more than a matter of degree regarding a single exogenous variable. The differences are more like a 'bifurcation' where the event is the bifurcation point. None of the scenarios is necessarily considered as the most likely development. The resulting what-if scenarios hence reflect what will happen, provided one or more events happens (Börjeson *et al.*, 2006).

2. Within the exploratory mode of thinking, **external scenarios** respond to the user's question 'What can happen to the development of external factors?', while **strategic scenarios** that respond to the question 'What can happen if we act in a certain way?'

   - **External scenarios** focus only on factors beyond the control of the relevant actors. They are typically used to inform strategy development of a planning entity. Policies are not part of the scenarios but the scenarios provide a framework for the development and assessment of policies and strategies. The external scenarios can then help the user to develop robust strategies, i.e. strategies that will survive several kinds of external development. Some advantages with external scenarios are that they open up the possibility to find flexible and adaptive solutions for an actor whose influence on external factors is small (Börjeson *et al.*, 2006). External scenarios lead the actor being more receptive to weak signals of radical changes in his environment.

- **Strategic scenarios** incorporate policy measures at the hand of the intended scenario user to cope with the issue at stake. The aim of strategic scenarios is to describe a range of possible consequences of strategic decisions. Strategic scenarios focus on internal factors (i.e. factors it can possibly affect), and take external aspects into account. They describe how the consequences of a decision can vary depending on which future development unfolds. In these scenarios, the goals are not absolute but target variables are defined (Börjeson *et al.*, 2006).

These two types of explorative scenarios, by intending to span a wide scope of possible developments, resemble what-if scenarios. But the explorative scenarios are elaborated with a longer time-horizon (Dreborg, 2004; Börjeson *et al.*, 2006). Moreover, explorative scenarios studies typically leads to the development of **alternative scenarios** by describing futures that differ significantly from one another (van Notten *et al.*, 2003).

3. Within the visionary mode of thinking, the aim is not anymore to provide the most likely projections of future conditions but to explore the feasibility and implications of achieving certain desired end-points. The main approach, related to this mode of thinking is called backcasting ; a term coined by Robinson (Robinson, 1982). Two types of scenarios are developed. **Preserving scenarios** respond to the question ‘How can the target be reached, by adjustments to current situation?’, while **transforming scenarios** respond to the question ‘How can the target be reached, when the prevailing structure blocks necessary changes?’

   - **Transforming scenarios** are elaborated when a marginal adjustment of current development is not sufficient, and a trend break is necessary to reach the target. The backcasting method (Dreborg, 1996; Robinson, 2003) is often used and typically results in a number of target-fulfilling images of the future, which present a solution to a societal problem, together with a discussion of what changes would be needed in order to reach the images. It has a rather long time-perspective of 25–50 years (Robinson, 1990).
   - **Preserving scenarios** are built to find out how a certain target can be efficiently met, with efficiently usually meaning cost-efficiently.

This categorisation stresses out important basic differences transversal to modes of thinking in the scenarios conception:

- The underlying view development process. The assumption that the laws governing the development of the system under study will prevail during the time period considered grounds preserving scenarios as well as forecasts;
- The balance in the respective focus given on the role of environment and decisions. Strategic scenarios and preserving scenarios favour the exploration of the future impacts of decisions, while the role of the environment is given a much wider consideration in external and transforming scenarios.

However, in practical situations, it can be difficult to clearly distinct e.g. forecast and what-if scenarios or what-if scenarios and explorative scenarios. There remains a grey area between these types of scenarios and the categorization of scenarios types must been seen as landmarks (Börjeson *et al.*, 2006).

The characteristics of the scenario conception adopted depend in fact of many factors, first of all **the focus** of the scenario exercise (van Asselt, 2000): global, focused or theme-specific approaches lead to privilege distinct contextual questions and methods for building scenarios.

Categorisation of scenarios as a correlate of the objectives and development method of the scenario study

The review by Van Notten and al. (2003) offers an overview of various aspects of a scenario study that condition the basic conception of scenarios and the approach to their development as well as the terminology used. These authors attached to categorise them scanning a set of scenarios studies covering a wide array of purposes and topics, such as a renowned scenario process designed to stimulate debate about the shape of post apartheid South African society - the Mont Fleur project (Roux, 1992)– or a scenario study for achieving sustainable development and to assist the European Commission in future decisions about the Common Transport Policy –the Possum project (Dreborg, 2004). Their work stresses the strong connections between objectives, methods and scenario conception in scenarios studies. They identified and fourteen characteristics discriminating the scenario conception and the terminology used that range into three "overarching themes": (1) the "project goal" of the scenario study, (2) the methodological design used ("process design") and (3) the "scenario content" (Fig. 4).

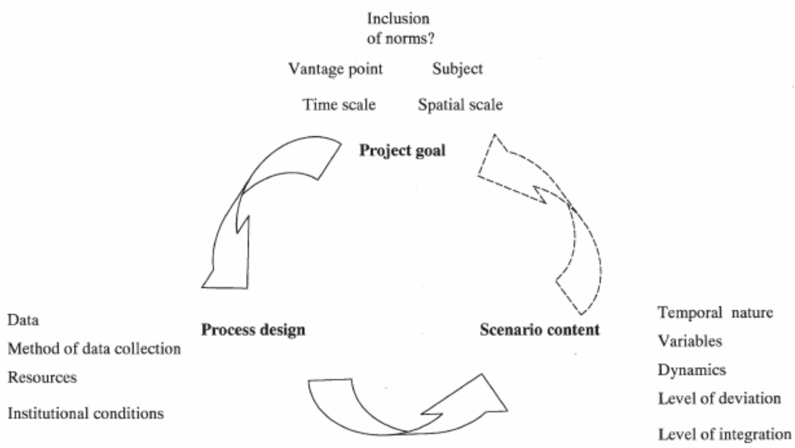


Fig. 4: The scenario typology in brief. Source: (van Notten *et al.*, 2003)

The "project goal"
Under this theme the authors emphasise the scenario analysis' objectives as well as the subsequent demands on the design of the scenario development process. They categorise the **subject of scenario study** in reference to societal issues such as the future of crime (**issue-based**), the future of a particular geographical area (**area-based**) or the future of an organisation or sector (**institution-based**). They categorise the types of scenarios according to their **vantage point** (**starting from the present**, e.g. exploratory and forecasting scenarios versus **reasoning from a specific future situation**, e.g. what-if scenarios and backcasting scenarios). They also stress out the importance of the **time scale** (long-term versus short-term), and the **spatial scale** (global, supranational, national, sub-national, regional or local) in the basic conception of scenarios.

The "process design"
The authors address the role on scenario conception of the general design adopted for their elaboration in relation to the project goal, such as:

- The **nature of data** (qualitative or quantitative). **Qualitative or narrative scenarios** are appropriate in the analysis of complex situations with high levels of uncertainty and when relevant information cannot be entirely quantified (e.g. human values, emotions, and behaviour). **Quantitative scenarios**, often using computer models, have been used to develop energy, technology, macro-economic, and environmental forecasts. As other authors, e.g. Greeuw et al., (2000), they state that a combination of qualitative and quantitative elements can make a scenario more consistent and robust. A quantitative scenario can be enriched and its communicability enhanced with the help of qualitative information. Likewise, a qualitative scenario can be tested for plausibility and consistency through the quantification of information where possible. However, they consider that the fusion of quantitative and qualitative data in scenarios remains a methodological challenge. They stress out that a promising technique in this regard is agent-based modelling that aims to incorporate qualitative elements such as actors' behavioural patterns in the otherwise quantitative realm of computer simulation;
- The **method of data collection** (participatory approach or desk research). They consider the poles regarding data collection methods as the **participatory approach** on the one hand, and **desk research** on the other. They stress the variety in participatory approaches from the ones that draw on experts in the field and the ones where expert input is complemented by stakeholder-input, more and more widespread in today's scenario projects, and in participatory techniques (e.g. focus groups, citizens' juries, envisioning workshops);
- The type and level of resources allocated to the project (extensive or limited). The resources describe a scenario study's financial resources, research resources, time invested in the project, available manpower and its competencies;
- The nature of the institutional conditions (open or constrained). The nature of the institutional conditions is related to the nature of the resources. Institutional conditions address the room for manoeuvre that a scenario project is given. For example, informal aspects such as personal relations, and the political sensitivity to an analysis determine institutional conditions. Formal aspects such as institutional constraints also establish boundary conditions.

The "scenario content"
The authors point out the variety into composition of the scenarios developed. They describe it according to basic categories according to:

- Their temporal nature with the developmental or chain describing the path of development to a particular end-state on the one hand, and the end-state or snapshot describing the end-state of a particular path of development but addressing the processes only implicitly on the other;
- The nature of variables (actors, factors, and sectors; heterogeneous or homogeneous variable) and the nature of dynamics (peripheral or trend scenario) considered in a scenario, and how they interconnect. Contrast or peripheral scenarios describe a discontinuous path to the future whilst trend scenarios are considered to be linear trajectories;
- Their level of deviation (alternative or conventional), i.e. the range of possible futures that is taken into account. Alternative scenarios address futures that differ significantly

from one another. They are often developed in an effort to raise awareness and understanding about new or uncertain issues, and as an exercise for challenging assumptions. At the opposite, conventional or business-as usual scenarios (also called trend scenario, baseline scenario, or status quo scenario) adhere to the status quo or to present trends and their extrapolation into the future. No disruptive events or developments occur in conventional scenarios and overlap between the scenarios is possible. Conventional scenarios are developed when the aim is to fine-tune current strategy rather than to develop new strategy;

- Their level of integration (high or low), i.e. the extent in which components relevant to the subject of a study are incorporated and brought together to form a whole. A scenario study with a high level of integration unifies in an interdisciplinary and transparent manner the relevant variables and dynamics across time and spatial scales, and across relevant social, economic, environmental, and institutional domains.

Van Notten and al. (2003)'s analysis highlights the rationales for which grounds the variety of terms and definitions used in scenarios. It helps in particular understanding the variety in the attributes to describe a scenario and the overlaps they often include as a result of the characteristic of a scenario study their authors intend to put forwards. For instance, what some call a normative scenario -in the sense of desirable or preferable- (Robinson, 2003) can also be referred to as prospective, strategy, policy or intervention scenarios (van Notten *et al.*, 2003).
But these authors identified also in their work "a frequent weakness of the link between scenario content and project goal". Additionally in many cases, the type of scenario the author refers to is not explicitly specified. A lot of scenario definitions in the literature start with 'a scenario is…'.

Common features of scenario concepts

Scenario definitions found in literature and used by scenario developers vary according to the mode of thinking the authors implicitly or explicitly refer to. Their contents depend also on the area of application authors refer to, as illustrated in Table 1.
Nevertheless, some authors have been trying to suggest a global definition that could include the diversity of scenario types by identifying some common features. In the first place, "scenarios describe processes, representing sequences of events over a certain period of time. Scenarios are also hypothetical, describing possible future pathways. Further, scenarios contain elements that are judged with respect to importance, desirability, and/or probability. Scenarios consists of 'future configurations' (Walker *et al.*, 2002), driving forces, events, consequences and actions which are causally related" (Rotmans *et al.*, 2000). "Scenarios include the depiction of an initial state, usually lying in the present, and of a final state at a fixed time horizon" (Greeuw *et al.*, 2000). In essence, scenarios are alternative, dynamic stories that capture key ingredients of our uncertainty about the future of a study system. Scenarios are constructed "to provide insigths into drivers of change, reveal the implications of current trajectories, and illuminate options for the future" (Peterson et al., 2003).

Scenario category	Source	Definition
Predictive scenarios	(Dreborg, 2004)	"Forecasts, as a rule, are conditional, i.e. they are based on a **set of assumptions** (e.g. temporal evolution of incomes). Some analysts call these scenarios"

Explorative scenarios	(MacNulty, 1977)	In reference to corporate planning "**A quantitative or qualitative picture** of a given organization or group, developed within the framework of a **set of specified assumptions**"
	(Schwartz, 1991)	Area: policy exercises/ policy planning "A tool for ordering one's perceptions about **alternative future environments** in which one's decisions might be played out"
	(Shoemaker, 1993)	Area: corporate planning "Focused **descriptions** of fundamentally different futures presented in coherent script-like or narrative fashion"
	(van Notten & Rotmans, 2001)	Area: general review of scenario method "Scenarios are descriptions of possible futures that reflect different perspectives on **the past, present and the future**"
	(Alcamo, 2001)	Area: international environmental assessment "Intergovernmental Panel on Climate Change (IPCC) describes scenarios as 'images of the future' that are **neither predictions nor forecasts**, but an alternative image of how the future might unfold"
	(United Nations Environment Programme, 2002)	Area: international environmental assessment "Scenarios are descriptions of **journeys** to possible futures. They reflect different assumptions about how current trends will unfold, how critical uncertainties will play out and what new factors will come into play"
	Merriam-Webster Dictionary On-line 2003	Area: general review of scenario method "In common usages scenarios refer to a **sequence of events** especially when **imagined**; especially: an account or synopsis of a possible course of action or events"
	(Henrichs, 2003)	Area: international environmental assessment "… a plausible description of how the future may unfold based on a set of **'if-then' propositions**"
	(van der Heijden, 2004)	Area: policy planning "**Internally consistent and challenging** descriptions of possible futures (…) intended to be representative of the ranges of possible future developments and outcomes in the external world"
Normative scenarios	(Greeuw et al., 2000)	Area: general review of scenario method "Backcasting scenarios reason from a desired future situation and offer a number of different strategies to reach this situation"
	(Godet & Roubelat, 1996)	Area: policy exercise / policy planning **Prospective scenarios: "**A description of a future situation and the course of events which allows one to move forward from the original situation to the future situation"

Table 1: A selection of definition of scenarios

Basic elements of a scenario

The way to settle the contents of a scenario depends deeply on the type of scenario considered. They are however made of a set of broadly similar elements. As an example, the principal elements of a typical scenario in environmental studies are (Alcamo, 2001):

- **Description of step-wise changes**. The portrayal of step-wise changes in the future state of society and the environment is the main element of such a type of scenario (e.g. change in temperature or other climatic variables);
- **Driving forces**. They are the main factors or determinants that influence the changes described in the scenarios (e.g. population, economic growth, efficiency of energy use for gas emission scenarios);
- **Base year.** It is the beginning year of the scenario. For quantitative scenarios, the base year is usually the most recent year in which adequate data are available to describe the starting point of the scenarios;
- **Time horizon and time steps**. The time horizon describes the most distant future year covered by a scenario. The selection of an appropriate time horizon depends very much on the objectives of the scenarios. Time steps to the successive descriptions of the future state of the system under study between the base year and the time horizon. The more numerous they are the more analytical effort they require;

Scenario contents and the set of scenarios considered in a scenario study are conceived in close reference to requirements and demands of the "users" of the scenario study, i.e. the institution or the social group which is the promoter or the target of the scenario study. As stressed upper (1.3.3) scenarios are therefore to be regarded firstly as a component of a method in a scenario.

Chapter 2

BASIC MODES OF THINKING AND RELATED SCENARIO METHODS

In this section of the paper, we review scenario methods related to the three basic modes of thinking. We describe the underlying and general **concepts** of each mode of thinking, before presenting a '**general description**' of the scenario development in the corresponding scenario studies and their main **application fields** (policy, business enterprise, research, etc.). Then we present the panel of scenario methods applied and we recapitulate in a table the main techniques used for the three tasks to handle in scenario studies (Börjeson *et al.,* 2006):

- **Generating techniques** are techniques for generating and collecting ideas, knowledge and views (e.g. workshops, panels or surveys)
- **Integrating techniques** are techniques for integrating parts into whole (e.g. mathematical modelling such as time-series analysis, explanatory modelling and optimising modelling; or conceptual modelling)
- **Consistency techniques** are techniques for ensuring consistency between or within scenarios (e.g. cross-impact analysis or morphological field analysis).

We finally illustrate the main scenario methods related to each of the modes of thinking with a detailed description of several scenario case studies.

If some of future studies focus on social learning and communication processes or constitute a research exercise, most of them concentrate on supporting decision makers, in particular in policy and business. In the field, two broad concepts are used and their definitions vary depending upon the author's point of view: the decision-making and decision support concepts. In this paper, we consider that decision-making is the cognitive process leading to the selection of a course of action among alternatives; the decision can be either an action or an opinion. It begins when we need to do something but we do not know what. Therefore, decision-making is a reasoning process that can be rational or irrational, and can be based on explicit assumptions or tacit assumptions. According to van Ittersum and al. (1998) the decision-making process can be subdivided into four phases:

1. problem definition;
2. agreement on the need for intervention;
3. identification of objectives; and
4. identification of the means to realize these objectives.

Due to the large number of considerations involved in a decision-making process, decision support systems (DSS) have often been developed to assist decision makers in considering the implications of various courses of thinking. A DSS can be defined as "a computer-based system that aids the process of decision making" (Finlay, 1994) or in a more precise way as "an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making" (Turban, 1995).

Predictive scenario studies

Concept

Predictive scenarios are primarily drawn up to make it possible to plan and adapt to situations that are expected to occur. Predictive studies intend to predict either where do we likely go within the "opportunity space" (see § 0) or where will we go within the opportunity space after implementing different near foreseeable events or changes (e.g. agricultural or technological changes) (Stoorvogel & Antle, 2000). The concepts of probability and likelihood are closely related to predictive scenarios since trying to foresee what will happen in the future in one way or another has to relate to the (subjectively) estimated likelihood of the outcome. Predictions are usually made within one structure of the predicted system, i.e. it is assumed that the laws governing a system's development will prevail during the relevant time period (linear approach in contrast with the adaptive cycle of Holling). The focus is on causalities, which in a step-wise manner lead to an outcome (Dreborg, 2004; Börjeson *et al.*, 2006). Due to uncertainties in the prognoses of many drivers governing the system development, predictive scenario studies can only be applied with a short time horizon.

Two types of predictive scenario can be distinguished (Fig. 3). The **Forecasts** respond to the question: 'What will happen, on the condition that the likely development unfolds?', and the **What-if scenarios** which respond to the question: 'What will happen, on the condition of some specified events?' (Börjeson *et al.*, 2006).

General description and application fields

The process design of predictive scenario analysis leans strongly on quantified knowledge - tables, graph, maps…- (Henrichs, 2003) from which scenario are developed, and often uses computer simulation techniques (Rotmans *et al.*, 1994; Schneider, 1997). The predictive mode of thinking regards scenarios not so much as an art form but as a rational and analytical exercise. The data incorporated in the scenario are typically collected though a desk research approach. They may come from existing databases, experiments and/or enquiries. Typically, no disruptive events or developments occur and thus the resulting scenarios are often 'conventional' scenarios (van Notten *et al.*, 2003). Overlaps between the scenarios are even possible in the case of forecasts (Börjeson *et al.*, 2006).

More often, predictive studies are used and useful for the first (problem definition) and second (agreement on the need for intervention) phases of a decision making process. They show plausible developments for the near future if trends do not really change, and as such, might have the role of a mirror showing the current situation and likely developments for the near future. For instance, the extrapolation of trends method is useful to policy makers because it indicates possible changes without policy interventions or as a result of technological changes. Policy makers can subsequently decide whether these trends are desired or not and whether intervention is justified (Stoorvogel & Antle, 2000). After the first and second phases of a decision making process, in general the debate shifts towards the measures before having identified the objectives, and thus especially for policy making. Exploratory studies often play a role here, but a particular predictive approach is also sometimes used: the what-if predictions. Built under certain conditions, these what-if predictions (also called intervention predictions) are useful to planners and investors, who need to deal with foreseeable challenges and take advantage of foreseeable opportunities, and to decision-makers, who need to be aware of

problems that are likely to arise if some conditions on the development are fulfilled (Dreborg, 2004; Börjeson *et al.*, 2006).
In the field of land-use change studies, predictive models are required to analyse the likely land use changes in the short term as a result of introducing agricultural policies and technologies - called scenarios- (Bouman *et al.*, 2000) and to indicate where agricultural land use will move within the opportunity space after implementing a certain agricultural policy. See for example Kruseman and Bade (1998) that use the technique of farm household modelling (FHM) for simulating the impact of feasible changes in policy and technology choice for different (model) farm groups (Kruseman & Bade, 1998).

Methodologies

Traditionally, the predictive mode of thinking applies quantitative techniques and often relies on one of the following techniques: **the extrapolation of trends** or **the predictive modelling** (Dreborg, 2004). Nevertheless, when there is a shortage of data, inadequate models and lack of time or resources to make a thorough scientific study, or when the complexity of the problem at stake is too big, panels of experts are suitable. The technique often used in this way is **the Delphi method** (Börjeson *et al.*, 2006). This method has been developed by the Rand Corporation for the U.S. Air Force in the late 60s.
When predictive scenario study relies on quantitative techniques, different types of models are used according to the objective of the study: some seek mostly to explain the causes of past events, others have been designed to predict where, when, or how much specific events (e.g. deforestation, intensification …) will occur in the future, when some others are designed to assess, a priori, how policy interventions will influence a specific event. To a certain extent, these objectives overlap, but distinct methods and variables are more effective at achieving particular objectives (Kaimowitz & Angelsen, 1998; Lambin *et al.*, 2000). Hence, the method must be tailored to the questions of interests and choose the model(s) with considering its optimal application field and its limitations.

Qualitative methods

The classical Delphi method (in contrast to the modified Delphi method) is about collecting and harmonising the opinions of a panel of experts on the issue at stake from which emerge one or several scenarios of likely future development. It recognises human judgement as a legitimate input to forecasts and also that the judgement of a number of informed people is likely to be better than the judgement of a single individual. The questions are sent to a panel of experts in various rounds (Börjeson *et al.*, 2006).

Quantitative methods

The extrapolation of trends method is based on an assumption that patterns in the past will continue into the future. To perform this method, information is collected about a variable over time, and then extrapolated to some point in the future. This analysis can be either qualitative or quantitative. In the simplest form, trend extrapolation can be based on linear or other straightforward projections. The models used for extrapolation of trends are called **projective models** (Van Ittersum *et al.*, 1998; Stoorvogel & Antle, 2000). In the case of land use studies, these models study past land cover and land use changes in relation to bio-physical and socio-economic parameters and project future trends given certain changes in the parameters. Some assumptions about future development are made to demonstrate how are modelled the dynamics. These are often called scenarios -or line scenario or base-line scenario- in the literature. Projective models answer the question: ‘Where do we go within the opportunity space?’ (Stoorvogel & Antle, 2000). The projective models commonly used are either empirical-statistical models, e.g. CLUE (de Koning *et al.*, 1999), or stochastic models when the focus is on transitions that have been observed in the recent past. Stochastic models consist mainly of transition probability models (Lambin *et al.*, 2000).

The predictive scenario method has been developed to answer scenario type 'What-If' questions. The idea is that the future cannot be only seen as an extrapolation of current trends and the aim is to analyse the effects of likely changes, as a result of which optimisation or simulation modelling are required. The scenarios mainly address policy (economic, agricultural or environmental policies) or technological changes. The use of predictive modelling often relies on computer models to represent the studied system. The models originally based on expert knowledge are increasingly elaborated within a participatory process with policy makers, scientists and other stakeholders using experience and expert knowledge (van Asselt *et al.*, 2001). Different types of computer models are used in predictive modelling: optimisation, simulation and tradeoff models. In the field of land-use changes, the technique of farm household modelling (FHM) is often used. In such an approach, the simulated policy scenarios are alternative combinations of existing policy measures (e.g. price policies, structural reform, access to appropriate technologies…). The impact of these policy scenarios are often evaluated against the results of a base-run simulation of the model, in which the current behaviours and activities are reflected (Kruseman & Bade, 1998).

Related techniques

The main techniques used in the development of predictive scenarios studies are reported in Table 2. Detail about the techniques is provided in the Appendix.

Predictive scenarios	Techniques			application fields
	Generating	Integrating	Consistency	
Forecasts	•surveys •workshops •Original Delphi method	•time series analysis •explanatory modelling •optimising modelling		•decision support
What-if	•surveys •workshops •Delphi methods •desk-top •time series •experiments	•explanatory modelling •optimisation modelling •dynamic simulation modelling		•scientific research •risk/impact assessment •local and regional (environmental) impact assessment •planning (mainly regional) •implementation of governmental policies at local level

Table 2: Main techniques used in future studies based on forecasts or what-if scenarios

Illustration of main methods

In this section, we concentrate on the type of model utilized and its place in the approach.

Example of extrapolation of trends analysis

The model structure reported is taken from the regression based dynamic model CLUE (Conversion of Land Use and its Effects). The CLUE model has been first designed to indicate the most likely locations for future land use and land change at the regional and national scales. It offers scenarios based on driving forces such as climate, soil quality and population growth. An economic model develops projections of land demand, which in turn feed into a statistical regression model that relies on data provided by a geographic information system (Veldkamp & Fresco, 1996; de Koning *et al.*, 1999). A hypothetical future base-line scenario of increasing demands for agricultural commodities was used to demonstrate how dynamics of land use are modelled (Fig. 5).

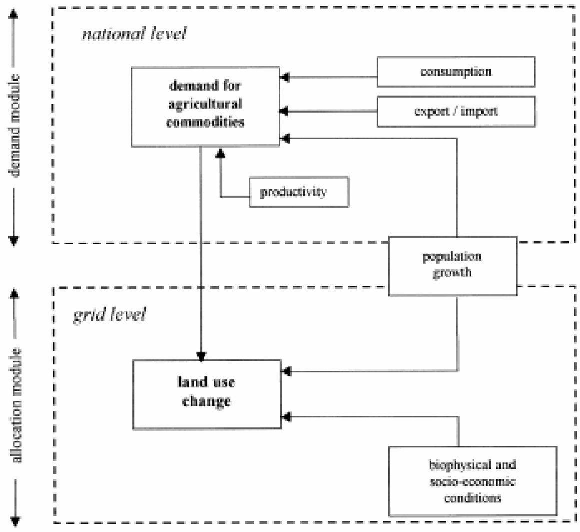


Fig. 5: General structure of the CLUE modelling framework. Source: (de Koning *et al.*, 1999)

Note that CLUE model is now one of the most widely applied models with approximately 30 applications spread over the different regions of the globe focusing on a wide range of land use change trajectories that include agricultural intensification, deforestation, land abandonment and urbanization. If the CLUE model is one of the most quoted examples in the field of extrapolation of trends, the model has also been used to better understand the processes that determine changes in the spatial pattern of land use change and explore possible future changes in land use at the regional scale (Bouman *et al.*, 2000; Manson, 2002).

Example of optimisation modelling used in combination with What-if scenarios

The model structure reported is taken from the study of impact of the anticipated co-evolution of farm performance and agro-ecosystem functions in south-western Niger towards adoption of more intensive forms of management, privatisation of commonly managed grazing resources, and their combination (La Rovere *et al.*, 2005).
The authors followed a method that integrates socio-economic and bio-physical databases and tools for data generation and management, with a bio-economic model (Fig. 6).

The farm household database includes information on the composition and activities of households, on farm assets, land rights and management, livestock owned and managed, and equipment, documented for 542 farms, spatial information on land tenure, land use, crop yields, seasonal vegetation mass and composition, and herd grazing itineraries over the three sites covering a total area of about 500 km2. Five types of farms were then stratified. The bio-economic model is an optimising model that maximizes an inter-temporal utility function. Three scenarios are tested towards the model: intensification of management, privatisation of common grazing resources and their combined effect. They are then analysed with respect to social and ecological indicators and compared to the trend scenario (La Rovere *et al.*, 2005).

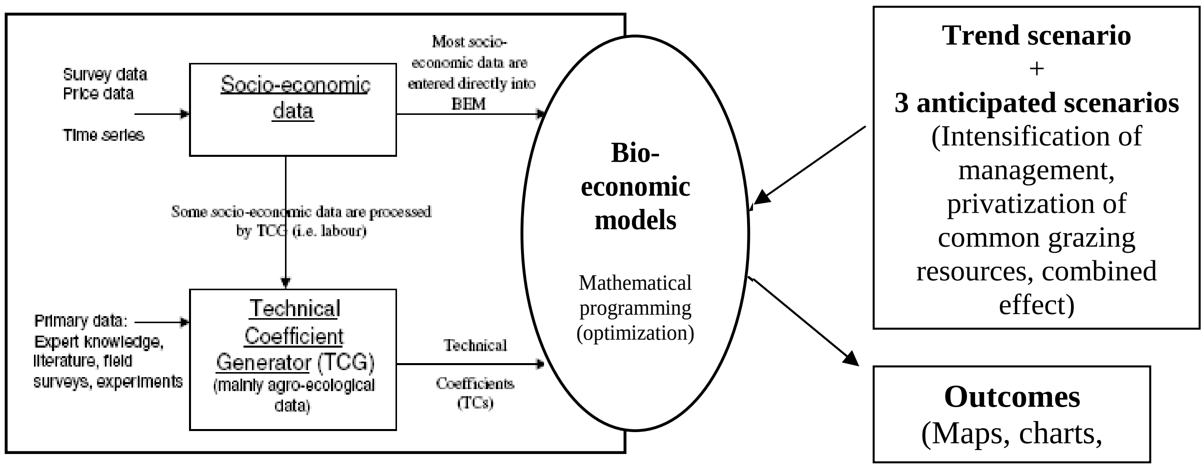


Fig. 6: General Framework of method and materials. Source: (La Rovere *et al.*, 2005)

One methodological trend is such scenario method concerns the modelling part. To better integrate interactions and complexity, the system is more and more represented by combination of several modules (or submodels). See for example the ‘ARLAS’ project (Land use and landscape development, illustrated with scenarios) that intends to predict ecological and economic consequences of land use changes by means of ‘Biotope Landscape Model’ and elaborating scenarios to illustrate the effects of different policy strategies (Munier *et al.*, 2004) (Fig. 7).

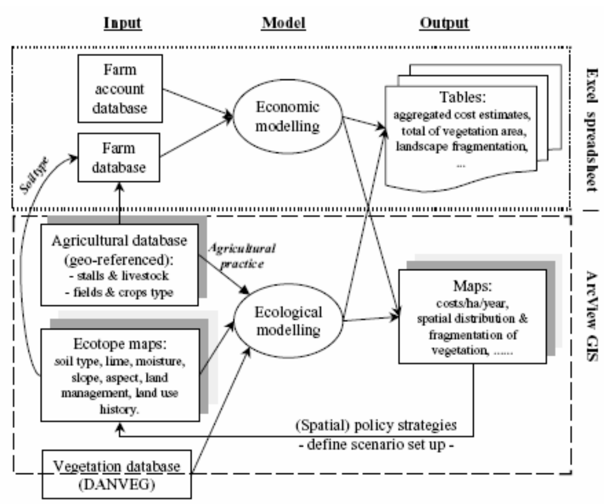


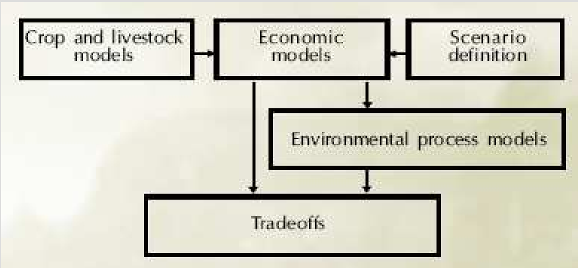
Fig. 7: Framework for integrated spatial economic and ecological modelling in ARLAS.
Source: (Munier *et al.*, 2004)

Example of tradeoff analysis

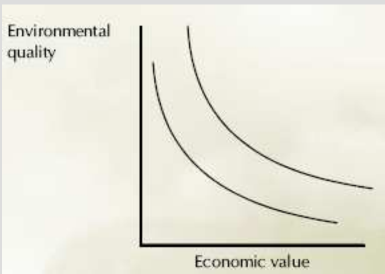
The model structure and methodological steps reported in Box 1 are taken from the study of environmental impact of pesticide use in potato-dairy pasture system ran in Carchi, Ecuador (Crissman, 1998; Stoorvogel & Antle, 2000).
The tradeoff analysis aims are to analyze the potential impacts of different policy instruments and technological changes in close interaction with stakeholders (Stoorvogel & Antle, 2000). It is a policy decision support system designed to quantify tradeoffs between key sustainability indicators under alternative policy and technology scenarios. The results are presented in the form of tradeoffs curves that are intuitive and easy to understand for policy makers. The tradeoff analysis model is based on econometric production models estimated on observed behaviour and is applied at the farm field scale.

Box 1: Steps in a tradeoff analysis - an illustration (Crissman, 1998; Stoorvogel & Antle, 2000)

1. building of the tradeoff analysis model:



2. A series of scenarios are defined that simulate i) the impact of a policy that changes output and/or input prices, and ii) the introduction of a new production technology
3. For a given scenario, simulation analysis shows how changes in prices and technologies affect farmers' decisions on i) land use choices–how much land is put into different crops, and ii) input use choices-quantity of inputs used to produce a given crop
4. These land use and input use choices are used as inputs into the environmental model to simulate environmental impacts under different policy and technology scenarios
5. The model estimates economic and environmental impacts for each scenario definition
6. Results are elaborated into tradeoff graphs. Type of tradeoff graph



Explorative scenario studies

Concept

The aim with explorative scenarios studies is to explore situations or developments that are regarded as possible to happen, usually from a variety of perspectives. Typically a set of scenarios are worked out in order to span a wide scope of possible developments (Börjeson *et al.*, 2006). Explorative scenarios, by intending to span a wide scope of possible developments, resemble what-if scenarios. But the explorative scenarios are elaborated with a long time-horizon and the scenarios are not given the same value. The main objective is to stimulate a creative thinking and to gain insights into the way societal processes influence one another (Schwartz, 1991; Ringland, 1998; Greeuw *et al.*, 2000; Rotmans *et al.*, 2000; van Notten & Rotmans, 2001; Carpenter, 2002; van der Heijden, 2004). Thus, in explorative scenario studies, the focus is one the scenario development (process as mean) rather than on the outcomes or results of the process (process as goal), e.g. van Notten and al. (2003). In an explorative scenario exercise, the process is often as important as the product; in some cases, the product – a scenario or set of scenarios- is even discarded at the end of the process (van Notten *et al.*, 2003). The aptly entitled ‘Which World?: scenarios for the 21st century’ is one example (Hammond, 1998).
Explorative scenarios studies are mainly useful in the case of strategic issues (Börjeson *et al.*, 2006). They allow exploring developments that the intended target group in one way or another may have to take into consideration. This can be in situations when the structure to build scenarios around is unknown, e.g. in times of rapid and irregular changes or when the mechanisms that will lead to some kind of threatening future scenario are not fully known. Explorative scenarios can also be useful in cases when the user may have fairly good knowledge regarding how the system works at present, but is interested in exploring the consequences of alternative developments (Börjeson *et al.*, 2006).

The goals of explorative scenarios studies can be:
- to support planning decisions (policy, management, local development);
- to educate/teach users, such as students, citizens or pupils;
- to raise the awareness of users, such as policy-makers and stakeholders(Henrichs, 2003);
- to support the communication process among participators;
- to explore the opportunity space and support the formulation of desirable and feasible objective;
- to better understand the functioning of a system dynamics by mean of scenarios and appreciate the influence of several indicators.

General description and application fields

The process design of external scenarios studies typically leans strongly on qualitative knowledge and insights -e.g. the *Scenarios Europe 2010* project (Bertrand *et al.*, 1999)- even if few case studies combine both qualitative and quantitative knowledge and data –e.g. the *Vision* project (Rotmans *et al.*, 2000; Siebenhüner & Barth, 2005). The process design of strategic scenarios studies leans on quantitative and/or qualitative knowledge and insights. The data for the scenario are often collected through a participatory process between individuals (Toth, 2001; van Asselt *et al.*, 2001). The scenarios developers were used to draw on experts in the

field. However, expert input is more and more complemented by stakeholder-input in today's scenario projects (van Asselt & Rijkens-Klomp, 2002).
The use of **external scenarios** has traditionally been for planning purposes. Nowadays, external scenarios studies' application varies from planning to teambuilding, vision development to conscience raising and communal learning. Among this diversity of applications, Van Notten and al. (2003) distinct between scenario planning studies that have a goal of exploration and those that have a project goal of decision support. One of the differences is that the second type converges towards decision scenarios.

Examples of the first type are *Biotechnology Scenarios* project -that developed three scenarios on the role of biotechnology in society between 2000 and 2050- , *Which World?: scenarios for the 21st century* project –that describes three global scenarios from the perspective of the year 2050- (Hammond, 1998), *British Airways* project -that examined societal developments and their implications for the airline industry- (Moyer, 1996) and *The Future of Women* project – that addresses the question of whether men and women will be equal by the year 2015 and what the implications of achieving or failing to achieve equality will be- (McCorduck & Ramsey, 1996). Examples of the second type are *Mont Fleur* project – that aims to stimulate debate about the shape of postapartheid South African society- (Roux, 1992), and *Destino Colombia* project – that aims to define alternative routes for Colombia to the year 2015 and to develop a shared vision that allowed for the drafting of long-range policies- (Global Business Network, 1998).

The use of **strategic scenarios** has typically been for testing different policies and studying their impact on some target variables. The strategic scenarios are not only relevant to decision makers; they are also useful as inspiration for interested parties, such as policy analysts or research groups. The explorative approach by building strategic scenarios is useful for the third (identification of objectives) and the fourth (identification of the means to realize these objectives) phases of a decision-making process. The strategic scenario method is widely applied in the field of land use analysis. The goal is often to analyse potential (im)possibilities of strategic natural resource use configurations and it is often done at regional or farm scale (Van Ittersum *et al.*, 1998; Van Ittersum *et al.*, 2003). For example, Etienne and Rapey (1999) developed a model that simulate the grazing resources production at farm scale as a function of the canopy cover, and propose to the farmer simulations of predefined scenarios of introduction of new techniques of agro-forestry (agroligniculture, agroforestry and sylvopastoralism) and offers the possibility to the farmer to confront his individual scenario (Etienne & Rapey, 1999).

Methodologies

Methodologies for external scenarios building

The most widely used method for building external scenarios is **Scenario Planning** also referred to as Scenario Analysis or Scenario Learning method or Scenario Workshop (Bousset *et al.*, 2005). Scenario planning method was initially aimed at creating business strategies that are robust across a range of different possible future developments (van der Heijden, 2004). Elsewhere, scenario planning has demonstrated an ability to help policy-makers anticipate hidden weaknesses and inflexibilities in organizations and methods, and furthermore to contribute to the creation of a common understanding in organisations and when people from different backgrounds and with different goals meet (van der Heijden, 2004).

Scenario planning is an approach to strategy that accounts for uncertainty in ways that traditional strategic planning falls short (Chermack *et al.*, 2006b). Thus, scenario planning assumes the best way to cope with uncertainty is to include it in the planning process. Scenario planning usually occurs over multiple workshops in which key driving forces in the business environment are identified as well as the main concerns of managers and executives. Then, two techniques are often used to map out uncertainties: **the dimensional analysis** and **the scenario axes technique**. The dimensional analysis is a common method of producing scenarios. This involves seeking the critical uncertainties - i.e. the two or three main dimensions on which the future under consideration is most uncertain, and creating scenarios around the extremes of those dimensions. A clear example can be found in (South Wind Design, 2001). The scenario axes technique is portrayed as a technique to align divergent views on how the future may unfold by identifying the two most important driving forces according to their degree of uncertainty (Fig. 8). A distilled list of issues is compiled and then ranked first according to impact on the business agenda and then uncertainty (Chermack *et al.*, 2006a). This ranking exercise produces a matrix with impact on the "X" axis and uncertainty on the "Y" axis, also called the scenario-axes technique (van't Klooster & van Asselt, 2006). In both techniques, scenarios are combinations of fact and possible social changes that result from including subjective interpretations of facts, shifts in values, new regulations or inventions. Finally, further workshops allow participants to explore the "what ifs" in each of the scenarios and eventually, the current strategic agenda is assessed in the context of each scenario (Chermack *et al.*, 2006a).

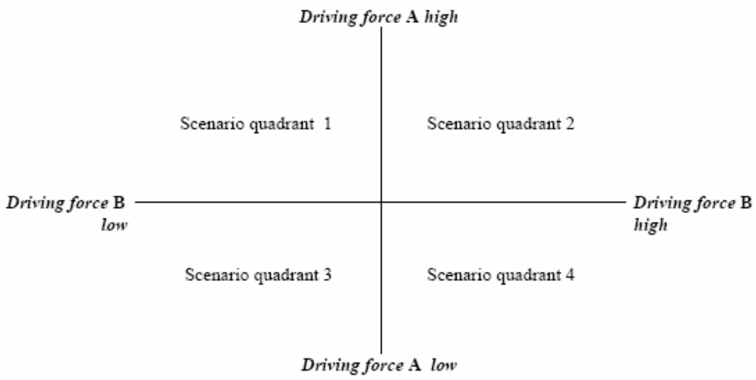


Fig. 8: Scenarios axes as starting point for scenarios. Source: (van't Klooster & van Asselt, 2006)

A typical feature of contemporary scenario planning is the involvement of decision-makers and important stakeholders in the scenario development process in addition to the traditional group composed of scientists and experts. The involvement of stakeholders is done at different degree (from a single interview to workshops) (van Notten *et al.*, 2003; Börjeson *et al.*, 2006) with the aim to ensure the quality of scientific inputs into the scenario building process. This trend addresses the objectives of 'post-normal science' to formulate a more socially oriented process of knowledge production (Funtowicz & Ravetz, 1993; Rist *et al.*, 2006). As an illustration of this trend, we suggest the critical analysis of the scenario-axes technique of Van't Klooster and van Asselt (2006). The authors point out that the scenario axes do not function as a unifying structure fostering alignment of different perspectives in the way that scenario theorists and practitioners often suggest. In the theory, the most uncertain and important driving forces constitute the 'backbone' of the scenario development. But some scenarios developers argue that these two driving forces do not "exist" a priori but are the outcome of social processes: "Driving forces should not only be considered uncertain but also debated with practitioners" (van't Klooster & van Asselt, 2006). This lead to two over applications of the scenario axes technique: the scenario axes as 'building scaffold' and the scenario axes as 'foundation' (van't Klooster & van Asselt, 2006). In the building scaffold perspective, the scenario axes technique is used to make sure that the scenarios diverge sufficiently. Once divergence is established, the axes are to be abandoned. In the foundation perspective, the axes are chosen from a number of candidate driving forces. The choice for the scenario axes is considered both a social outcome of a systematic process of weighing different arguments for and against candidate driving forces. So, social and methodological arguments are used to legitimise the use of the scenario axes. Since the proponents of the foundation perspective do not consider the driving forces as given, but as a deliberative choice, this perspective gives more room for a flexible interpretation of the axes.

One variant of scenario planning which seems to be of interest is the Scenario Network Mapping (SNM) elaborated by Dennis List (List, 2005), which has similarities with another variant called Causal Layered Analysis (CLA) (Inayatullah, 2005) not developed in this paper. The SNM technique differs from 'conventional' scenario planning mainly on three aspects: first the focus is more on the links between the various scenarios than on the scenarios themselves. Second, the SNM maps are produced in workshops with a wide range of stakeholders participating. Third, the SNM usually produces 30 or 40 minimal scenarios (List, 2005).

Methodologies for strategic scenarios building

Strategic scenario method are typically used for testing different scenarios and studying their impact on some target variables. The method followed has some similarities with what-if scenarios building (cf. § 0): many studies integrate quantitative data and use computer techniques. The main difference with predictive studies is that the horizon is often long-term.
Most often, programming models and simulation models are used for testing strategic scenarios. Examples are the SOLUS model (Sustainable Options for Land Use) -an optimising linear programming framework designed to conduct cost-benefit analyses of varying configurations of biophysical, socioeconomic and policy factors at the regional scale over relatively long time scales of twenty to thirty years- (Bouman *et al.*, 1999), the economic environmental model WorldScan (De Jong & Zalm, 1991), and the TARGETS (Tool to Assess Regional and Global Environmental and Health Targets for Sustainability) model (Rotmans & de Vries, 1997). In the field of land-use changes, a frequently used procedure is interactive multiple goal linear programming to generate optimal land use options under different set of objectives and constraints (Van Ittersum *et al.*, 1998). Nevertheless, if linear programming models are the most commonly encountered in the literature, this established and tested modelling technique is increasingly joined by methods such as cellular automata or agent-based models (Manson, 2002). The use of multi-agent systems allow capturing more fully the spatial and temporal interactions, and proves to be well suited when heterogeneity and interactions of agents and environments are significant (Etienne & Le Page, 2002; Bousquet & Le Page, 2004). See for example the agent-based bio-economic model developed by Berger and al. (2006) for assessing the impacts of technology adoption and policy intervention in Chile (Berger *et al.*, 2006).

Related techniques

The main techniques used in the development of explorative scenarios studies are reported in Table 3. Detail about the techniques is provided in the Appendix.

Explorative scenarios	Techniques			application fields
	Generating	Integrating	consistency	
external	•surveys •workshops •Delphi modified	explanatory modelling and / or optimising modelling	•morphological field analysis •cross impact	•policy planning •local development •regional planning
strategic	•surveys •workshops •Delphi method	•explanatory modelling •optimising modelling •dynamic simulation modelling •agent-based modelling •hybrid/integrated modelling	morphological field analysis	•strategic planning

Table 3: Main techniques used in future studies based on external or strategic scenarios

Illustration of main methods

Methodologies for external scenarios building

Scenario analysis for planning
The methodological steps reported in Box 2 are taken from a general stepped approach to scenario planning suggested by the Center for Innovative Leadership (Chermack & van der Merwe, 2003). There are multiple other specific approaches to scenario planning, but the one presented here is chosen because of its ability to synthesize many of the available methods into a clear and coherent set of general steps (Chermack *et al.*, 2006b).

Box 2: General steps to scenario planning method (Chermack *et al.*, 2006a)

1. Identify a strategic organizational agenda, including assumptions and concerns about strategic thinking and vision,
2. Challenge existing assumptions of organizational decision makers by questioning current mental models about the external environment,
3. Systematically examine the organizations external environment to improve understanding of the structure of key forces driving change,
4. Synthesize information about possible future events into three or four alternative plots or story-lines about possible futures,
5. Develop narratives about the story lines to make the stories relevant and compelling to decision makers, and
6. Use stories to help decision makers “re-view” their strategic thinking.

Definition of story-line (Rotmans and al. 2000)
This approach currently involves a combination of knowledge and expertise provided by various experts in the form of lectures, and “free-format” creative thinking by selected stakeholders. This leads to a multitude of ideas, which are then structured by clustering and prioritising them, ultimately leading to so-called storylines. Storylines are sequences of events, linked in a logical and consistent manner. These storylines provide rather unconventional future pathways, which go far beyond the business-as-usual perception. The storylines produced by the stakeholders are first aggregated into a limited set of common storylines, and then fleshed out and enriched using background research material.

Scenario analysis for raising awareness and empowering stakeholders

The scenario analysis method differs from the 'classical' one (and presented above) by completely involving the users into the process of alternative scenarios building. They include a relatively standard succession of steps in spite of variations in contents according to the given resources, incentives and organizational capacities inside the project. The explorative scenarios building process we present here (**Box 3**) was suggested by Wollenberg and al. (2000), in the context of community-based forest management in the tropics.

Box 3: Suggested steps for building explorative scenarios in the context of local development (Wollenberg *et al.*, 2000)

1. Ask participants to brainstorm about several **possible uncertainties**
2. Ask participants which **dimensions and ranges of importance and uncertainty** they most want to explore in more detail through scenarios.
3. For each key uncertainty, it may be desirable to specify a **further set of scenarios** showing a range of possible values, based on assumptions or principles, and lighting the potential risks.
4. To **stimulate creativity** and overcome biases in choosing scenario, it might be suitable to use extreme outcomes (not just predictable ones), to first focus on divergent themes (instead of ones that reflect a gradient such as high, medium and low values) even including undesirable ones, to create disruptions to historical trends, and to construct the scenario backward from imagined futures in order not to fall in extrapolation of current trends.
5. Choose a number of **initial scenarios to generate** that correspond each of them to one theme.
6. Form small groups and assign each group a scenario theme.
7. Ask participants in each group to select a **target time** in the future for which they expect the uncertainty to play out and have an impact.
8. Ask each group to draw a picture of (or otherwise express) the present and future condition related to their scenario theme.
9. Ask participants to describe the resources, actors, institutions, events and relations among them in each picture.
10. Have participants **tell a story** to explain what happened (or happens) to make the transition from present to future pictures. To make out of this story a storyline, it is necessary, during the telling of the story, to assist participants and work with them to identify **predictable trends** affecting these elements, **uncertainties**, and potential major **drivers of change**.
11. Work with participants to develop a way of expressing their story and highlighting

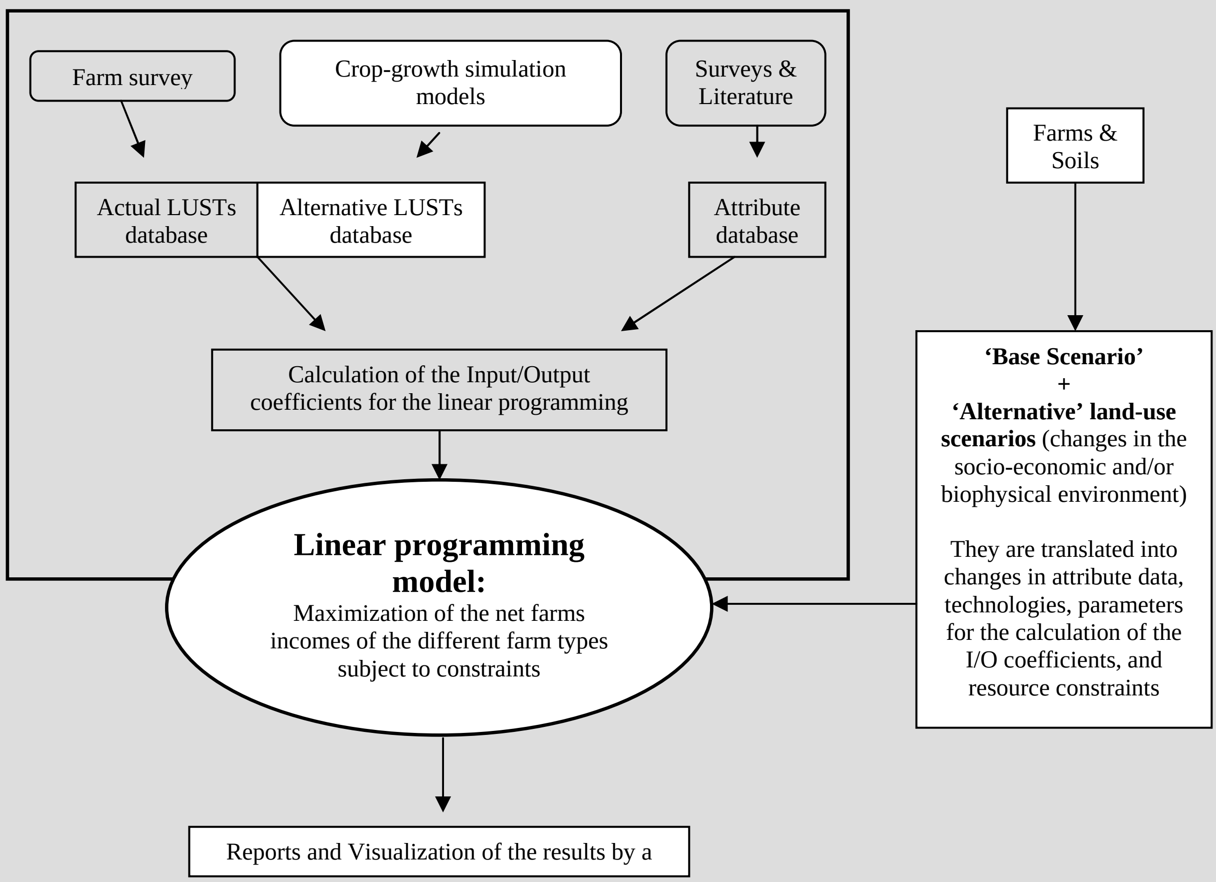
Methodologies for strategic scenarios building

Computer based method of strategic scenarios studies

In most case studies, the analysis of scenarios is done with an optimization model which is often a linear programming model. The model structure reported in Box 4 is taken from the USTED method (Uso Sostenible de Tierras en El Desarollo; Sustainable Land Use in Development). This method has been developed for the Neguev settlement in the perhumid lowlands in the north-east of Costa Rica (Stoorvogel, 1995).

It begins by the building of the linear programming model which is not of concerns in this paper. Ultimately, land-use scenarios are aimed at the evaluation of agricultural policies and economic incentives for a more sustainable agricultural production. The author defines a land-use scenario as a set of hypothesized changes in the socio-economic and/or bio-physical environment (Stoorvogel, 1995).

Box 4: The USTED method for conducting a strategic scenario study (Stoorvogel, 1995)



Like in predictive studies, one methodological trend in scenario method applying computer techniques is to represent the system by mean of a combination of several modules in order to better integrate interactions and complexity, see for example (Lu *et al.*, 2004).

Method of strategic scenarios studies, without computer technique

If the use of a computer technique is the most encountered case study among strategic scenarios studies, few of them do not utilize quantitative techniques, e.g. (Penning de Vries *et al.*, 1995) that investigated possibilities for world food production and food security. The methodological steps reported in Box 5 are taken from the operational framework for sustainable agricultural development at the local or regional level developed by Lancker and Nijkamp (1999) and illustrated by means of an extensive case study on the Bagmati region in Nepal (Lancker & Nijkamp, 1999). In this case study, several agricultural policy scenarios are described and analysed with a view to the identification of a development option for the area concerned that is fulfilling the sustainability conditions to a maximum extent.

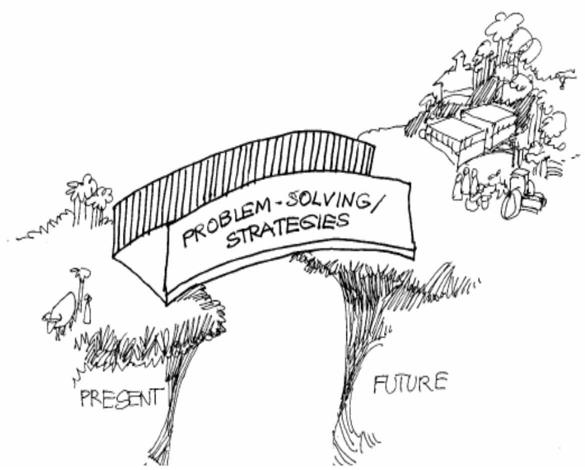
Box 5: Suggested steps for building strategic scenarios (Lancker & Nijkamp, 1999)

1. A target variable is defined (e.g. sustainable agricultural development)
2. Some relevant indicators are chosen depending on the target variable and the related issues at stake in the studied system. They can be biophysical, social or economic indicators. It is often done towards a panel of experts.
3. A ‘critical’ threshold value (CTV) for each indicator is established. This is often done towards a panel of experts. To take into account uncertainty, experts are often asked to provide a band width for the corresponding value of the CTV, defined as a minimum CTV and a maximum CTV.
4. Some policy scenarios are formulated. The range of possible policies which affect the targeted variable is often sizeable that’s why only a few divergent policies are often chosen. Some previous studies can be helpful to choose the policy scenarios to analyse.
5. A quantitative impact analysis is then made for each policy scenario towards the chosen indicators and their related CTV.

Visionary scenario studies

Concept

This approach to futures studies involves the development of normative scenarios (also known as anticipatory or prescriptive scenarios) aimed at exploring the feasibility and implications of achieving given desired end-points or set of goals. This approach intends to respond to the question “What do you have to do to reach a defined aim?” (Robinson, 2003). The visionary mode of thinking can be illustrated by a Cheshire Cat sentence in Alice in Wonderland “If you don’t know where you want to go, it doesn’t matter which road you take”. Desirable (sustainable) future images (or visions) are designed, followed by looking back at how this desirable future could be achieved, before defining and planning follow-up activities an developing strategies leading towards that desirable future (Henrichs, 2003; Schroth & Wissen, 2004; Quist & Vergragt, 2006).



Source: (Wollenberg *et al.*, 2000)

Due to its normative and problem-solving character, the visionary mode of thinking is better suited for long-term problems and long-term solutions (Quist & Vergragt, 2006), in case of complex problems and in case of a need for major change (Dreborg, 2004). Two types of normative scenario can be distinguished (cf. 0). The **preserving scenarios** respond to the question ‘How can the target be reached, by adjustments to current situation?’, and the **transforming scenarios** which respond to the question ‘How can the target be reached, when the prevailing structure blocks necessary changes?’. The second type of normative scenarios is strongly linked with the backcasting approach (Dreborg, 1996; Robinson, 2003).

General description and application fields

The process design of visionary scenarios studies leans on qualitative knowledge and insights (such as human values, perceptions, emotions, and behaviour), and/or quantitative data. The use of quantitative and/or qualitative data mainly depends on how the system structure is addressed. In one hand, only adjustments to the current system can be needed to reach the targeted goals. In this case, a model of the system structure can be built using quantitative data in order to reach the optimized path (in term of satisfaction and not in the mathematical sense) to the desired future (Börjeson *et al.*, 2006). This approach refers to the preserving scenarios. In another hand, the system structure can be not suitable to reach the targeted goals. A break trend is then needed and the idea of modelling the structure (at least in the traditional sense of modelling) is often rejected. In such case, mainly qualitative knowledge and data are used and quantitative elements can be added (Börjeson *et al.*, 2006). This approach refers to the transforming scenarios. The data, knowledge and insights incorporated in the scenario are often collected through a desk research approach even if since the early 1990s occurred a shift to participatory backcasting using broad stakeholder involvement evolving towards what Robinson calls the second generation of backcasting (Robinson, 2003). The visionary mode of thinking typically leads to the development of alternative scenarios by describing futures that differ significantly from one another.

The first kind of normative scenario studies –the preserving scenarios studies- are mainly applied for regional planning. We have not found many examples of case studies in the literature.

The second kind of normative scenario studies –the transforming scenarios studies- is by far the most encountered in the literature and is often likened to backcasting approach. The origin of backcasting is in the 1970s and has been proposed as an alternative planning technique for electricity supply and demand (Robinson, 1982; Quist & Vergragt, 2006). See for instance a swedish energy futures study that outlined a nuclear and a solar energy system as a basis for an analysis of technical, economic, and institutional issues (Lonnroth *et al.*, 1980). Since the late 1980s, backcasting approach has then moved towards sustainability applications (Robinson, 1990) at different levels like regions or companies. See for instance, the OECD Environmentally Sustainable Transport (EST) project ran towards two phases (Organisation for Economic Co-operation and Development, 1999). First, the participants of the project elaborated environmentally sustainable transport scenarios for the year 2030 that reached predefined criteria of sustainability. Then, they undertook a backcasting exercise where participants worked back from the scenarios in order to determine what type of measures will be needed in order to achieve environmentally sustainable transport in their region and or country. Another example of sustainability application of backcasting is Bending the Curve project (Raskin *et al.*, 1998). It has been carried out by the Global Scenario Group and looks at what it would take to steer human development onto a more sustainable pathway during the 21st century. The project started by using an explorative scenario previously built within an earlier project: ‘Conventional Worlds’. From this base, a backcasting method has been applied to examine the possibilities for sustainable development by pushing for important changes in policies within an evolutionary Conventional Worlds context.

Such a normative approach has the additional advantage that it introduces the question of policy choice into the analysis, and is thus less able to be used to provide an apparently neutral cloak of scientific objectivity to justify decisions taken for other reasons (Robinson, 2003).

Nowadays, applications of the backcasting approach are extended further, including the role of backcasting approach in a learning process about the future, in the issue of broadening the process to a larger group of potential users and how to alter the hegemony of existing dominant perspectives (Quist & Vergragt, 2006). Elsewhere, the use of backcasting is not only about how desirable futures can be attained, but also about analysing the degree to which undesirable futures can be avoided or responded to (Robinson, 1990).

Methodologies

Normative preserving scenarios

The building of preserving scenarios can be done either in a qualitative way or with some kind of optimising modelling (Börjeson *et al.*, 2006). When it is done in a qualitative way, a group of targets concerning environmental, social, economic and/or cultural factors are chosen, and then planners or experts make judgements on which is the most efficient path (in a 'satisfying' sense) to reach a specific target or several targets. This method is called backcasting Delphi method. We have not found case studies using computer techniques to build preserving scenarios.

Normative transforming scenarios

The backcasting approaches for normative transforming scenarios, found in the literature, show differences in number of steps. We summarize them into a methodological framework consisting of three main steps (Dreborg, 1996; Höjer & Mattsson, 2000; Robinson, 2003; Dreborg, 2004):

1. The first step consists in designing future goals and objectives, also called targets. For instance, in the Dutch COOL project, the goal was a reduction of greenhouse gas emissions by 50-80 % by 2050 as compared to the levels of 1990 (Hisschemöller & Mol, 2002),
2. the next phase of the method requires the generation of scenarios that define the technological, social, political, and economic pathways that would lead to the specified goals,
3. finally, the potential pathways from the end-point design back to the present are assessed in terms of feasibility (analysis of the drives that may influence their realisation) and implications in various respects (e.g. policy implications). Different kind of mathematical modelling can be important tools in the third step.

A key goal of the second step of the method is to articulate scenarios of the future that are different from conventional views of what is likely to happen. This suggests that it is important that some thought be given as to how alternative values and preferences get incorporated into the analysis. In most cases, the source of normative content of the backcasting exercise is external to the analysis itself (Robinson, 2003; Carlsson-Kanyama *et al.*, 2003). The research team articulates the criteria for choosing, and evaluating, alternative desired future configurations (the scenarios back-office). It may come from a formal study of what stakeholders consider desirable or simply from the values of the analysts themselves. This method refers to think-tank model (Börjeson *et al.*, 2006) and has been the method chosen in most 'soft energy path' and 'sustainable society' backcasting studies (Robinson, 2003; Börjeson *et al.*, 2006). This method has been used in cases where the purpose of the study was to show implications of achieving one or more normatively defined end-points, with the goal of making that information available, via publication of the results, to others (decision makers, general public) who can make up their own mind what they think about the findings (Robinson, 2003).

In the early 1990s occurred a shift to participatory backcasting (Robinson, 2003; Quist & Vergragt, 2006), by involving experts groups, e.g. (Green & Vergragt, 2002), or grass-root movements and ordinary citizens, e.g. (Carlsson-Kanyama *et al.*, 2003), directly in the process of defining and evaluating the desirability of the scenarios that are developed. These backcasting studies are called by Robinson (2003) 'second generation backcasting'.
But the review of current practice with backcasting shows that local stakeholders have not been included so far (Carlsson-Kanyama *et al.*, 2003). Moreover, when it is done, the involvement of stakeholders is limited: the team of researchers support the image formulation process by calculating or otherwise analysing the environmental consequences of the solutions proposed by stakeholders within meetings or workshops. Another method, using a participatory modelling framework, seems to be better suited for an active involvement of stakeholders (Robinson, 2003). A model can be used for exploration of desirable futures (step 2) by simulating alternative scenarios such that the users can iterate through the scenario generation process until they reach a future scenario with which they are happy (Robinson, 2003). This imposes specific requirements on the design and implementation of the modelling framework. In particular, it is important that the models do not themselves optimize or solve for least cost or equilibrium solutions. They need to be able to show the implications of different user choices but not choose the most likely or optimal (e.g. least cost) solution. This has led to the development of what has been called the "design approach" to modelling (Gault *et al.*, 1987), which involves building bottom-up models which, to a large degree, exogenise key behavioural relationships so that they are not hard-wired into the model and alternative forms of those relationships can be specified by the user. Moreover, to be used by non-scientists considerable time has to be spent in designing the interface of backcasting models (Robinson, 2003). See for instance the GB-QUEST modelling tool (Robinson, 2003). The central goal of the Georgia Basin Future Project was to engage residents of the Georgia Basin region in Western Canada in thinking through the implications of trying to achieve a desirable future. The QUEST model that combines the characteristics of a computer game (fun to use) and of an academic modelling system (true to life), has been used.

Related techniques

The main techniques used in the development of visionary scenarios studies are reported in Table 4. Detail about the techniques is provided in the Appendix.

Normative scenarios	Techniques			application fields
	Generating	integrating	consistency	
Preserving	•surveys •workshops	optimising modelling	morphological field analysis	regional planning
transforming	•surveys •workshops •backcasting Delphi		morphological field analysis	•local development •long-range planning

Table 4: Main techniques used in future studies based on preserving or transforming scenarios

Illustration of main methods

In this section, we concentrate on participatory backcasting method. We illustrate the method towards an example of local development and social learning that could be suitable and useful for studies focusing on interactions between agricultural activities and landscape dynamics.

Participatory backcasting method

The methodological steps reported in Box 6 are taken from Wollenberg and al. (2000) and have been suggested for local development in the context of community-based forest management in the tropics (Wollenberg *et al.*, 2000).

Box 6: Suggested steps for participatory backcasting exercise in the context of community-based forest management (Wollenberg *et al.*, 2000)

1. Ask participants to produce a vision of what they would like to see changed. The question can be general, or more specific.
2. Give participants a chance to reflect individually in group settings to start the visioning process. Depending on the level of complexity of information desired in the vision or the amount of consultation necessary, this step may take minutes or days. It may be done simply by individuals quietly thinking by themselves, through focus group discussions or through the collection of additional information.
3. Ask the participants to express their scenarios to each other. Simple media like sketches on flipchart paper or dramas can be sufficient. These should be accompanied by explanations by the creators.
4. Facilitate discussion among the participants about the implications of the scenarios presented and related action points.
5. Ask participants to characterize the current resources, actors, institutions, events and relations among them (correspond to their own current image).
6. Ask participants individually or in small groups to contrast what is different about the two images.
7. Work with participants to identify the main constraints and opportunities to achieving their vision, given these starting conditions. What are the existing capacities and weaknesses among actors in achieving their vision? What are the external forces affecting their capacity to achieve their vision?
8. Ask participants to brainstorm about a strategy for achieving their vision given these constraints and opportunities.
9. Invite participants to reflect upon differences in strategies among their groups (see vision and projection scenarios for examples of discussion points) and produce action points.

Evolution trends in scenario studies

Since their first applications, scenario methods evolved to include a variety of objectives and steps. This evolution in scenario studies follows from the search for an improved address of their focal issue using a combination of techniques and concepts, and from an enlargement of their scope and their application fields. The increased recognition of the importance of the relationships between sectors and society and the environment led to invest into system dynamics methodologies (Holling, 1978; Kruseman & Bade, 1998; Lambin & Geist, 2002;

Walker *et al.*, 2002; Carpenter, 2002; Walker *et al.*, 2004; Wittmer *et al.*, 2006), which is stressed towards examples reported within each archetypal approaches in section 2. Additionally, with the recognition of the incompletude of information requested and the important role of decisions of the stakeholders in the dynamics of change, a growing interest was put into participatory approaches (Caswill & Shove, 2000; Toth, 2001; van Asselt & Rijkens-Klomp, 2002; ComMod, 2005; Bousset *et al.*, 2005; Quist & Vergragt, 2006). Thus, Robinson (2003) state that in recent years, the original sharp distinctions made between different scenario approaches, such as descriptive versus normative, bottom-up versus top-down, quantitative versus qualitative, exploration versus goal-oriented, began to blur. As illustrated by the examples reported, current scenario studies increasingly rely upon a sequence of steps in which alternative approaches to scenario development are used, the type of approach depending upon the step considered.

Sustainability and uncertainty challenges emerging from ecological and societal complexities of environmental issues have been the main spur for setting up hybrid scenarios studies combining exploration and goal-oriented support (e.g. Greeuw and al. 2000; Alcamo 2001). In particular, experience gained over the years with global assessment projects in the ecological and environmental realm has shown that prediction over large time periods is difficult if not impossible, given the complexity of the systems examined and the large uncertainties associated with them—particularly for time horizons beyond 10–20 years (Alcamo et al., 2005). The scenario developers currently attempt to deal with both the socio-ecologic and the bio-economic systems into an **integrated and functional system approach**. Therefore, methods that were initially deep-rooted in quantitative and predictive approaches progressively let apart the predictive forecasting approach for a more exploratory one or goal-oriented one based on normative scenarios. Even if the futures were predictable, in the cases of long-term societal problems like sustainability, the most likely future may well not be the most desirable. In such a situation, it is important to explore the desirability and feasibility of alternative futures, not simply focus on likelihood (Robinson, 2003). Furthermore, predictions are contingent on drivers that may be even more difficult to predict, such as human behaviour (Alcamo et al., 2005). Uncertainties that result from unpredictable key drivers, reflexive human actions, the swiftness of system changes, a lack of knowledge about system conditions and underlying dynamics, do not make it impossible to say anything meaningful about future possibilities. However, they do seriously compromise our ability to predict the likelihood of alternative outcomes for complex human systems over the periods extending decades into the future (Walker *et al.*, 2002; Robinson, 2003). Increasingly, scenarios developers that intend to face uncertainties developed new approaches among which (Participatory) Integrated Assessment (PIA) and Adaptive Environmental Assessment and Management (AEAM) approaches. Consequently, scenario methods are adapted to these new frames. Combined approaches intending to better integrate the whole parts of the system under study, to better investigate the different steps of the decision-making process, and to respond to the need of sustainable development, are developed.

For example, the latest IPCC emissions scenarios project applies a mixed highly complex method covering predictive, explorative and normative elements and also quantitative and qualitative approaches (van Notten *et al.*, 2003; Börjeson *et al.*, 2006). Another example is the POSSUM project (Policy Scenarios for Sustainable Mobility in Europe) which combines external scenarios with a backcasting approach in order to formulate sustainable transport goals for the year 2020 and then to explore strategies to reach the goals (Dreborg, 2004).

A major characteristic in recent scenario studies is the increasing use of **participatory methods** to face the challenges raised by sustainable development, complexity of the systems and uncertainty of the future. Participatory methods are used either for the learning and empowering processes of people, or for a decision-making process leading to legitimate, acceptable, robust, adaptive an enriched scenarios. The development of enriched assessments and decision-making by combining scientific, expert and lay-knowledge is inspired by social scientific theories on trans-science, social-constructivism, post-modernism and post-normal science arguing that science is socially constructed and that science should not have the monopoly of knowledge (van Asselt & Rijkens-Klomp, 2002). Both the degree of involvement of participants and the type of method used for participation depend on the goal of participation (van Asselt & Rijkens-Klomp, 2002; Fig. 9).

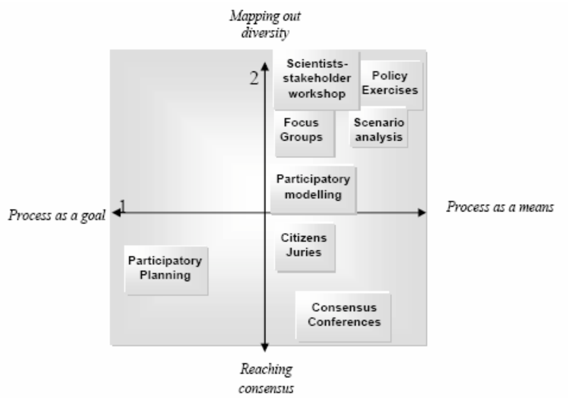


Fig. 9: Typology of goals of participation: (1) aspiration/motivation axis (2) targeted output axis. Source: (van Asselt & Rijkens-Klomp, 2002)

A recent review by Bousset and al. (2005) provides with a comprehensive overview of the array of participatory methods available according to their goal and the degree of involvement of participants (table 5). This review also includes detail descriptions of each of the participatory methods supporting the understanding of their respective interest in scenario studies.

		Degree of involvement of participants	
		Consultation	Involvement
Objectives of the process	Mapping	POLICY EXERCISES (*) SCENARIO WORKSHOPS (*) ENVISIONING WORKSHOP POLICY DELPHI FOCUS GROUPS WORLD CAFÉ *Policy Conference* *Open/Public Meetings* *MYSTERY SHOPPING* *WEB FORUMS*	*USERS PANELS* *USERS FORUMS* *PLANNING FOR REAL* *COMMUNITY PROFILING / APPRAISAL* *COMMUNITY VISIONING* *OPEN SPACE EVENT*
	Convergence	CONSENSUS CONFERENCES (*) CONVENTIONAL DELPHI Expert Panels	PARTICIPATORY MODELLING CHARRETTE *FUTURE SEARCH CONFERENCE* CITIZENS' JURIES (*) PLANNING CELLS
	Democratisation		PARTICIPATORY PLANNING (*) PRA PAM&E (*)

(*) means that method includes high co learning capabilities

Table 5: Participatory methods clustered according both to their goal (mapping diversity, or consensus building) and to the degree of involvement of stakeholders (consultation or involvement) (Bousset *et al.*, 2005).

These evolutions influence the methods used for scenario development in environmental studies. Traditionally, scenario development processes were categorized into those mainly based on stakeholder and expert workshops and the use of qualitative data on the one hand, and into those mainly based on desk research for providing the most likely projection of future conditions on the other hand (van Notten *et al.*, 2003). Creative techniques such as the development of storylines are typical from the first kind of scenario studies. Interactive group sessions with a high variety of people are often central to storyline development. The storyline approach is flexible and can easily be adapted according to the needs that emerge from earlier steps in the scenario development process. The second kind of scenario studies tended to work from quantified scientific knowledge to use computer simulation techniques in its scenario development. Current approaches in environmental studies increasingly benefit the techniques and expertise gained from both kinds in a search for more integrated assessments.

Chapter 3

SCENARIO METHODS IN INTEGRATED ENVIRONMENTAL STUDIES

Integrated Assement in the environmental realm traditionally aims at developing a coherent framework for assessing trade-offs between social, economic, institutional and ecological determinants and impacts (Rotmans & de Vries, 1997). There is no generally agreed definition upon what constitutes integration (Parker *et al.*, 2002). The term ‘integrated’ is often used interchangeably with similar terms in the environmental management literature, such as comprehensive, ecosystem and holistic. Risbey and al. (1996) state that the linking of mathematical representations of different components of natural and social systems in a computer simulation model is one way in which integration is undertaken (In Parker and al. 2002). Rotmans and Van Asselt (1996) provide a more inclusive definition and state that “Integrated Assessment” is an interdisciplinary and participatory process combining, interpreting and communicating knowledge from diverse scientific disciplines to allow a better understanding of complex phenomena” (In Parker and al. 2002). Therefore, especially in the abundant literature related to global and international environmental assessments, two types of IA methods have generally been distinguished: analytical methods and participatory methods (Sharma & Norton, 2005). Analytical methods refer to Integrated Assessment Models (IAM) – also called computer-aided IAMs- used to analyse complex systems. The use of IAMs evolved from the earlier quantitative models that were typically global climate change models which assumed climatic determinism and didn’t incorporate feedbacks (human adaptation) to a contribution into largely integrated climatic impact and policy assessments that explicitly consider changing value systems and explore surprises affecting social systems and values (Sharma & Norton, 2005). In this document, we make use the term Integrated Assessment and Modelling coined by Parker et al. (2002) -and the acronym IAM- for designing later type of approaches.

Scenario methods are increasingly applied in environmental studies within an Integrated Assessment and Modelling (IAM) framework, with the explicit aim to inform decision-makers and to support decision-making process. IAM projects are generally undertaken to address specific sustainability or management issues, in contrasts to previous systems modelling when research was often science driven and focused on providing complex systems descriptions and prescriptions for decision-makers. IAM approaches have been developed at a variety of scales, from the global scale as far as the small region and the landscape scales (Parker *et al.*, 2002).

Integrated Assessment and Modelling (IAM)

General description

The need for IAM has heightened as the extent and severity of environmental problems in the 21st Century worsens, while the modelling of environmental processes has been undertaken for decades (Parker *et al.*, 2002). A major factor in the adoption of IAM is the increasing awareness of the need to account for the adaptive capacity of behaviour of the agents of both the natural world and the society, e.g. (Harris, 2002). The objective is to consider emergence properties of the complex adaptive systems they form together (Holling *et al.*, 1998). Risbey and al. (1996) argue that IAM is more than just a model exercise: it is also a “methodology that can be used for gaining insights over an array of environmental problems spanning a wide variety of spatial and temporal scales” (In Parker and al. 2002). Actually, five different types of integration can be identified within IAM (**Erreur ! Source du renvoi introuvable.**):

- Issues: IAM seeks to avoid the fragmented approach traditionally adopted by science and recognises links between environmental issues and the need to include such interactions as part of the study,
- Disciplines: the integration of different disciplines is required to gain insights into complex processes,
- Stakeholders: the aim is to engage the “users” of the research actively in the research process itself, not just as subjects of analysis or consumers of the final products of the research process (Caswill & Shove, 2000),
- Scales: scale issues arise in all stages of the scenario development process, including the definition of the addresses of the scenarios, the scenario building, the quantification of the driving forces and the impact of modelling. They encompass spatial, temporal and societal scales (Briassoulis, 2000; Döll *et al.*, 2002),
- Models: decision-support requires application development where the general scientific model is embedded in a ‘user friendly’ application to meet the needs of decision-makers.

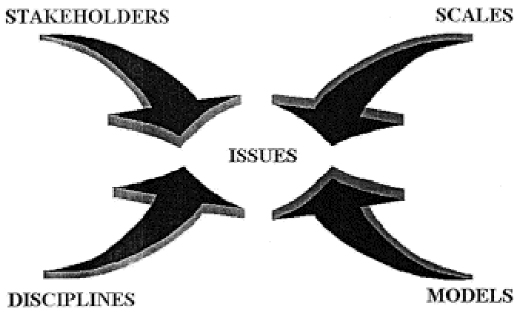


Fig. 10: Types of integration to address environmental issues (Parker *et al.*, 2002)

The ideal of IAM is when it contains all five elements of integration. However, in practice one or more of these elements of integration may be ignored. Among these elements, the scale integration remains one of the main methodological problems in IAM (Parker *et al.*, 2002).

IAM is currently a problem-focused research area: the goal of IAM is to assemble the constituent, disciplinary parts of the overall model according to what is thought to be appropriate to the problem at hand, along the lines of what has been called ‘demand-side’ modelling (Parker *et al.*, 2002; Quist & Vergragt, 2006) or demand/supply mechanism (Greeuw *et al.*, 2000). The model is adapted along the process of integrated assessment, as a vehicle of problem exploration, for instance, or as a device for communicating the relevant science to a lay audience. The resulting complexity is a blend of the complexity of the constituent disciplines and the exigencies of the stakeholders’ hopes and fears for the future (Parker *et al.*, 2002).

Conceptual framework to IAM

Integration is needed because multiple anthropogenic factors have an impact on the environment or lead to changes in the provision of ecological services for society (Raskin *et al.*, 2005). Sustainability implies maintening the capacity of ecological systems to support social and economical systems. Sustaining this capacity requires analysis and understanding of feedbacks and more generally the dynamics of the interrelations between ecological and social systems (Berkes *et al.*, 2003). To capture this nexus of interactions, a systemic framework is required that includes key economic, social, and environmental subsystems and links. Environmental issues are increasingly considered in the framework of integrated systems of human and nature considered as are social–ecological systems (SES) (Berkes & Folke, 1998; Walker *et al.*, 2002) (Fig. 11). Building resilience in integrated human and nature systems or social–ecological systems (SES) is key for sustainability. Sustainability is to be considered as a process, rather than an end-product, a dynamic process that requires adaptive capacities for societies to deal with change (Berkes *et al.*, 2003). Resilience theory offers a vision of sustainability, not as stability, but as persistence borne out of change out of adaptive renewal cycles (Gunderson & Holling, 2002). Resilience is related to the magnitude of shock that a system can absorb and still remain within a given state, the self-organization capability of that system, and its capacity for learning and experimentation. The notion applies as well to ecological systems as to social systems and their relationships within socioecological systems. The direct drivers (or stressors) of environmental change include pollution, climate change, hydrological change, resource extraction, and land degradation and conversion. In turn, these direct drivers result from long causal chains of indirect socioeconomic drivers, such as demographic, economic, and technological developments. Finally, changing patterns of human values, culture, interest, and power set the conditioning framework (or ultimate drivers) for unfolding social and ecological systems.

A major challenge in this context is to build knowledge, incentives, and learning capabilities into institutions and organizations for governance that allows for the adaptive management of local, regional, and global ecosystems and to incorporate actors in new and imaginative roles (Folke *et al.*, 2005).

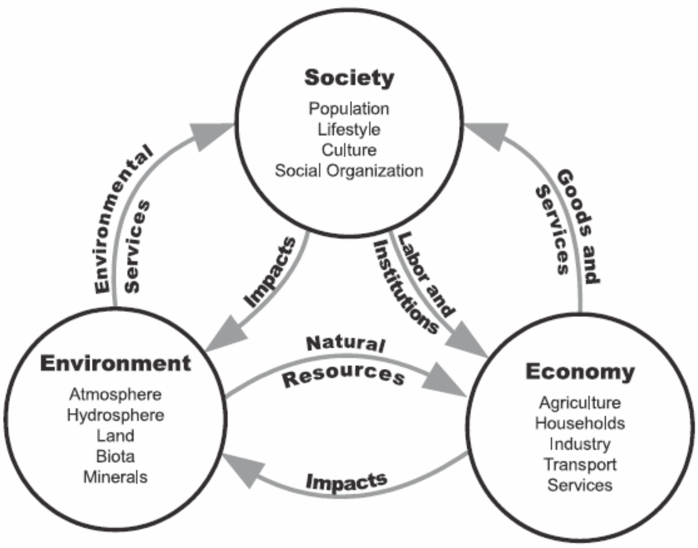


Fig. 11: The socioecological System and Its Components (Raskin *et al.*, 2005)

The modelling component of an integrated scenario study

A common method adopted in IAM is to use integrated models incorporating human components that facilitate scenario generation and decision support function and moreover, to make an integration of models or linking of discrete modules (Parker *et al.*, 2002). The integration of these various models is done in a transparent and interactive framework that allows for the participation of the stakeholders in all the stages of the process. This framework offers a means to integrate the individual models of stakeholders at a variety of scales and it organizes the stakeholders' community by helping them to communicate understanding, values, and concerns. Thus, IAM process may include (Parker *et al.*, 2002):

- Data models that are representations of measurements and experiments;
- Qualitative, conceptual models as verbal or visual descriptions of systems and processes involved;
- Quantitative numeric models that are formalizations of the qualitative models;
- Mathematical methods and models used to analyze the numeric models and to interpret the results;
- Decision-making models that transform the values and knowledge into actions.

The trend in IAM is to combine wide conceptual frameworks and computer based simulation models (Rotmans and Van Asselt, 1996 In Parker and al., 2002).

Scenarios studies in global IAM approaches

In literature on international environmental studies, the term of Integrated Assessment (IA) broadly refers to the study of complex global change, which includes several interconnected physical, biological, economic and social systems (Sharma & Norton, 2005). Integrated approaches appears to be necessary for facing complex dynamics of strongly interacting short-term and long-term processes on various scale levels (Greeuw *et al.*, 2000). Integrating assessment arguably began in the 70s with the publication of "the limits to growth" report by Meadows and al. (1972) which concluded that the limits to growth on earth would be reached within a century if the trends on world population, industrialization, pollution, food production, and resource depletion continued unchanged (Sharma & Norton, 2005). A variety of methods which correspond to various steps in the integration process have been developed since there to integrate climate and economy, greater level of model detail, a larger subset of regions, explicit inclusion of stochastic variability and uncertainty, and consideration of human adaptation. It is commonly considered that we are entering the area of the "fifth generation" of integrated assessment models (Sharma & Norton, 2005). Fifth-generation assessments are largely integrated climatic impact and policy assessments that explicitly consider changing value systems and explore surprises affecting social systems and values. Therefore participatory methods are currently used in IA research using three types of approaches (Rotmans and Dowlatabadi 1998, In Tansey and al., 2002):

1. Simulation gaming, which involves the 'representation of a complex system by a simpler one with relevant behavioural similarity';
2. Qualitative IA, which eschews the use of formal models and strongly resembles expert systems, applied to the task on future-oriented assessment;
3. Scenarios, which are used as tools for identifying and exploring a range of possible futures, in order to assess their desirability or feasibility, or, particularly when applied

in the business context to identify possible adaptive strategies. The current scenario methodologies applied for Integrated Assessment are qualitative scenario analysis and backcasting (cf. Section 2).

A number of recent studies have sought to combine these methods (Tansey *et al.*, 2002). The objective is to build scenarios that (Greeuw *et al.*, 2000):

- describe dynamic patterns of changes,
- include a variety of perspectives,
- include both social, economic, environmental and institutional indicators,
- are consistent among different sectors, problems and scales,
- are coherent in the sense that all relevant dimensions are addressed and that all relevant interactions between the various processes are considered,
- are transparent with regard to assumptions and choices,
- are challenging, with a strong narrative as well as quantitative component,
- are developed in an iterative way involving a balanced and heterogeneous group of people.

The modelling system used has to be capable of simulating alternative scenarios such that the user can iterate through the scenario generation process until they reach a future scenario with which they are happy (Robinson, 2003). The model must not itself optimize or solve for least cost or equilibrium solutions. It needs to be able to show the implications of different user choices but not choose the most likely or optimal solution: "design approach" to modelling (Gault *et al.*, 1987). Moreover, it has to combine the characteristics of a computer game (“fun to use”) and of an academic modelling system (“true to life”) (Robinson, 2003). One approach to do so is the ‘interface-driven modelling approach”, that has been applied for instance for the building of the GB-QUEST modelling tool in the Georgia Basin Futures Project (Robinson, 2003).

Difficult methodological challenges in global and international assessments follow from the integration of different scales in space and time. Multi-scale approaches, encapsulating regional and local IAM are regarded as necessary for an improved tackling of the adaptive systems in which the natural world and humans change their behaviour as the problems emerge and grow (Harris, 2002; Alcamo *et al.*, 2005).

About temporal scale, the integration of disjunct processes, with periods of rapid change, and unforeseeable changes, instead of integrating continuous processes is a major issue (Lambin & Geist, 2002). Another major problem of time scales in scenario development is the modelling and assessment of human behaviours facing natural dynamics that are based on different temporal scales. For example, forest dynamics simulations have to be done with long-time horizon whereas sheep farmers land management is done at a short-time horizon (Etienne & Le Page, 2002).

The current frameworks and trends in IAM at an international level are illustrated below from the Millenium Assessment project.

Example of scenario studies using IAM at the global scale: the Millennium Ecosystem Assessment (Alcamo *et al.*, 2005)

The goal of the Millennium Ecosystem Assessment is to provide decision-makers and stakeholders with scientific information on the links between ecosystem change and human well-being. The MA focuses on ecosystem services (such as food, water, and biodiversity) and on the consequences of changes in ecosystems for human well-being and for other life on Earth. Scenario analysis is used as a tool to address the uncertainty of the future, providing concrete information about plausible development paths of ecosystem services and their relation to human well-being. Scenarios were developed to explore alternative future on the basis of coherent and internally consistent set of assumptions. The Millennium Ecosystem Assessment scenarios break new ground in global environmental scenarios by explicitly incorporating both ecosystem dynamics and feedbacks between social and ecological systems. Another novelty is that they consider the connection between global and local socioecological processes.

The approach to scenario development combined qualitative storyline development and quantitative modelling. The procedure consists of 14 steps organized into three phases (Box 7). In the first phase, the scenario exercise was organized and the main questions and focus of the alternative scenarios were identified. In the second phase, the storylines were written and the scenarios were quantified using an iterative procedure. During the third phase, the results of the scenario analysis were synthesized, and scenarios and their outcomes were reviewed by the stakeholders of the MA, revised, and disseminated.

Box 7: MA Procedure for Developing Scenarios (Alcamo *et al.*, 2005)

Phase I: Organizational steps

1. Establish a scenario guidance team
2. Establish a scenario panel
3. Conduct interviews with scenario end users
4. Determine the objectives and focus of the scenarios
5. Devise the focal questions of the scenarios

Phase II: Scenario storyline development and quantification

6. Construct a zero-order draft of scenario storylines
7. Organize modelling analyses and begin quantification
8. Revise zero-order storylines and construct first-order storylines
9. Quantify scenario elements
10. Revise storylines based on results of quantifications
11. Revise model inputs for drivers and re-run the models

Phase III: Synthesis, review, and dissemination

12. Distribute draft scenarios for general review
13. Develop final version of the scenarios by incorporating user feedback
14. Publish and disseminate the scenarios

The first phase in the MA scenario development consisted of establishing a scenario guidance team to lead and coordinate the scenario-building process. In addition, a larger panel, composed mainly of scientific experts, was assembled to build the scenarios. The scenario guidance team conducted a series of interviews with potential users of the scenarios to obtain their input for developing the goals and focus of the scenarios. These interviews ensured input from stakeholders and users early on in the study. Understanding the needs and desires of users and their outlook on future development helped the team to devise the main focal questions of the scenarios. Based on the results of the user interviews and discussions with the scenario panel, the objectives, focus, leading themes, and hypotheses of the scenarios were derived by the scenario guidance team and panel. The key focal question was defined through a series of more specific questions, that is what are the consequences for ecosystems and human well-being of strategies that emphasise:

- economic and human development (e.g. poverty alleviation, market liberalisation) as the primary means of management
- local and regional safety and protection
- development and use of technologies allowing greater eco-efficiency and adaptive control
- adaptive management and social learning about the consequences of management interventions for ecosystem services?

The scenario storyline development and quantification phase (phase II) started with a review of current and past scenario efforts, scenario building blocks for driving forces, ecological management dilemmas, branch points, etc. While the initial storylines were being developed, a team of modellers was organised to quantify scenario using a set of pre-existing global models. Linkages among models and projections out to 2050 did require adjustments for several of them. Test calculations were carried out using preliminary driving force assumptions. These test calculations were helpful in identifying the potential contribution of different models to the analysis and in clarifying the procedures of linking the different models.
After a series of iterations, the zero-order storylines were revised and cross-checked for internal consistency. One measure used to accomplish this was the development of timelines and milestones for the various scenarios. In the next step, the modeling team, in consultation with the storyline team, developed quantitative driving forces that were considered to be consistent with the storylines.
Based on the model outcomes of the quantitative scenarios, the scenario team further elaborated or adapted the storylines. A number of feedback workshops with the MA Board and stakeholder groups were held to improve the focus and details of the storylines. Based on the results of the first round of quantified scenarios, small adjustments in the specification of drivers and linkages among models were made, new model calculations were carried out with the modeling framework, and the storylines were revised (in other words, there was one iteration between storyline development and quantification). At as ending result of this phase, scenarios were partly quantified using linked global models that allow ensuring integration across future changes in ecosystem services.

A multi-scale approach
Developing both global and local scenarios simultaneously within a single approach first aimed at producing a higher level of consistency and integration than if they were independently developed. The objective was also to be able to compare local adaptive management strategies with regional and local explorations of future change in ecosystems and human well-being. Therefore, the address of the multi-scale aspects of the relationships between ecosystem

services and human well-being involved a large number of sub-global assessments in addition to the global assessments. Several of the sub-global assessments also developed scenarios. Some of them are also multi-scalar and contain nested assessments (Fig. 12).

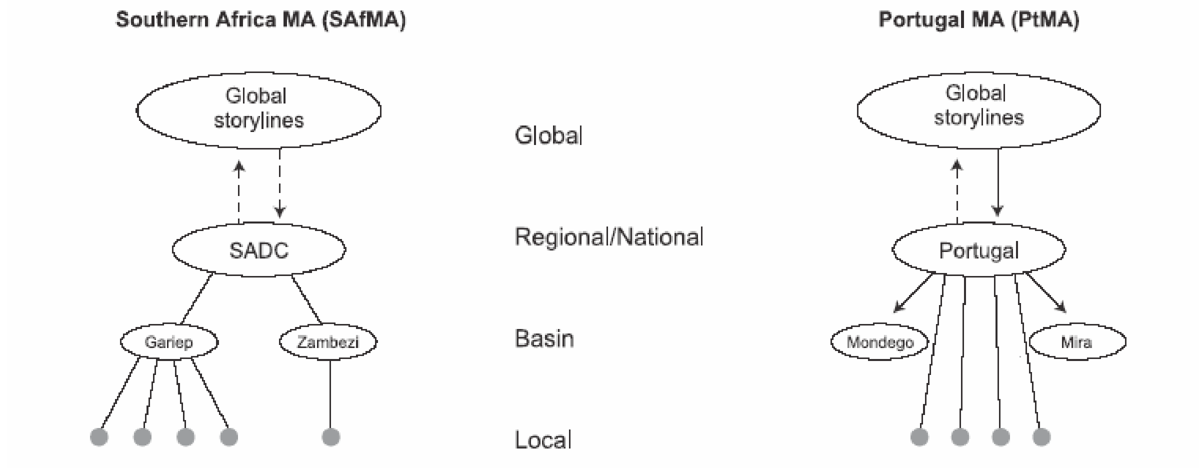


Fig. 12: Multiscale Design of the Sub-global Assessments in Southern Africa and Portugal (Alcamo *et al.*, 2005)

Local assessments could not be directly linked to global assessments. To harmonize the global and sub-global scenario exercises, the following steps were taken:

- Representatives of sub-global assessments participated in the global scenario team and contributed to the scenario development.
- Members of the global scenario guidance team participated in meetings of the sub-global scenario assessments, explaining both the preliminary global scenario results and the procedure followed in developing the global scenarios.
- Sub-global assessments linked their scenarios to the global assessment, e.g. using the storylines of the global assessment as background for their work.
- After the storylines and the model runs of the global scenarios were finalized, results and findings of the sub-global assessment were used to illustrate how the scenarios could play out at the local scale.

Combination of qualitative and quantitative methods in the scenario development
The storyline-writing and modelling exercise complemented each other as part of an overall method.
The qualitative storylines were developed through a series of discussions among the scenario development panel alterning with feedbacks from MA users groups and outside experts. The process included several steps within other the harmonisation of the storylines with modelling results. It cycled through some of the steps many times until a consensus was reached on the storylines.
The purpose of the modelling exercise was both to test the consistency of the storylines and to illustrate the scenarios in numerical form.
The "quantification of the scenarios" had five main steps:

- Assembling several global models to assess possible future changes in the world's ecosystems and their services.
- Specifying a consistent set of model inputs based on the scenario storylines.
- Running the models with the specified model inputs.

- Soft-linking the models by using the output from one model as input to another.
- Compiling and analyzing model outputs about changes in future ecosystem services and implications for human well-being. The models were used to analyze the future state of indicators for ‘‘provisioning,’’ ‘‘regulating,’’ and ‘‘supporting’’ ecosystem services.

The storylines were translated into a set of model assumptions that correspond to the “indirect drivers” of ecosystem services. These included:

- population development, including total population and age distribution in different regions;
- economic development as represented by assumed growth in per capita GDP per region and changes in economic structure;
- technology development, covering many model inputs such as the rate of improvement in the efficiency of domestic water use or the rate of increase in crop yields;
- human behavior, covering model parameters such as the willingness of people to invest time or money in energy conservation or water conservation; and
- institutional factors, such as the existence and strength of institutions to promote education, international trade, and international technology transfer. The latter are represented directly (trade barriers, for instance, and import tariffs) or indirectly (income elasticity for education) in the models, based on the storylines.

Soft-linking of the models was done to achieve greater consistency between the calculations of the different models: the output files from one model were used as inputs to other models. The time interval of data that were exchanged between the models was usually one year.

Scenarios studies in IAM at the local scale

Local and regional integrated assessments are first developed as a variety of R&D approaches in support to sustainable management of natural resource and land/landscape planning. In these approaches, scenario methods constitute firstly a means to enhance adaptive capacity of the stakeholders for facing sustainable development challenges, e.g. (CGIAR-INRM-Group, 1999; White, 2001; Lynam *et al.*, 2002).

Multi-agent systems: an integrated framework for scenario studies in local IAM

Recently, researchers embedded in exploration of the future of natural resource management, started to use MAS in different fields among which ecosystem and resources management that take into account interactions between natural and social dynamics (Bousquet & Le Page, 2004). Above all, multi-agent models provide at the micro-level perspective facilities to incorporate, into a virtual realistic landscape, aggregated spatial entities defined at different levels either to connect them with their scale-specific dynamics processes or to build specific perceptions of the ecosystem that each agent uses to determine its actions (Etienne & Le Page, 2002). Moreover, thanks to cellular automata techniques, behavioural models of land-use decisions by agents can be made spatially explicit (Veldkamp & Lambin, 2001). Finally, by explicitly addressing interactions among individuals, multi-agent models allow to simulate emergent properties of systems that are not predictable from observing the micro-units in isolation (Verburg *et al.*, 2004).

In parallel, theoretical approach has been evolving from a system approach to an emerging one based on the concept of the individual (Bousquet & Le Page, 2004). The system approach is based on the system dynamics method (Von Bertallanffy, 1968): the system is represented as a set of modules or compartments interlinked by flows and controls in which compartments are used to represent the stocks and flows (of matter, energy or information). The emerging approach based on the concept of individual focuses on problems of behaviour and interactions (Bousquet & Le Page, 2004). It has been developed either by using individual based models (IBM) that find their roots at the end of the 1980s (Huston *et al.*, 1988), or by using Multi-agent System (MAS). The later one gives more emphasis to the decision making process of the agents and to the social organisation in which these individuals are embedded. Moreover MAS relies typically on a bottom-up approach: through the modelling of agents' behaviour and interactions, properties emerge that can be observed at the level of the system (Bousquet & Le Page, 2004). The underlying idea, which is to produce a system that behaves like reality, is always present, with the aim of using the simulator to ask the question "and what if ...?". By adapting the model to reality the aim is not to make the model into a predictive tool, but rather to understand the dynamics that exist or have existed (Bousquet & Le Page, 2004). The vocation of a model is generally to serve as decision support tool -e.g. (Le Ber *et al.*, 1999)- but simulation can also be used and can contribute to decision-making processes -e.g.(Gimblett *et al.*, 1998). Different methods are proposed among which companion modelling (Bousquet *et al.*, 1999) that proposes to use MAS to deal with problems of common property management as part of a constructivist approach with the players of the system (Bousquet & Le Page, 2004) that have different representations. Thus, adaptive management not only consists of the objective of increasing the adaptiveness of the ecosystem but also deals with the social process that leads to this ecological state. What are important are solutions that emerge from interaction and with them comes a portfolio of interventions including:

1. Mediation to resolve conflicts, e.g. (Wittmer *et al.*, 2006),
2. Facilitation of learning, e.g. (Bousquet & Le Page, 2004),
3. Participatory approaches that involve people in negotiating collective action, e.g. (Bousset *et al.*, 2005).

Scenario studies that combine the use of MAS and scenario methods in a participatory manner do not all address the same purpose and consequently do not follow the same methodological process. Among scenario studies that actively involve users into the scenario building process (van Asselt & Rijkens-Klomp, 2002) two kinds of approaches can be distinguished: scenarios studies in which only decision-makers are actively involved and those in which both decision-makers and stakeholders are actively involved (both decision-makers and stakeholders become users). If both kinds of approaches intend to support the decision-making process, the second one intends additionally to support a social learning process and this way, computer-enhanced modelling becomes a tool for collective learning (Bousquet *et al.*, 1999), instead of tools for piloting the system. The approach adopted for ADD TRANS project relies on the first kind with the objective to support decision-making process and local governance. But from a methodological perspective, we consider of better interest to depict the second methodological approach in the way that it encompasses the methodological steps followed within the first approach. For this purpose, we depict examples of scenario studies that adopt the companion modelling approach: a scientific posture developed by French researchers that have worked for number of years in the field of renewable resource management, using various tools, particularly Agent-Based Models and Role-Playing Games, to tackle issues regarding decision processes, common property, co-ordination among actors (Barreteau, 2003a).

Examples of scenario studies embedded into a Companion modelling approach

The companion modelling approach (ComMod, 2005) uses MAS as a decision-support tool and/or to contribute to decision-making processes,in the context of ecosystem and resources management at the micro-level perspective (Bousquet *et al.*, 1996; Herimandimby *et al.*, 1998) and to a related methodological framework elaborated by Bousquet and al. (1996), e.g. (D'Aquino *et al.*, 2002; Etienne *et al.*, 2003; Becu *et al.*, 2003; Barreteau, 2003b; Castella *et al.*, 2005; Simon & Etienne, 2006). From a methodological perspective most of the scenario studies run under this perspective frely on ‘patrimonial approach’.
Thus, in this section we describe the patrimonial methodological framework (Bousquet *et al.*, 1996; Herimandimby *et al.*, 1998), before illustrating its concrete application with two scenarios case studies: the step-by-step methodology developed by Etienne and al. (2003) and the self-design process to accompany collective decision-making developed by D’Aquino and al. (2002). We consider the first scenario study as typically illustrating the ‘patrimonial methodological framework’ and the basic steps in its application, and the second scenario study as an illustration of possible adaptation of the ‘patrimonial methodological framework’ to the specific scope, context and goals of a scenario project. Additional scenario studies based on similar frameworks are evoked at the end of the section.

A methodological guideline based on the patrimonial approach

(Ostrom, 1990) and (Burton, 1994) have firstly developed the ‘patrimonial approach’ (In Bousquet and al. 1996). The main idea is that long-term is not predictable in the social and economic fields; it is however partially decided. It is on the basis of a shared conception and perception of the current state of a system that stakeholders can decide long-term objectives, on the basis of whose scenarios that could allow to reach them will be discussed. All stakeholders interact during workshops for first a negotiated definition of the problem, then for an analysis of the whole set of possible solutions and finally make their choise based on transparent criteria (translated from “tous se concertent pour une définition négociée du problème, puis pour une analyse de l’ensemble des solutions possibles et, enfin, choisissent sur des critères transparents”, modèle CAC) (Mermet *et al.*, 2004).
Bousquet and al. (1990) use the concepts of the patrimonial approach within a methodological frame integrating the use of MAS, and based of three overarching steps:

1. **The building of an ‘artificial world’**: after a (partial) identification of the thematic results either from stakeholders’ demand or from researchers’ observations, the first step consists in eliciting, gathering and collecting knowledge (data and information) about the thematic to study. The process begins by an identification of the relevant stakeholders responsive and concerned by the thematic. It can be driven either exclusively by the researchers on the basis of their perceptions of the system and thanks to the information collected with stakeholders, or in participative manner with the stakeholders –those that contributed to initiate the study- excluding or including the researchers. The process goes on by an identification of stakeholders’ perceptions, their uses of renewable resources and performed operations on the ‘resources space’, and by an analysis of stakeholders’ interactions. Because of using MAS, the investigation of the system under study is done towards problems representations, interactions and

controls. The authors advise to drive in parallel the information gathering and the implementation of the model. The implementation of the model (done by a modeller) lights out lacks of data or information, and calls for further ‘field investigations’ that in turn provide new elements to the model.

2. **Restitution step**: the second step is an evaluation of the ‘cognitive model’ according to its role of supporting the decision-making process it has been built for. To share with stakeholders what is inside the model and avoid the ‘black box effects’, two methodologies can be applied. In a first case, stakeholders are able to interact directly with the MAS itself and manage to understand the way natural and social dynamics are simulated. The evaluation is currently done by simulating the trend scenario towards different viewpoints based on indicators. In the second case, an intermediate step is necessary and consists in working first with a role-playing game (RPG) that can be computer-based or qualitative. Participants are plunged into an artificial world similar to the MAS’ one, with which they directly interact. In the RPG, they may be user of resources (like a farmer), regulator of the resource management or observer of the system (like researcher). In both cases, aims are to evaluate the model and to improve it, and to confront stakeholders’ perceptions of natural and social processes with dynamic simulations or into RPG. Stakeholders are engaged into a collective learning of their common system. Feedbacks with the first step can appear to be necessary towards, for example, the identification of new stakeholders.

3. **Simulations step**: simulations show how system dynamics result from interactions between stakeholders that have different behaviours, interests, temporal and spatial scales, representations and weight in the negotiation (Bousquet *et al.*, 2002; ComMod, 2005). Then, stakeholders negotiate and define one or several common long-term objectives by using MAS as mediation tool. The negotiation process is often supported by a mediator-facilitator (van den Belt, 2004), sometimes called in the French literature ‘accoucheur’ (Bousquet *et al.*, 1996). Defined objectives are not necessarily shared by all stakeholders and can result from negotiation of groups of stakeholders that did not manage to agree with the others or that considered the others not concerned by their objective. For the same reasons than in the previous step, RPG or MAS simulations can be used to reach this intermediate phase. Subsequently begins an iterative phase of scenarios building to explore the different paths to reach the objectives and the related means. Scenarios are built by stakeholders supported by the facilitator, and are simulated and discussed towards various viewpoints.

These three steps constitute a methodological guideline that scenario developers adapt to the scope, the context and the aim of their scenario study. On one hand, some scenario studies are used to support only partially the decision-making process and do not follow all three steps. On another hand, some steps are particularly time consuming (Herimandimby *et al.*, 1998) and can lead scenario developers to concentrate on few steps. Thus, the followed research sequence varies according to the considered scenario study. Moreover, scenario developers have at their disposal several tools such as MAS and role-playing game (RPG) to accompany stakeholders in their decision-making process along their research sequence and can combined their use or use them separately.

The step-by-step method

A pedagogic example to illustrate the combination of scenario approaches to explore the future is the step-by-step method elaborated by Etienne and al. (2003) for the development of collective land management scenarios with local stakeholders, by mean of a Multi-agent System (MAS). Local stakeholders of the Causse Méjan (farmers, foresters and National Park of Cévennes rangers) endangered by pine encroachment called for a better understanding of the ongoing natural dynamics and an exploration process of related future alternative strategies. The authors elaborated a problem solving research sequence integrating a social learning -or collective learning (Rist *et al.*, 2006)- phase and an exploratory step of possible individual alternative land management scenarios with local stakeholders, before converging towards collective agreements on common goals and engaging a backcasting approach to reach these goals by mean of collective alternative scenarios.
The research sequence followed by Etienne and al. (2003) is based on the principle that an adaptive management not only consists of the objective of increasing the adaptiveness of the ecosystem but also deals with the social process that leads to this ecological state (Bousquet & Le Page, 2004). The bottom-up approach constituting the step-by-step method emphasis the concept of "community-based natural resource management". In such approach, the MAS both serves as a decision-support tool -which is the classical use of modelling (Bousquet & Le Page, 2004)- and contribute to the improvement of the decision-making process, following the companion modelling approach (ComMod, 2005).
The resulting land management scenarios elaborated towards the step-by-step method are strongly normative, take into account quantitative and qualitative information, are concerted and collectively built that make them feasible, and are legitimize by an active involvement of stakeholders.

Box 8: Research sequence of the step-by-step method (Etienne *et al.*, 2003)

1. First contact with the stakeholders and identification of the problematic
2. Building of the conceptual model
   The conceptual model is often built by the team of researchers supported by local technical experts.
7. Data gathering and enquiries
   This step consists in collecting the data and information needed for implementing the conceptula model into the MAS. Some enquiries have been individually made with each type of agents to collecte information about their practices.
8. First implementation of the model
   The MAS is built with the Cormas platform. Natural dynamics (structure, composition and productivity) are simulated by a cellular automaton. The global landscape dynamics result from a combination of natural vegetation dynamics processes and the operations performed by the agents (sheep farmers, foresters, National Park rangers). Some meetings gathered several agents of the same category to validate the implemented practices.

…see the next box for following steps

…Next steps of Box8

5. Role-playing game: collective learning of the ongoing processes and of the impact of each stakeholders on the common “resources space”, and share of individual representations
   Because of the long-term natural dynamics processes, differences among stakeholders (sheep farmers, foresters and National Park of Cévennes rangers) of perceptions of the resources, stakeholders’ specific spatial entities of management and specific time scales for managing the resources, the team of researchers decided to develop a role-playing game (RPG). The aim was to project the stakeholders in the future and force them to react to the ongoing processes and dynamics. Then some meetings were organised by the local district community to stimulate discussion around the pine encroachment problem. The RPG has been used both as training tool for social learning (Barreteau, 2003b) and to facilitate the understanding and appropriation of the MAS by stakeholders (Bousquet *et al.*, 2002).
6. Understanding of the MAS and validation by the stakeholders
   For this step, the modeller designs a basic dynamic viewpoint of land resources and proposes the simulation of the trend scenario to the stakeholders. This step led to an appropriation of the MAS by the stakeholders. They suggested some corrections to the model and finally validated it. Then, they elaborated new viewpoints to visualize indicators better suited to plan their activities and understand the dynamics of their resources.
7. Analysis of the trend scenario by the stakeholders and individual scenario building
   The analysis of the trend scenario simulation by each category of agents (sheep farmers, foresters, conservationists) towards their specific viewpoints led them to imagine new actions to react to environmental changes and new indicators to visualise the impacts of these later ones. The MAS is here used to simulate the alternative scenarios imagined by each user such that the user can iterate through the scenario generation process until they reach a future scenario with which they are happy. This step is potentially usefull for the exploration of numerous individual alternatives.
8. Collective visualisation and confrontation of individual scenarios simulations
   Every individual scenario is visualized and discussed among stakeholders through the different available viewpoints. In the Causse Méjan case study, the need to agree to a compromise among the three kind of agents has been raised and this step led to new scenarios based on collective management of pine encroachment. The collective process started by the identification of common and concerted targets to reach through a collective management. Two agreements have been found: the first one was on the pressing need to conserve most of the endangered habitats and thus to establish a global strategy of pine encroachment control. The second one was based on an agreement to promote sustainable development of agricultural and forestry practices aiming at a progressive decrease of the area covered by pine woodlands.
9. Building of collective scenarios
   This step is a goal-oriented approach: after having identified concerted targets, the stakeholders explore the possible paths to reach these targets. This step can be considered as a backcasting step. The collective alternative scenarios are evaluated through specific indicators chosen by the stakeholders and visualised thanks the cellular automaton. Then, a set of feasible scenarios has been chosen.

The ability to make out of a set of isolated management plans a collective planning of a concerted local development plan has been encouraged and facilitated in this scenario study by the combined use of MAS and RPG, and by the role of the modeller-facilitator. However, the efficiency of the method completely depends on the capacity of the stakeholders involved in the scenario building process to find compromises, and on their interest in finding collective and concerted scenarios in comparison to their individual scenarios.

The scenario study developed by Simon and Etienne (2006) used a similar methodological sequence. Responding to a specific demand of the Société Civile des Terres du Larzac (SCTL) sheep farmers, authors developed a methodological sequence using MAS. The demand of sheep farmers was to better understand and anticipate Pinus sylvestris encroachment and find collectively with 30 farmers among whom 10 farmers elected to manage SCTL lands, alternative management of resources to control pine dynamic, to secure the pasture, to improve the grazing potential of pine forests. The alternative solutions had also to be economically sustainable for the SCTL (Simon & Etienne, 2006). The followed methodological sequence was almost the same than step-by-step method, except that no RPG have been developed. Because farmers used to manage collectively the SCTL fields (6300 ha of fields, pastures and woods) and because they easily understood processes integrated into the MAS as well as simulations of the trend scenario, authors considered not necessary to develop a RPG. Thus, the fifth step of the step-by-step method has been displayed. Note that this scenario study is still an ongoing project: the last step is reached and one collective scenario has already been built. It has been simulated, discussed and validated at landscape scale, but farmer-managers ask to simulate, discuss and validate the collective scenario at each farm scale of the 30 farmers to analysis its impact on individual farms (Simon & Etienne, 2006).
Another similar methodological example is the case study of water resource management in the Senegal River (Barreteau *et al.*, 2001). A MAS is designed in conjunction with a role-playing game to analyse a negotiation situation. In addition to creating decision scenarios the model has been used as learning and mediating tool within a negotiation process for the water resource conflict. This approach also shows the conjunction of stakeholder participation with model development in a validation process.

The self-design process to accompany collective decision making

The main concept of this method is that fostering the internal representation of the complexity involved has not a lower operational value than classical experts' analysis. Indeed, the self internal construction by the stakeholders –supported by facilitators- enhance the use of computer tools in the decision-making process. Moreover, the computer tool will be most efficient when its design speaks closely to the matter such as it appears to the decision-makers, than when its design addresses the matter such as it appears to exogenous people (experts or scientists) (D'Aquino *et al.*, 2002; D'Aquino *et al.*, 2003). The method seeks to help people to progressively formalize the elements-as they move forward through their debates-which appear useful to all for the improvement of their decision-making abilities. The method developed by D'Aquino and al. (2002) uses a role-playing game (RPG) created by the stakeholders and supported by the research team (the facilitators and modellers). This RPG is used as a mediating support to facilitate the emergence of worthwhile debates by taking into account all the different perspectives and building upon some truly common technical devices(D'Aquino *et al.*, 2002; D'Aquino *et al.*, 2003).
This learning-by-doing approach has been experimented by D'Aquino and al. (2003) in the Northern Senegal. The focus was on tackling multipurpose land use management issues and

solving the puzzle of sustainable development, in a context of strained competition for the use of renewable resources and tricky relationships between agriculture and breeding.

Box 9: Research sequence of self-design process method (D'Aquino *et al.*, 2003)

1. endogenous construction of the situation by the stakeholders
   This step consists in i) identifying the kinds of stakeholders to take into account and of their satisfaction criteria (“the fundamental elements necessary for every stakeholder to succeed in providing a living for his family”), and ii) identifying over the course of time, throughout the entire year, the same satisfaction criteria for each activity. For each kind of stakeholders, participants were asked to define a list of places/resources/other elements needed for his activity, and to rank the quality of these places. This step is done towards workshops with participants (stakeholders, representatives and principals).
2. Iterative game sessions
   The first RPG was elaborated on the basis of previously given elements and information. The previously identified stakeholders are the players of the game. Each player must attempt to satisfy the needs required by his character throughout the yearly cycle. The requirements of the player were quantified thanks the scores given by the participants for each type of resource. The scenario tested in this step consists of the “trend scenario”, i.e. basic rules of functioning, such as perceived by the participants. The first iteration allows validating every participant’s understanding and rectifying the rules of the RPG. In other words, it leads to a rectification of the first trend scenario by discovering incompatibilities.
   Afterwards, subsequent sessions lead to productive debate that helps participants imagine together collective solutions for everybody’s satisfaction realize that some of the negative aspects of a given situation are not necessarily due to a specific user but were perhaps caused by some elements that simply did not function well together. Moreover, participants pointed out the underlying causes of difficulties to manage common resources. This culminated in alternative agreements and proposals. Because participants asked for including in the mix the dynamics effects of interactions between the different uses and the medium-term evolutions, the research team provided them with the necessary supports for a simulation process involving RPG and MAS modelling.
3. Simulation process involving RPG and MAS modelling
   The authors elaborated a method called SelfCormas using the Cormas platform, and allowing participants to take part into the building of the MAS. With this new tool, it was then possible to simulate scenarios imagined by the participants and to generate group discussions of possible interactions between users and resources. After playing out the scenario identified in the previous RPG, new situations emerge, are simulated and then discussed.

Compared to step-by-step method, self-design method gives more emphasis to the communication and exploration processes.

Conclusion

The first lesson learned from section 1 is that scenarios are to be regarded firstly as a component of a method in a scenario study, and the applied scenario method as conceived in close reference to requirements and demands of the “users” of the scenario study.

As stated in section 1, the array of scenario method and their applications currently available in the literature can be considered as consisting of “classical approaches” that rely on one of the three main modes of thinking to explore the future: the predictive, the eventualities and the visionary modes of thinking (Greeuw *et al.*, 2000; van Notten *et al.*, 2003; Dreborg, 2004; Börjeson *et al.*, 2006). These three modes of thinking respectively address three questions a user may ask about the future: What will happen?, what can happen?, how can a specific target be reached?
In spite of the apparent variety of the modes of thinking currently used in scenario method, Marien (2002) considers that the great majority of futurists still think in only one, or at most two of the categories probable, possible or preferable (Marien, 2002). Furthermore, Dreborg (2004) argues that “typically one of the modes of thinking and a related method are dominant and give the future study its character” (Dreborg, 2004).

The predictive approach was classically used to deal with foreseeable challenges and take advantage of foreseeable opportunities (forecasts). Recently, it has been used on a more general basis to make decision-makers aware of problems that are likely to arise if some condition on the development is fulfilled (What-if scenarios) (Stoorvogel & Antle, 2000; Börjeson *et al.*, 2006). Predictions are usually made within one structure of the predicted system, i.e. it is assumed that the laws governing a system’s development will prevail during the relevant time period. Thus, the predictive approach is most suited to the short term when the uncertainty in the development of external factors is not too great (Dreborg, 2004).

The explorative approach is used to explore situations or developments that are regarded as possible to happen, usually from a variety of perspectives. Typically a set of scenarios are worked out in order to span a wide scope of possible developments (Börjeson *et al.*, 2006). The main objective is to stimulate a creative thinking and to gain insights into the way societal processes influence one another (Schwartz, 1991; Ringland, 1998; Greeuw *et al.*, 2000; Rotmans *et al.*, 2000; van Notten & Rotmans, 2001; Carpenter, 2002; van der Heijden, 2004). The use of external scenarios has traditionally been for planning purposes. Nowadays, external scenarios studies’ application varies from planning to teambuilding, vision development to conscience raising and communal learning. The use of strategic scenarios has typically been for testing different policies and studying their impact on some target variables (van Notten *et al.*, 2003; Dreborg, 2004; Börjeson *et al.*, 2006).

The visionary approach is used to explore the feasibility and implications of achieving certain desired end-points or set of goals, by involving the development of normative scenarios (Robinson, 1982). Desirable (sustainable) future images (or visions) are designed, followed by looking back at how this desirable future could be achieved, before defining and planning follow-up activities an developing strategies leading towards that desirable future (Henrichs, 2003; Schroth & Wissen, 2004; Quist & Vergragt, 2006). Due to its normative and problem-solving character, the visionary mode of thinking is better suited for long-term problems and long-term solutions (Quist & Vergragt, 2006), in case of complex problems and in case of a need for major change (Dreborg, 2004). The visionary mode of thinking was initially developed for policy optimisation and vision building. Nowadays, application of backcasting approach is wider extended including a role in a learning process about the future, in the issue of broadening the process to a larger group of potential users and how to alter the hegemony of existing dominant perspectives (Robinson, 2003; Quist & Vergragt, 2006). Elsewhere, backcasting is not only about how desirable futures can be attained, but also about analysing the degree to which undesirable futures can be avoided or responded to (Robinson, 1990).

Due to the application of future studies to a continuously growing number of areas and societal concerns and in relation to technological evolution of utilized tools (Ringland, 1998; Greeuw *et al.*, 2000), scenario methods diversified tremendously over the last decades, by either developing specifically new methods or adapting existing ones for application to other purposes (Greeuw *et al.*, 2000; van Notten *et al.*, 2003; Dreborg, 2004; Börjeson *et al.*, 2006).

The increased recognition of the importance of the relationships between sectors and society and the environment led to invest into integrated approaches based on **system thinking** (Holling, 1978; Kruseman & Bade, 1998; Lambin & Geist, 2002; Walker *et al.*, 2002; Carpenter, 2002; Walker *et al.*, 2004; Wittmer *et al.*, 2006). This trend is stressed in section 2 towards the increased use within the different approaches of the 'system dynamics method' elaborated by Von Bertallanffy (1968): the system is represented as a set of modules or compartments interlinked by flows and controls in which compartments are used to represent the stocks and flows (of matter, energy or information).

Additionally, with the recognition of the incompletude of information requested and the important role of decisions of the stakeholders in the dynamics of change, a growing interest was put into participatory approaches (Caswill & Shove, 2000; Toth, 2001; van Asselt & Rijkens-Klomp, 2002; ComMod, 2005; Bousset *et al.*, 2005; Quist & Vergragt, 2006). Integration of participatory methods within each kind of approach is also stressed in section 2. In the predictive approach, predictive computer models originally based on expert knowledge are increasingly elaborated within a participatory process with policy makers, scientists and other stakeholders using experience and expert knowledge (Stoorvogel & Antle, 2000; van Asselt *et al.*, 2001). In the explorative approach, van Asselt and Rijkens-Klomp (2002) state two important changes. First, if explorative scenarios developers were used to draw on experts in the field, expert input is more and more complemented by stakeholder-input in today's scenario projects. Second, decisions-makers and stakeholders are increasingly involved in the scenario development process itself. In the visionary approach, Quist and Vergragt (2006) and Robinson (2003) state that there has been recently a clear tendency to involve experts groups or grass-root movements and ordinary citizens into the process of building the normative scenarios towards a participatory visionary mode of thinking.

However, a clear distinction must be made between participatory scenario studies, which results from the purposes addressed by scenario developers when using participatory methods. In first case, participatory methods are used to develop legitimate, acceptable (by stakeholders), robust and enriched scenarios. Combination of scientific, expert and lay-knowledge in this case is related to principles that science is socially constructed and that science should not have the monopoly of knowledge (van Asselt & Rijkens-Klomp, 2002). In other case, participatory methods are used to actively involve users of scenarios studies into the scenario building process itself. Within this case, two kinds of approaches can still be distinguished: scenarios studies in which only decision-makers are actively involved and those in which both decision-makers and stakeholders are actively involved. If both kinds of approaches intend to support the decision-making process, the second one intends additionally to support a social learning process.

Scenario studies have been increasingly developed over the past years in the environmental field in reference to sustainability. They were first applied for dealing with assessing global environmental change, but they are currently to a variety of scales, from the global to the local level. Section 3 stresses the main recent evolutions in their development, which increasingly consider the links between societal change and ecosystem for assessing possible trade-offs between social, economic, institutional and ecological aspects of development. Environmental issues are increasingly considered in the framework of integrated systems of human and nature considered as social–ecological systems (Berkes and Folke 1998)(Walker *et al.*, 2002). Sustainability is considered as a process, rather than an end-product, a dynamic process that requires adaptive capacities for societies to deal with change (Berkes *et al.*, 2003). Scenarios studies are increasingly aimed at "building resilience" in social–ecological systems from the global to the local level. Resilience theory offers indeed a vision of sustainability as persistence borne out of change out of adaptive renewal cycles (Gunderson & Holling, 2002). A major challenge in this context is to build knowledge, incentives, and learning capabilities into institutions and organizations for governance that allows for the adaptive management of local, regional, and global ecosystems and to incorporate actors in new and imaginative roles (Folke *et al.*, 2005).

Therefore, as well at the global scale as at the local scale, recent scenario studies in the environmental area combine qualitative storyline development and quantitative modelling. A set of scenarios generating methods and computer models are encapsulated within participatory approaches including various steps and cycled processes. Alternative scenarios are generated until reaching future scenarios with which the users are happy.
The important emphasis given to the learning processes allowing adaptive management of ecosystems towards sustainability led in particular to a wealth of scenario studies at the local scale, where the interaction between ecosystem functioning and decisions of the agents of the social systems can be concretely modelled. Combined use of multi-agent systems and scenario methods appears as suitable methodology to support decision-making process at micro-scale perspective and to enhance social learning process. The illustrations of such facts given in section 3 based on the "companion modelling approach" developed by the Commod network (ComMod, 2005).

Appendix: Related techniques to scenario building

GENERATING TECHNIQUES

Brainstorming (Bousset *et al.*, 2005)

Brainstorming is a commonly known technique for the creative generation of ideas, approaches or solutions without taking into account constraints such as cost, practicality or feasibility. In order to create optimum conditions for creative thinking the members of the group are asked not to criticise, discard or disparage any ideas generated by others. Instead they are encouraged to build on the ideas of others by suggesting embellishments, improvements and modifications.

Workshops (Börjeson et al., 2006)

Workshops can facilitate broadening of the perspectives, since decision-makers, stakeholders and experts can be included in the process. Moreover, workshops can increase the acceptance of decisions or scenarios among the participants. In the workshop process, it is also possible to include techniques that liberate the creativity of the human mind such as Brainstorming.

Delphi method (Börjeson et al., 2006)

The main idea of a classical Delphi study is to collect and harmonise the opinions of a **panel of experts** on the issue at stake. It recognises human judgement as a legitimate input to forecasts and also that the judgement of a number of informed people is likely to be better than the judgement of a single individual. In the original Delphi method, questions are sent to a panel of experts in various rounds. The method is a cheap and quick way of getting the information needed for making decisions. It is at hand when there is a shortage of data, inadequate models and lack of time or resources to make a thorough scientific study. Hence, the Delphi method is primarily useful when other studies cannot be done due to lack of data, time or resources. It can also be useful when the complexity of the problem at stake is too big for ordinary forecasting.

Delphi modified (Börjeson et al., 2006)

A modified Delphi method was devised by Best and al. (1986) (In Burleson and al. 2006). In this modified version, **different groups of opinions** are identified after the first round of questionnaires. Within these groups, a procedure similar to a conventional Delphi method is performed with a view to producing meaningfully different but cohesive alternative futures. The point is that the study results in different possible futures, while still being subjugated to the Delphi process. The study concerns factors in the future environment that could have an impact on the system under analysis.

Backcasting Delphi (Börjeson et al., 2006)

A backcasting Delphi method, which is a combination of backcasting and Delphi studies, has been developed by Höjer (1998). The backcasting Delphi method starts with the first part of a backcasting study, i.e. formulating scenarios of a future that is desirable in some sense. The second part, examining the path to the images of the future, is left out of the study. Instead, a Delphi-like process is initiated where experts are asked to evaluate and improve the scenarios in respect of their feasibility and coherence to the defined targets.

INTEGRATING TECHNIQUES

- **Explanatory models**

Explanatory models are based on **causal links** in the form of equations connecting variables. This consists of quantitative description of the mechanisms and processes that cause the behaviour of the system. To create this model, a system is analyzed and its processes and mechanisms are quantified separately. The model is built by integrating these descriptions for the entire system. A specific model can thus only produce scenarios within a given structure. By changing the causal links, a new model with possibly a new system structure can be developed.

Empirical-statistical & GIS based models (Lambin *et al.*, 2000)

Empirical, statistical models attempt to identify explicitly the causes of changes, using multivariate analyses of possible exogenous contributions to empirically-derived rates of changes. Multiple linear regression techniques are generally used for this purpose. The finding of a statistically significant association does not establish a causal relationship. Moreover, a regression model that fits well in the region of the variable space corresponding to the original data can perform poorly outside that region. Thus, regression models cannot be used for wide ranging extrapolations. Such models are only able to predict patterns of land-use changes which are represented in the calibration data set. These models are only suited to predict changes where such changes have been measured over the recent past: in most studies this assumption is not valid.

Stochastic models (Lambin *et al.*, 2000)

A stochastic model is a mathematical model which takes into consideration the presence of some randomness in one or more of its parameters or variables. The predictions of the model therefore do not give a single point estimate but a probability distribution of possible estimates, in contrast with deterministic. For land-use change, stochastic models consist mainly of transition probability models and describe stochastically, processes that move in a sequence of steps through a set of states. Transition probability approaches are limited in their application because they only use transitions which have been observed in the recent past, which is similar to empirical-statistical models.

Optimisation models (Lambin *et al.*, 2000; Rounsevell *et al.*, 2006)

Optimisation models are useful tools for the representation of human decision-making processes. They seek to describe what an individual should do, based on his goals and constraints, and assume that the individual will behave in a manner that is close to this optimum. Linear programming is the most common method of optimisation used in agricultural land use studies. Linear programming has been used, for example, in the determination of crop selection decisions by farmers, based on the goal of profit maximisation. Optimisation models are limited by their inability to describe dynamic processes (that change through time), and to simulate less than optimal decision-making, e.g. where additional non-economic factors need to be considered, that leads to a non-optimal behaviour of people, e.g. due to differences in values, attitudes and cultures. While, at an aggregated level, these limitations are likely to be non-significant, they are more important as one looks at fine scale land-use change processes and is interested in the diversity between actors.

Dynamic (process-based) simulation models (Lambin et al., 2000)

Patterns of land-cover changes in time and space are produced by the interaction of biophysical and socio-economic processes. Dynamic (process-based) simulation models have been developed to imitate the run of these processes and follow their evolution. Simulation models emphasise the interactions among all components forming a system. They condense and aggregate complex ecosystems into a small number of differential equations in a stylised manner. Simulation models are therefore based on an a priori understanding of the forces driving changes in a system.

Agent-based models & cellular automata (Parker *et al.*, 2003; Bousquet & Le Page, 2004)

An agent-based model of land-use/land-cover change consists of two key components. The first is a cellular model that represents the landscape under study. This cellular model may

draw on a number of specific spatial modelling techniques, such as cellular automata, generalized cellular automata, and Markov models. The cellular automata operate in a lattice of congruent cells. Each cell exists in one of a finite set of states and future states depend on transition rules based on a local spatio-temporal neighbourhood. The system is homogeneous in the sense that the set of possible states is the same for each cell and that the same transition rules applies for each cell. The second component is an agent-based model that represents human decision making and interactions. An agent-based model consists of: autonomous decision-making entities (agents), an environment through which agents interact, rules that define relationship between agents and their environment and rules that determine sequencing of actions in the model. Autonomous agents are composed of rules that translate both internal and external information into internal states, decisions, or actions. Agent-based models are usually implemented as multi-agent systems (MAS), a concept originated in the computer sciences that allows for a very efficient design of large and interconnected computer programs.
In the context of a LUCC model, an agent may represent a land manager who combines individual knowledge and values, information on soil quality and topography (the biophysical landscape environment), and an assessment of the land-management choices of neighbours (the spatial social environment), to calculate a land-use decision. The model agents may also represent higher-level entities or social organizations such as a village assembly, local governments or a neighbouring country.

Hybrid/integrated models (Lambin et al., 2000)
Newer approaches are increasingly based on combining elements of these different modelling techniques. In principal, the best elements are combined in ways that are most appropriate in answering specific questions. These types of models are increasingly referred to as integrated models, although in many cases they are better described as hybrid models because the level of integration is not always high.

- **Time-series analysis**

Time Series are an ordered sequence of values of a variable at equally spaced time intervals. There are many methods used to model and forecast time series.

CONSISTENCY
Cross-Impact Analysis (Asan *et al.*, 2004)
The most popular method used to overcome interdependencies among events and developments is a cross impact analysis. It uses different techniques to analyze interrelationships by using a cross impact matrix which is a tool for systematic description of all potential modes of interaction between a given set of variables and the assessment of the strength of these interactions. Since the 1960s several versions of cross impact analysis have been developed. They can be classified into three groups, qualitative, quantitative and mixed cross impact analysis. In quantitative ones, a mathematical model relating to the variables is constructed. In qualitative ones, experts are asked to provide subjective estimates of the relationships among the variables, usually in the form of a matrix of conditional probabilities or impacts.

Morphological Field Analysis (MFA) (Ritchey, 1998)
Morphological analysis is a technique developed by Fritz Zwicky (1966, 1969) for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex. As a problem-structuring and problem-solving technique, morphological analysis was designed for multi-dimensional, non-quantifiable problems where causal modelling and simulation do not function well or at all. Zwicky developed this approach to address seemingly non-reducible

complexity. Using the technique of cross consistency assessment (CCA), the system however does allow for reduction, not by reducing the number of variables involved, but by reducing the number of possible solutions through the elimination of the illogical solution combinations in a grid box.

BIBLIOGRAPHY

Alcamo, J. 2001. *Scenarios as tools for international assessments*, 24, European Environmental Agency (Eds.), Office for Official Publications of the European Communities, 31 p

Alcamo, J., D. van Vuuren, C. Ringler, J. Alder, E. Bennett, D. Lodge, T. Masui, T. Morita, M. Rosegrant, O. Sala, K. Schulze, and M. Zurek 2005. *Methodology for Developing the MA scenarios*, Pages 145-172 In Ecosystems and Human Well-being: Scenarios, Volume 2. Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment, Chapter 6 of Scenarios Working Group Assessment Report, Millennium Ecosystem Assessment, S. R. Carpenter, P. R. Pingali, E. M. Bennet, and M. B. Zurek editors., Island Press, Whashington

Amara, A., 1981. *The futures field: searching for definitions and boundaries*, The Futurist 15 (1): 25-29

Asan, U., C. Erhan Bozdag, and S. Polat., 2004. *A fuzzy approach to qualitative cross impact analysis*, Omega 32 (6): 443-458

Barreteau, O., 2003a. *Our Companion Modelling Approach*, Journal of Artificial Societies and Social Simulation 6 (1)

Barreteau, O., 2003b. *The joint use of role-playing games and models regarding negotiation processes: characterization of associations*, Journal of Artificial Societies and Social Simulation 6 (2)

Barreteau, O., F. Bousquet, and J. M. Attonaty., 2001. *Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to Senegal River Valley irrigated systems*, Journal of Artificial Societies and Social Simulation 4 (2)

Becu, N., P. Perez, A. Walker, O. Barreteau, and C. L. Page., 2003. *Agent based simulation of a small catchment water management in northern Thailand: Description of the CATCHSCAPE model*, Ecological Modelling 170 (2-3): 319-331

Berger, T., P. Schreinemachers, and J. Woelcke., 2006. *Multi-agent simulation for the targeting of development policies in less-favored areas*, Agricultural Systems 88: 28-43

Berkes, F., J. Colding, and C. Folke 2003. *Introduction*, Pages 1-29 In Navigating social-ecological systems. Building resilience for complexity and change, F. Berkes, J. Colding, and C. Folke editors., Cambridge University Press, Cambridge

Berkes F., and C. Folke 1998. *Linking social and ecological system. Management practices and social mechanisms for building resilience*, eds Berkes F. and Folke C., Cambridge University Press, Cambridge

Bertrand, G., Michalski, A., and Pench, L. R. 1999. *Scenarios Europe 2010. Five possible futures for Europe*, European Commission Forward Studies Unit, 121 p

Börjeson, L., M. Höjer, K. H. Dreborg, T. Ekvall, and G. Finnveden., 2006. *Scenario types and techniques: Towards a user's guide*, Futures In Press, Corrected Proof

Bouman B. A. M., H. G. P. Jansen, R. A. Schipper, H. Hengsdijk, and A. Nieuwenhuyse 2000. *Tools for land use analysis on different scales. With examples from Costa Rica*, eds Bouman B.A.M., Jansen H.G.P., Schipper R.A., Hengsdijk H., and Nieuwenhuyse A., Kluwer Academic Publishers, Dordrecht, The Netherlands

Bouman, B. A. M., H. G. P. Jansen, R. A. Schipper, A. Nieuwenhuyse, H. Hengsdijk, and J. Bouma., 1999. *A framework for integrated biophysical and economic land use analysis at different scales*, Agriculture, Ecosystems & Environment 75 (1-2): 55-73

Bousquet, F., O. Barreteau, P. D'Aquino, M. Etienne, S. Boissau, S. Aubert, C. Le Page, D. Babin, and J. C. Castella 2002. *Multi-agent systems and role games: collective learning processes for ecosystem management*, Pages 248-285 In Complexity and ecosystem management: The theory and practice of multi-agent approaches, M. Janssen editor., Edward Elgar

Bousquet, F., O. Barreteau, C. Le Page, C. Mullon, and J. Weber 1999. *An environmental modelling approach. The use of multi-agents simulations*, Pages 113-122 In Advances in Environmental and Ecological Modelling, F. Blasco, and A. Weill editors., Elsevier, Paris

Bousquet, F., O. Barreteau, C. Mullon, and J. Weber 1996. *Modélisation d'Accompagnement : Systèmes Multi-Agents et Gestion des Ressources Renouvelables* In Colloque International "Quel environnement au XXIème siècle ? Environment, maîtrise du long-term et démocratie", Abbaye de Fontevraud 8-11 septembre 1996

Bousquet, F., and C. Le Page., 2004. *Multi-agent simulations and ecosystem management: a review*, Ecological Modelling 176: 313-332

Bousset, J. P., Macombe, C., and Taverne, M. 2005. *Participatory methods, guidelines and good practice guidance to be applied throughout the project to enhance problem definition, co-learning, synthesis and dissemination*, SEAMLESS report n°10, ref.: D7.3.1, Cemagref, 248 p

Briassoulis H. 2000. *Analysis of Land Use Change: Theoretical and Modelling Approaches*, The Web Book of Regional Science

Burton, M., 1994. *The irrigation management game: a role playing exercise for training in irrigation management*, Irrigation and drainage systems 7: 305-348

Carlsson-Kanyama, A., Dreborg, K. H, Engström, R., and Henriksson, G. 2003. *Possibilities for long-term changes of city life: Experiences of backcasting with stakeholders*, Fms-Report 178, FOI/Fms, Environmental Strategies Research Group, Stockholm, 21 p

Carpenter, S. R., 2002. *Ecological futures: building an ecology in long now*, Ecology 83 (8): 2069-2083

Castella, J. C., T. Ngoc Trung, and S. Boissau., 2005. *Participatory simulation of land-use changes in the northern mountains of Vietnam: the combined use of an agent-based* *model, a role-playing game, and a geographic information system*, Ecology and Society 10 (1): 1-27

Caswill, C., and E. Shove., 2000. *Introducing interactive social science*, Science and Public Policy 27 (3): 154-157

CGIAR-INRM-Group 1999. *Integrated Natural Resource Management: The Bilderberg Consensus*, Summary Report of the INRM workshop held at Bilderberg, The Netherlands, 3-5 September 1999. Consultative Group for International Agricultural Research-Integrated Natural Resources Management

Chermack, T. J., and L. van der Merwe., 2003. *The role of constructivist learning in scenario planning*, Futures 35 (5): 445-460

Chermack, T. J., S. A. Lynham, and L. van der Merwe., 2006a. *Exploring the relationship between scenario planning and perceptions of learning organization characteristics*, Futures In Press, Corrected Proof

Chermack, T. J., L. van der Merwe, and S. A. Lynham., 2006b. *Exploring the relationship between scenario planning and perceptions of strategic conversation quality*, Technological Forecasting and Social Change In Press, Corrected Proof

ComMod, C., 2005. *La Modélisation comme outil d'accompagnement*, Nature Sciences Sociétés 13: 165-168

Crissman, C. 1998. *Regional scaling of field-level economic-biophysical models*, DME-NOR progress report 3, International Potato Center (CIP), 7 p

D'Aquino, P., C. Le Page, F. Bousquet, and A. Bah., 2002. *A novel mediating participatory modelling: the self-design process to accompany collective decision making*, International Journal of Agricultural Resources, Governance and Ecology 2 (1): 59-74

D'Aquino, P., C. Le Page, F. Bousquet, and A. Bah., 2003. *Using Self-Designed Role-Playing Games and a Multi-Agents System to Empower a Local Decision-Making Process for land Use Management: The SelfCormas Experiment in Senegal*, Journal of Artificial Societies and Social Simulation 6 (3): 1-24

De Jong, A., and G. Zalm 1991. *Scanning the future: A long term scenario study of the world economy 1990-2015*, Pages 27-74 In Long-term Prospects of the World Economy, Organisation for Economic Co-operation and Development, Paris

de Koning, G. H. J., P. H. Verburg, A. Veldkamp, and L. O. Fresco., 1999. *Multi-scale modelling of land use change dynamics in Ecuador*, Agricultural Systems 61 (2): 77-93

Döll, P., G. Petschel-Held, and R. Leemans 2002. *Scale issues in scenario development* In International Workshop of the Future - The Future of Scenarios, Center for Environmental Systems Research, University of Kassel, July

Dreborg, K. H., 1996. *Essence of backcasting*, Futures 28 (9): 813-828

Dreborg, K. H 2004. *Scenarios and structural uncertainty*, Department of Infrastructure, Royal Institute of Technology, Stockholm, Sweden, 60 p

Ducot, C., and H. J. Lubben., 1980. *A typology for scenarios*, Futures 12 (1): 15-57

Etienne, M., and C. Le Page 2002. *Modelling contrasted management behaviours of stakeholders facing pine encroachment process: an agent-based simulation approach*, Pages 208-213 In Integrated assessment and decision support, iEMSs "1st biennial meeting of the International Environmental Modelling and Software Society" June 24-27, A. E. Rizzoli, and A. J. Jakeman editors., Lugano, Switzerland

Etienne, M., C. Le Page, and M. Cohen., 2003. *A Step-by-Step Approach to Building Land Management Scenarios Based on Multiple Viewpoints on Multi-agent System Simulations*, Journal of Artificial Societies and Social Simulation 6 (2): 1-27

Etienne, M. and H. Rapey 1999. *Analyse par simulation de l'effet de techniques agroforestières sur le fonctionnement d'exploitations agricoles* In Colloque final AIP AGRIFOR Cemagref-INRA, Clermont-Ferrand, 20-21 octobre 1999, Cemagref Editions, Antony, Pages 115-116

Finlay P. N. 1994. *Introducing decision support systems*, Oxford, UK Cambridge, Mass., NCC Blackwell, Blackwell Publishers

Folke, C., T. Hahn, P. Olsson, and J. Norberg., 2005. *Adaptive governance of social-ecological systems*, Annual Review of Environment and Resources 30: 441-473

Funtowicz, S. O., and J. R. Ravetz., 1993. *Science for the post-normal age*, Futures 25 (7): 739-755

Gault, F. D., K. E. Hamilton, R. B. Hoffman, and B. C. McInnis., 1987. *The design approach to socio-economic modelling*, Futures 19 (1): 3-25

Gimblett, H., M. Richards, and R. Itami., 1998. *A complex systems approach to simulating human behaviour using synthetic landscapes*, Complexity International 6

Global Business Network., 1998. *Destino Colombia*, Deeper News 9 (1)

Godet, M. 1997. *Scenarios and strategies: A toolbox for scenario planning,* Conservatoire National des Arts et Métiers (CNAM)

Godet M. 2001. *Manuel de prospective stratégique, tome 1 Une indiscipline intellectuelle*, Dunod

Godet, M., and F. Roubelat., 1996. *Creating the future: The use and misuse of scenarios. Version du 04/07/2003,* Long Range Planning 29 (2): 164-171

Green, K., and P. Vergragt., 2002. *Towards sustainable households: a methodology for developing sustainable technological and social innovations*, Futures 34: 381-400

Greeuw, S. C. H., van Asselt, M. B. A., Grosskurth, J., Storms, C. A. M. H., Rijkens-Klomp, N., Rothman, D. S., and Rotmans, J. 2000. *Cloudy crystal balls: an assessment of recent European and global scenario studies and models*, European Environment Agency, Copenhagen, Denmark, 96 p

Gunderson, L. H. and Holling, C. S. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*, Gunderson, L. H. and Holling, C. S. (Eds.), Island Press, Washington, D.C.

Hammond A. 1998. *Which World? Scenarios for the 21st century, Global destinies, regional choices*, Earthscan Publications Ltd., London

Harris, G., 2002. *Integrated assessment and modelling: an essential way of doing science*, Environmental Modelling and Software 17: 201-207

Henrichs, T. 2003. *Environmental Scenario Analysis - Overview and Approaches* In Global Environmental Change and Food Systems (GECAFS) Meeting, Comprehensive Scenarios "Initial Workshop", Reading, UK

Herimandimby, V., E. Randriajaona, O. Barreteau, F. Bousquet, and J. Weber 1998. *Systèmes multi-agents et démarche patrimoniale : Utilisation de jeux de rôle*, Pages 261-278 In Modèles et systèmes multi-agents pour la gestion de l'environnement et des territoires, N. Ferrand editor., Cemagref Editions

Heugens, P. M. A. R., and J. van Oosterhout., 2001. *To boldly where no man has gone before: integrating cognitive and physical features in scenario studies*, Futures 33 (10): 861-872

Hisschemöller, M. and Mol, A. P. J. 2002. *Climate OptiOns for the Long-Term (COOL) Evaluating Dialogues*, 410 200 119, Hisschemöller, M. and Mol, A. P. J. (Eds.), Dutch National Research Programme on Global Air Pollution and Climate Change

Höjer, M., and L. G. Mattsson., 2000. *Determinism and backcasting in future studies*, Futures 32 (7): 613-634

Holling C. S. 1978. *Adaptive environmental assessment and management*, ed Holling C.S., International Institute for Applied Systems Analysis, 377 p

Holling, C. S., F. Berkes, and C. Folke 1998. *Science, sustainability and resource management*, Pages 342-362 In Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, F. C. Berkes, C. Folke, and J. Colding editors., Cambridge University Press, Cambridge

Huston, M., D. DeAngelis, and W. Post., 1988. *New computer models unify ecological theory*, Bioscience 38: 682-691

Inayatullah S. 2005. *The Causal Layered Analysis (CLA) reader: theory and case studies of an Integrative and Transformative Methodology,* ed Inayatullah S., Tamkang University Press, Taipei, 576 p

Kahn H., and A. Wiener 1967. *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years*, Macmillan, New York

Kaimowitz D., and A. Angelsen 1998. *Economic models of Tropical Deforestation A Review*, Center of International Forestry Research, Bogor

Kok, K., D. S. Rothman, and M. Patel., 2006. *Multi-scale narratives from an IA perspective: Part I. European and Mediterranean scenario development*, Futures 38 (3): 261-284

Kruseman, G., and J. Bade., 1998. *Agrarian Policies for Sustainable Land Use: Bio-economic Modelling to Assess the Effectiveness of Policy Instruments,* Agricultural Systems 58 (3): 465-481

La Rovere, R., P. Hiernaux, H. Keulen, J. Schiere, and J. Szonyi., 2005. *Co-evolutionary scenarios of intensification and privatization of resource use in rural communities of south-western Niger*, Agricultural Systems 83 (3)

Lambin, E. F., and H. J. Geist., 2002. *Global land-use and cover change: What have we learned so far?*, Global Change Newsletter 46: 27-30

Lambin, E. F., M. D. A. Rounsevell, and H. J. Geist., 2000. *Are agricultural land-use models able to predict changes in land-use intensity?*, Agriculture, Ecosystems and Environment 83 (1-3): 321-331

Lancker, E. and Nijkamp, P 1999. *A policy scenario analysis of sustainable agricultural development options. A Case Study for Nepal*, Report n°0003, Free University Amsterdam, Faculty of Economics, Business Administration and Econometrics. Serie Research Memoranda, 22 p

Le Ber, F., A. Dury, V. Chevrier, and M. Benoit 1999. *Simuler l'organisation spatiale d'un territoire agricole: différentes approches* In Modèles et Systèmes Multi-Agents pour la Gestion de l'Environnement et des Territoires, N. Ferrand editor., Cemagref Editions

List, D. 2005. *Scenario Network Mapping: The Development of a Methodology for Social Inquiry*, University of South Australia, 394 p

Lonnroth, M., T. B. Johansson, and P. Steen., 1980. *Sweden beyond Oil: Nuclear Commitments and Solar Options*, Science 208 (4444): 557-563

Lu, C. H., M. K. Van Ittersum, and R. Rabbinge., 2004. *A scenario exploration of strategic land use options for the Loess Plateau in northern China*, Agricultural Systems 79: 145-170

Lynam, T., F. Bousquet, C. Le Page, P. D'Aquino, O. Barreteau, F. Chinembiri, and B. Mombeshora., 2002. *Adapting science to adaptive managers: spidergrams, belief models, and multi-agent systems modeling*, Conservation Ecology 5 (2): -24

MacNulty, C. A., 1977. *Scenario development for corporate planning*, Futures 9: 128-138

Manson, S. M., 2002. *Tools for Land Use Analysis on Different Scales with Case Studies for Costa Rica (Book Review),* Journal of Artificial Societies and Social Simulation 4 (3): -R1

Marien, M., 2002. *Futures Studies in the 21st Century: a reality based view*, Futures 34 (3-4): 261-281

McCorduck P., and N. Ramsey 1996. *The futures of women: scenarios for the 21st century*, Warner Books, New York

Mermet, L., I. Dubien, A. Emerit, and Y. Laurans., 2004. *Les porteurs de projets face à leurs opposants : six critères pour évaluer la concertation en aménagement*, Politique et aménagement public 1: 1-22

Moyer, K., 1996. *Scenario planning at British Airways-A case study*, Long Range Planning 2: 172-181

Munier, B., K. Birr-Pedersen, and J. S. Schou., 2004. *Combined ecological and economic modelling in agricultural land use scenarios*, Ecological Modelling 174 (1-2): 5-18

Organisation for Economic Co-operation and Development 1999. *Transport and Environment: Synthesis of OECD Work on Environment and Transport and Survey of related OECD, IEA and ECMT Activities*, Environment Directorate, Paris, 70 p

Ostrom E. 1990. *Governing the commons. The evolution of Institutions for collective action*, Cambridge University Press, 280 p

Parker, D. C., S. M. Manson, M. A. Janssen, M. J. Hoffman, and P. Deadman., 2003. *Multi-Agent Systems for the Simulation of Land-Use and Land-Cover Change: A Review*, Annals of the Association of American Geographers 93 (2): 314-337

Parker, P., R. Letcher, A. Jakeman, M. B. Beck, G. Harris, R. M. Argent, M. Hare, C. Pahl-Wostl, A. Voinov, and M. Janssen., 2002. *Progress in integrated assessment and modelling*, Environmental Modelling & Software 17 (3): 209-217

Penning de Vries, F. W. T., H. van Keulen, and R. Rabbinge 1995. *Natural resources and limits of food production in 2040*, Pages 65-87 In Eco-regional approaches for sustainable land use and food production, J. Bouma, A. Kuyvenhoven, B. A. M. Bouman, J. C. Luijten, and H. G. Zandstra editors., Kluwer Academic Publishers, Dordrecht, The Netherlands

Polak F. 1973. *The Image of the Future*, ed Sythoff A.W., Leyden, New York

Quist, J., and P. Vergragt., 2006. *Past and future of backcasting: The shift to stakeholder participation and a proposal for a methodological framework*, Futures In Press, Corrected Proof

Raskin, P., Gallopin, G., Gutman, P., Hammond, A., and Swart, R. 1998. *Bending the Curve: Toward Global Sustainability*, Report to the Global Scenario Group, Stockholm Environment Institute, Stockholm, Sweden, 81 p

Raskin, P., F. Monks, T. Ribeiro, D. van Vuuren, and M. Zurek 2005. *Global Scenarios in Historical Perspective* In Ecosystems and Human Well-being: Scenarios, Volume 2. Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment, Chapter 2 of Scenarios Working Group Assessment Report, Millennium Ecosystem Assessment, S. R. Carpenter, P. R. Pingali, E. M. Bennet, and M. B. Zurek editors., Island Press, Whashington

Ringland G. 1998. *Scenario planning*, John Wiley & Sons, Chichester

Rist, S., M. Chidambaranathan, C. Escobar, U. Wiesmann, and A. Zimmermann., 2006. *Moving from sustainable management to sustainable governance of natural resources:*

The role of social learning processes in rural India, Bolivia and Mali, Journal of Rural Studies In Press, Corrected Proof

Ritchey, T. 1998. *General Morphological Analysis. A general method for non-quantified modelling* In Adapted from the paper "Fritz Zwicky, Morphologie and Policy Analysis", presented at the 16th EURO Conference on Operational Analysis, Brussels

Robinson, J., 1982. *Energy backcasting: a proposed method of policy analysis*, Energy Policy 10 (4): 337-344

Robinson, J., 2003. *Future subjunctive: backcasting as social learning*, Futures 35 (8): 839-856

Robinson, J. B., 1990. *Futures under glass: A recipe for people who hate to predict*, Futures 22 (8): 820-842

Rotmans J., and B. de Vries 1997. *Perspectives on global change: The TARGETS approach*, Cambridge University Press, Cambridge

Rotmans, J., M. B. A. van Asselt, C. Anastasi, S. Greeuw, J. Mellors, S. Peters, D. Rothman, and N. Rijkens., 2000. *Visions for a sustainable Europe*, Futures 32: 809-831

Rotmans, J., van Asselt, M. B. A., de Bruin, A. J., den Elzen, M. G. J, de Greef, J., Hilderink, H., Hoekstra, A. Y., Janssen, M. A., Köster, H. W., Martens, W. J. M., Niessen, L. W., and de Vries, H. J. M. 1994. *Global change and sustainable development, a modelling perspective for the next decade*, National Institute of Public Health and Environmental Protection (RIVM).

Rounsevell, M. D. A., I. Reginster, M. B. Araujo, T. R. Carter, N. Dendoncker, F. Ewert, J. I. House, R. Kankaanpää, R. Leemans, M. J. Metzger, C. Schmit, P. Smith, and G. Tuck., 2006. *A coherent set of land use change scenario for Europe*, Agriculture, Ecosystems and Environment 114 (1): 57-68

Roux, P., 1992. *The Mont Fleur Scenarios. What will South Africa be like in the year 2002?*, Deeper News 7 (1): 1-22

Schneider, S. H., 1997. *Integrated assessment modelling of global climate change: Transparent rational tool for policy making or opaque screen hiding value-laden assumptions?*, Environmental Modelling and Assessment 2: 229-249

Schroth, O. and Wissen, U., 2004. Draft Paper on the Use of the Scenario Method in the Visulands Project, Unpublished Work

Schwartz P. 1991. *The Art of the long view: Planning for the future in an uncertain world*, Doubleday Publications, New York, 258 p

Sharma, M., and B. G. Norton., 2005. *A policy decision tool for integrated environmental assessment*, Environmental Science & Policy 8 (4): 356-366

Shearer, A. W., 2005. *Approaching scenario-based studies: three perceptions about the future and applications for landscape planning*, Environment and Planning B: Planning and Design 32 (1): 67-87

Shoemaker, P. J. H., 1993. *Multiple scenario development: its conceptual and behavioral foundation*, Strategic Management Journal 14: 193-213

Siebenhüner, B., and V. Barth., 2005. *The role of computer modelling in participatory integrated assessments*, Environmental Impact Assessment Review 25: 367-389

Simon, C. and Etienne, M., 2006. Modélisation d'accompagnement, aménagement forestier et gestion paysanne des forêts, Unpublished Work

South Wind Design 2001. *Window on the Future: a Scenario Planning Primer*, Michigan

Stoorvogel, J., and J. M. Antle., 2000. *Regional Land Use Analysis: The Development of Operational Tools*, Agricultural Systems 70 (2-3): 623-640

Stoorvogel, J. J., 1995. *Integration of computer-based models and tools to evaluate alternative land-use scenarios as part of an agricultural systems analysis*, Agricultural Systems 49 (4): 353-367

Tansey, J., J. Carmichael, R. VanWynsberghe, and J. Robinson., 2002. *The future is not what it used to be: participatory integrated assessment in the Georgia Basin*, Global Environmental Change 12 (2): 97-104

Toth, F. L. 2001. *Participatory integrated assessment methods: An assessment of their usefulness to the European Environment Agency*, EEA (European Environment Agency), Copenhagen

Turban E. 1995. *Decision support and expert systems : management support systems*, Prentice Hall, Englewood Cliffs, N.J.

United Nations Environment Programme 2002. *Global environment outlook 3: Past, present and future perspectives*, Earthscan, London, 416 p

van Asselt M. B. A. 2000. *Perspectives on Uncertainty and Risk: The PRIMA approach to decision support*, Kluwer Academic Pub, Dordrecht, The Netherlands

van Asselt, M. B. A., Mellors, J., Rijkens-Klomp, N., Greeuw, S. C. H., Molendijk, K. G. P., Beers, P. J., and van Notten, P. W. F. 2001. *Building blocks for participation in integrated assessment: a review of participatory methods*, ICIS Working Paper I01-E003, ICIS, Maastricht, the Netherlands, 71 p

van Asselt, M. B. A., and N. Rijkens-Klomp., 2002. *A look in the mirror: reflection on participation in Integrated Assessment from a methodological perspective*, Global Environmental Change 12: 167-184

van den Belt M. 2004. *Mediated Modelling. A system dynamics approach to environmental consensus*, Island Press, 339 p

van der Heijden K. 2004. *Scenarios: The Art of Strategic Conversation*, 2nd Edition, ISBN: 0-470-02368-6, Hardcover, Wiley, 380 p

Van Ittersum, M. K., N. de Ridder, R. P. Roetter, C. T. Hoanh, A. G. Laborte, and H. van Keulen 2003. *Agronomy and Policy Design: Tackling the 'where, what and how' Questions* In 11th Australian Agronomy Conference, Australian Society of Agronomy

Van Ittersum, M. K., R. Rabbinge, and H. C. van Latensteijn., 1998. *Exploratory land use studies and their role in strategic policy making*, Agricultural Systems 58 (3): 309-330

van Notten, P. W. F., and J. Rotmans., 2001. *The future of scenarios*, Scenario and Strategy Planning 3 (1): 4-8

van Notten, P. W. F., J. Rotmans, M. B. A. van Asselt, and D. S. Rothman., 2003. *An updated scenario typology*, Futures 35: 423-443

van't Klooster, S. A., and M. B. A. van Asselt., 2006. *Practising the scenario-axes technique*, Futures 38: 15-30

Veldkamp, A., and L. O. Fresco., 1996. *CLUE: a conceptual model to study the Conversion of Land Use and its Effects*, Ecological Modelling 85 (2-3): 253-270

Veldkamp, A., and E. F. Lambin., 2001. *Predicting land-use change*, Agriculture, Ecosystems and Environment 85: 1-6

Verburg, P., P. Schot, M. Dijst, and A. Veldkamp., 2004. *Land use change modelling: current practice and research priorities*, GeoJournal 61 (4): 309-324

Verburg, P. H., C. J. E. Schulp, N. Witte, and A. Veldkamp., 2006. *Downscaling of land use change scenarios to assess the dynamics of European landscapes*, Agriculture, Ecosystems & Environment 114 (1): 39-56

Von Bertallanffy L. 1968. *Théorie générale des systèmes*, Dunod, Paris

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, M. Janssen, L. Lebel, J. Norberg, G. D. Peterson, and R. Pritchard., 2002. *Resilience management in social-ecological systems: a working hypothesis for a participatory approach*, Conservation Ecology 6 (1): **6**(1): 14.

Walker, B., C. S. Holling, S. Carpenter, and A. Kinzig., 2004. *Resilience, adaptability, and transformability in social-ecological systems*, Ecology and Society 9 (2)

Westhoek, H. J., M. van den Berg, and J. A. Bakkes., 2006. *Scenario development to explore the future of Europe's rural areas*, Agriculture, Ecosystems and Environment 114: 7-20

White, S. S., 2001. *Public participation and organizational change in Wisconsin land use management*, Land Use Policy 18: 341-350

Wittmer, H., F. Rauschmayer, and B. Klauer., 2006. *How to select instruments for the resolution of environmental conflicts?*, Land Use Policy 23: 1-9

Wollenberg E., D. Edmunds, and L. Buck 2000. *Anticipating Change: Scenarios as tool for adaptive forest management - A guide*, SMT Grafika Desa Putera, Center for International Forestry Research, Bogor, Indonesia, 40 p