

Participatory scenario analysis for integrated regional modelling

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Abstract

Integrated numerical modelling, scenario analysis and participatory approaches have become common approaches to investigate possible future regional development in sustainability research. But in accordance with disciplinary backgrounds, the literature on specific case studies shows still great biases towards either qualitative social science or the numerical modelling perspective. By presenting a comprehensive case study on changes in agriculture for the Alpine region of Davos, Switzerland, the role of the participatory involvement and to what degree it was found instrumental in defining the scenarios for numerical simulation are discussed, and methodological benefits and limitations are outlined in this contribution. In the presented case study, the participatory process was intended to fulfil two functions: First, it aimed to support the elaboration of regional scenarios including their preparation for numerical simulation through an Input–Output Model, a Resource Flux Model, a Land Use Allocation Model and Ecosystem Service Validation; second, raising the issue of long-term development and capacity-building within the region and amongst key stakeholders was an important goal. In the course of the project, the participatory process proved very useful with regard to interest raised amongst the local participants. However, it could not contribute to the elaboration of scenarios for numerical simulation as much as expected. Reasons for that were (1) limitations in the numerical models so that the complexity of the system and the range of possible scenarios had to be reduced for scenario simulation, (2) the “bottleneck” between qualitative and quantitative data which had to be overcome, and (3) a shift in priorities for the participatory process towards capacity building in the course of the project which hindered the in-detail elaboration of scenarios for numerical simulation to some extent. From the presented case study and the relevant literature, recommendations to improve the integration of qualitative participatory and quantitative, model-based techniques are finally drawn.

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1. Introduction

Sustainability is increasingly being considered in regional development and holistic landscape research. In order to improve long-term regional development, it is helpful to understand how a region might react in response to socio-economic, political and environmental changes. This, however, is a complex and challenging problem which is ideally addressed by inter- and transdisciplinary approaches that goes beyond the boundaries of academic disciplines or single stakeholder groups (e.g. Naveh, 2000; Nowotny et al., 2005; Tress et al., 2003). These

issue-oriented approaches reflect the diversity, complexity and dynamics of the processes involved and take the knowledge of people involved and their interests at stake into account (Hirsch Hadorn et al., 2006).

Some of the approaches regularly applied in sustainability research are integrated numerical modelling, scenario analysis and various forms of participatory involvement (Hirsch Hadorn et al., 2006; Swart et al., 2004). Each of these methodologies has proved useful in the assessment of regional development, and they have been successfully used in various combinations (e.g. Alcamo, 2001; Antunes et al., 2006; Greiner, 2004; Tress and Tress, 2003).

Integrated numerical modelling allows the analysis and simulation of complex relationships between socio-economic, environmental and regulatory issues in regional development.

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Such models combine multiple disciplinary approaches (e.g. Rotmans and van Asselt, 1996) and are considered powerful tools for informing decision-making in policy and planning processes, especially if the cognitive and institutional limitations of the stakeholders and decision-makers involved are taken into account (e.g. Greiner, 2004). These numerical models use socioeconomic and ecological quantitative data on, for instance, the number of permanent residents, the number of employees, or the extent of certain land-uses. Although models of varying degrees of complexity are available (e.g. Greiner, 2004), their use for assessing future development and long-term sustainability is limited by the availability of quantitative data projected into the future (Kemp-Benedict, 2004).

Different techniques have been applied to derive quantitative estimates of future situations, such as extrapolation (e.g. Schönwiese, 1994) or forecasting based on process-based or statistical modelling using up-to-date measurements (e.g. Brabec et al., 2001; Vested et al., 1992). Such methods, however, are not considered appropriate for regional development issues because of uncertainties that include a wide range of possibly interacting aspects (e.g. consumer behaviour, regional marketing strategies, or changes in the attractiveness of landscapes) and several hierarchical levels (e.g. international markets, regional planning, or household-level decision-making). The most frequently used and valued technique to explicitly take into account these uncertainties is scenario analysis, as it allows to describe plausible future scenarios that contain these major uncertainties (e.g. Rockafellar and Wets, 1991). Scenarios describe potential future developments based on the present situation and logical chains of plausible events and their interactions (Rotmans et al., 2000; van den Berg and Veeneklaas, 1995) and have a strong tradition in the quantitative as well as qualitative sciences (Swart et al., 2004).

In regional development research, scenario analysis has often been linked with participatory approaches as local actors usually have considerable local knowledge and can thus provide information on “how the region works” (e.g. Kok et al., 2004). Here we define local system knowledge as the insights of individuals into the socio-economic, administrative, cultural, political and environmental dynamics within a particular region. Local system knowledge is mainly qualitative as it refers preliminarily to cause–effect relations between boundary conditions, decision-makers and activities (referred to as “factors, actors and sectors” in Kok et al., 2006). In previous studies, local actors have contributed either directly to the development of specific regional scenarios (e.g. Kok et al., 2003) or they have elaborated qualitative models of the local system, which provided a basis for subsequent scenario development by the researchers (e.g. Flückiger et al., 1998).

Procedures of combining all three techniques, however, have as yet been rarely described in detail in the literature. We find that scientific publications derived from such research design are mostly either biased towards aspects of qualitative social science (e.g. Soliva, 2007) or towards those of numerical modelling (e.g. Carmichael et al., 2004). One of the main reasons for these biases is that the boundary between quantitative and qualitative data has to be overcome in the process of such research design. This,

however, remains a major challenge in integrated, participatory and interdisciplinary research (Kok and van Delden, 2004; Pahl-Wostl, 2002).

In this study we explicitly address and discuss this aspect based on an example for the Swiss Alpine region of Davos. In this case study, a scenario analysis is conducted to investigate the possible impacts of a radical decrease in support for the local mountain agriculture. For that we combine a participatory approach and integrated numerical modelling in a scenario analysis. The questions to be addressed in the scenario analysis are: What are possible socioeconomic and ecological consequences for the regions? And, to what degree do these effects differ with regard to the identified uncertainties?

By presenting the comprehensive procedure, we outline the principal methodological benefits and limitations of combining participatory involvement and numerical modelling in such a scenario analysis. Within this context, we further discuss the role of the participatory involvement, and to what degree it was found instrumental in defining the scenarios for numerical simulation. Our main objective here is to assess the methodological implications of the combined approach and to identify its strengths and weaknesses.

2. Study area and relevant problems within the region

Davos is a mountain resort town at 1560 m a.s.l. in the canton of Grisons, Switzerland, with a population of around 11,000 permanent residents and up to 28,000 tourists during the high season in winter (Fig. 1). The local economy has been strongly dominated by tourism since 1865, when building of health resorts commenced. Within a few decades an urban centre had emerged from two of the many scattered settlements which formed the community of Davos, and already by 1910 the number of overnight stays exceeded 1 million. When winter sports began in the 1950s, Davos developed into one of the most popular mountain resorts in Switzerland, with about 2.5 million overnight stays in 2000.

While the main settlement with the urban centre is quite densely populated, the surrounding area has maintained its rural character, with scattered villages and a typical alpine landscape shaped by traditional mountain agriculture. In 1950 there were 120 farms in the area of which about 90 still remained in 2000, most of them obtaining a secondary income from tourism. While the farming activities in the region have constantly decreased as of the end of the 19th century, the forest area has gradually expanded. This is considered as one of the principal threats to landscape attractiveness (Bätzing, 2004; Messerli, 1989), with possible negative consequences on the tourist industry.

Changes that could well affect the development of the Alpine region of Davos include: (a) landscape and economic changes resulting from decreasing subsidies for mountain agriculture and the liberalisation of markets, (b) climate change, which is likely to have impacts on tourist demand and the skiing industry, and (c) changes in the region’s popularity as a tourist destination through the organisation of a mega-event. For each of these issues, scenarios were defined based on qualitative local knowledge, and further investigated with the numerical modelling

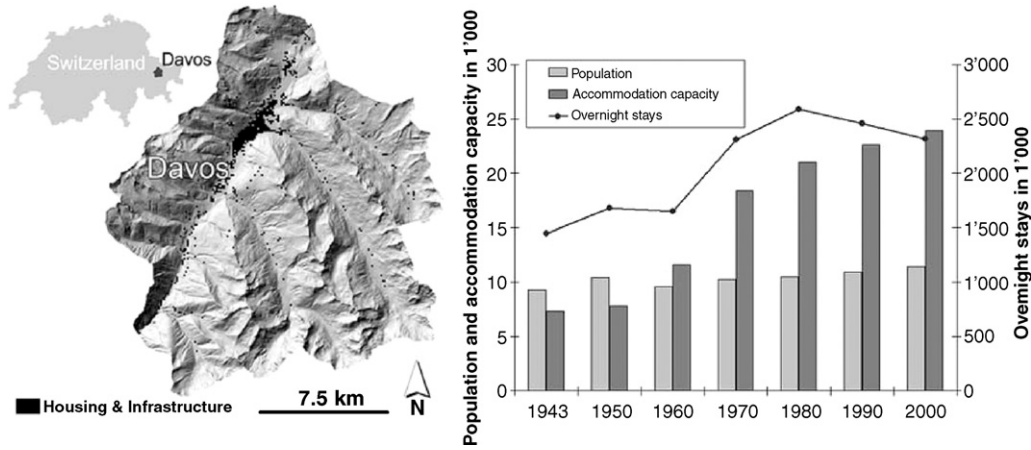


Fig. 1. Location and topographic overview over Davos and its tourism and population development since 1940s.

framework of ALPSCAPE (Bebi et al., 2005; von Ballmoos and Bebi, 2003). In this contribution, we focus on the issue of decreasing subsidies for mountain agriculture and liberalisation of markets to demonstrate the complete methodological procedure and to subsequently discuss the advantages and drawbacks of the participatory approach to the scenario analysis.

3. Methodological approach

In this study we combined three approaches to regional development with regard to a sustainable future: integrated numerical modelling, scenario analysis and participatory involvement. We developed an integrated numerical modelling framework to depict complex interrelations between the regional economy, resource and land use, and ecosystem services within our study area. Two scenarios were designed for numerical simulation,

depicting fundamental uncertainties with regard to regional development. In order to improve these regional scenarios, and to ensure their relevance to the region and their acceptance amongst the local population, local stakeholders were invited to participate in the project.

3.1. Overview of the integration process

We describe first the overall framework of the integration approach, and then present the sequence of individual techniques to develop and simulate the scenarios. The entire scenario analysis, consisting of the participatory scenario development and numerical simulation, is displayed as a circular process in Fig. 2, beginning with the involvement of local actors in participatory workshops and ending in joint discussions on the results of the scenario analysis with them.

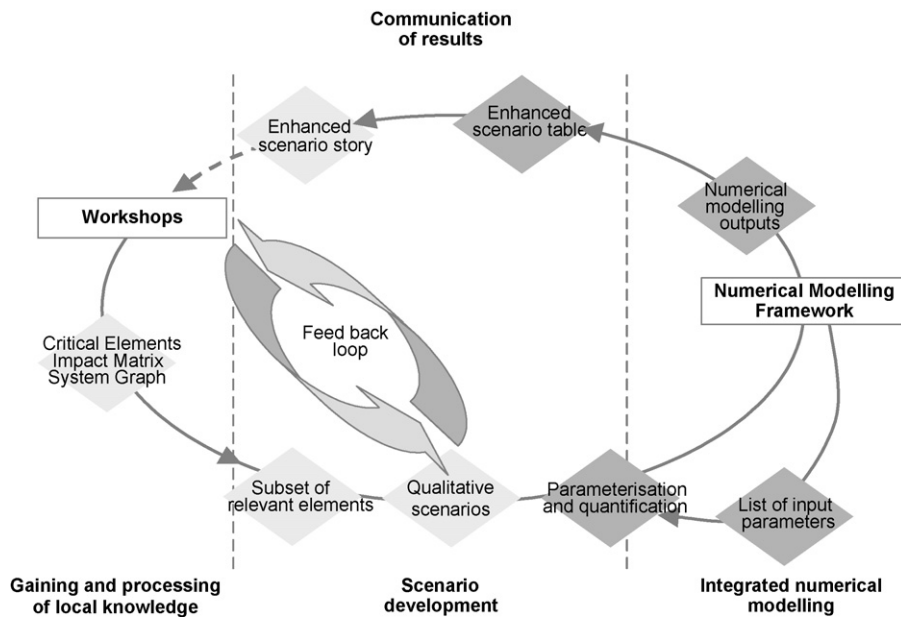


Fig. 2. Schematic representation of the integrated scenario analysis, including the participatory scenario development, the preparation of scenarios for numerical modelling and the simulations. The diamonds show the different datasets and how they evolve from each other. The light grey diamonds represent quantitative system knowledge and the dark grey diamonds represent model-based numerical knowledge.

In the initial workshops, local system knowledge was elicited and then further processed by the research team. The resulting qualitative system models identified the principal actors, their interests and the underlying regional boundary conditions, and outlined how these were interrelated. For the development of each scenario, a subset of relevant elements was selected. The qualitative scenarios were drawn from a logical sequence of plausible or likely events and the decisions for each of these elements. The process of scenario development included a feedback loop with the workshop participants to validate the scenario’s relevance and logic for the region.

A comprehensive list of modelling input parameters was drawn from the modelling framework, to further elaborate the qualitative scenarios for numerical simulation. The list provided the basis for parameterising the scenarios, i.e. for “coding” the scenarios for modelling. To determine the input values for the simulations, the parameters were quantified with the help of an in-depth literature review (Lardelli and Lundström, unpublished data). In the next step, these values were used in the integrated modelling framework to simulate the scenarios and feed the results into the scenario table. The enhanced scenario table was the basis for an “enhanced scenario story”, which allowed an effective back-communication of results to local stakeholders.

3.2. The numerical modelling framework

A regional model is a representation of a complex system. It behaves similarly to the real-world system and can be broadly experimented with to eventually support decision-making. The numerical modelling framework of ALPSCAPE is a good example of a modelling tool for regional development. It depicts inter-related processes of land use change, resource fluxes and economic issues by combining three simulation models, i.e. a Land Use Allocation Model, a regional Input–Output Model and a Resource Flux Model (Fig. 3).

The economic and the resource models consist of flux models. Both modelling approaches have been used in regional studies before (e.g. Aroca, 2001; Baccini and Bader, 1996; Fritz et al., 2003; Hug and Baccini, 2002; Isard, 1998). These two flux models provide the basis for selecting indicators of economic

and resource-related sustainability for the region, such as the added value to the region through certain economic activities, e.g. agriculture, tourism; or the degree of self-sufficiency (Hug and Baccini, 2002).

The regional Input–Output Table reflects the economic inter-relationships between different sectors by quantifying economic fluxes between them. The resource flux model operates similarly, but displays material and energy fluxes between producers, processing industry, and end-users. Within the ALPSCAPE modelling framework, food and energy are the target resources in the resource flux analysis, as they are the most important generated within the study region. Import and export are crucial aspects in both models and relate directly to the boundaries of the study area.

The Land Use Allocation Model consists of an enhanced cellular automaton based on statistical models (Walz et al., 2004), which calculates the most likely land-use pattern according to changing demands on land for particular land-use classes. The simulation results are used to derive indicators of landscape-related sustainability based on landscape metrics (e.g. McGarigal and Marks, 1995). Such indicators include the length of the boundary between forest and open land and Shannon’s Diversity Index (e.g. Hietala-Koivu et al., 2004) which stand for landscape attractiveness and biodiversity at the landscape scale, respectively. Additionally, the Land Use Allocation Model provides the basis for evaluating changes in ecosystem services for the simulated scenarios.

To indicate environmental changes and any resulting economic loss for the region, modifications in ecosystem services are derived for a set of services. The services investigated include the protection against snow avalanches, habitat modification for the capercaillie (*Tetrao urogallus*), and landscape attractiveness (Grêt-Regamey et al., in press-b). The monetarisation of these ecosystem services are based on a risk analysis for the protection function, on restoration costs for the habitat function, and on a willingness-to-pay survey for the scenic beauty assessment.

An additional model with specific focus on the local agricultural structures was applied for the agricultural scenario. This Local Agriculture Model includes parameters of agricultural production at the level of local farming structures. It differen-

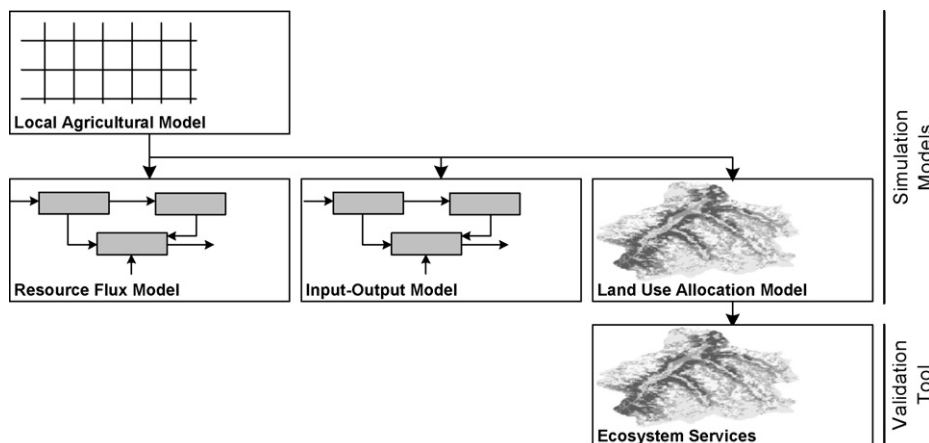


Fig. 3. Simplified representation of the ALPSCAPE modelling framework.

tiates between intensities of production and allows estimates on land requirements and production volumes on the basis of structural change in farming. Shifts in the agricultural markets and reduction in subsidies lead to such changes in farming structures, and their consequences for land requirements and production volume can be estimated by the Local Agricultural Model (Bebi et al., 2005).

The input parameters for the numerical modelling framework form the key to implementing the scenario and simulating further effects. The simulation of complex scenarios involves the simultaneous alteration of several input parameters in the modelling framework. A complete list of possible input and output parameters for all models was assembled in order to gain a comprehensive overview of the input, regulative, and output parameters, which can be altered for scenario simulation or transferred to another simulation model.

3.3. Obtaining and processing local system knowledge

Because several topics needed to be addressed through scenario analyses within the ALPSCAPE project, local system knowledge was first investigated independently of any particular scenario. The focus of the participatory workshops was to obtain an improved understanding of the structure, stability and resilience of the study area. In a later stage of collaboration, scenarios prepared by the researchers were discussed with the participants and adapted to their feedback.

The workshop participants comprised key stakeholders, such as policy-makers and official representatives of stakeholder groups, as well as representatives of the general public. The group covered a diverse spectrum of specific interests, of active involvement in the regional development process, and in relevance of their decision-making to the public. Because of their differing backgrounds, we refer to the participants as “local actors”.

3.3.1. Organisation of workshops and selection of participants

A four-step-approach was applied to optimise the knowledge gathering process in the workshops. In the first workshop, representatives of the local government, of different stakeholder groups (e.g. tourism, agriculture) and the general public (e.g. teachers, pastors) were invited to form an advisory group. The participants of the advisory group were selected in accordance to their function in various stakeholder groups. Generally, official or at least well-respected local representatives were personally invited to join the advisory group. Their tasks were to establish a common understanding of the research question, and to ensure the relevance of the study and the scenarios to the local community.

To increase the number of people involved and to thus improve the representativeness of the workshops' outcome, each representative was asked to find at least another five people and to convene a satellite group. The participants of the advisory group independently selected the members of the satellite group according to a snowball system. In a second step, a series of six workshops were organised in which the satellite groups met to

establish regional system models from their individual perspectives. Due to the differing background of each group, the individual outcomes of each satellite group could be used to focus on specific issues. For example, the results of the satellite group “agriculture” were directly re-examined in developing the scenario on agricultural policies. In contrast, the results of the group “tourism” and the group “construction” were of greater relevance for scenarios of climate change and on a mega-event which are not presented in this contribution, but in Bebi et al. (2005).

During an advisory group meeting in a subsequent workshop, the results of the satellite groups' work, qualitative scenarios, and first modelling results were presented and discussed. In the final workshop with the advisory group, we presented the simulation results and the conclusions drawn from them, and discussed their relevance for future decision-making, while exploring means how to disseminate these results among the local population.

3.3.2. Qualitative system models in satellite groups

In order to elaborate a graphical system model for each satellite group, we used the methodology of sensitivity models described in Vester and von Hesler (1980), which has often been applied since (e.g. Scholz and Tietje, 2002). The participants in the satellite groups were asked to identify the elements within the region they considered most relevant for the development of the region. These elements could include “factors, actors and sectors” (according to Kok et al., 2003; Rotmans et al., 2000), such as environmental conditions, social values, stakeholders, interests groups or economic sectors. After an initial brainstorming session, the satellite group condensed these elements down to the 17 most critical elements by aggregation and elimination of elements, while common definitions of these elements were agreed upon. The condensation was performed mainly by aggregation of elements and also by elimination of single elements as agreed upon in the group discussion.

The condensed set of elements was entered into a symmetrical impact matrix, so that the impact of one element on any other could be estimated within the matrix in a rating score. The maximum number of 17 elements kept the extent of this impact matrix at a manageable size. Following the suggestions in Vester and von Hesler (1980) and Scholz and Tietje (2002), the participants were asked to assess only direct impacts of one element on another, and to take care not to include indirect impacts an element might have through other elements. Each member of the satellite group filled in the impact matrix individually using a four-level rating scale: 0 = “no or very little impact”, 1 = “medium impact”, 2 = “high impact”, 3 = “very high impact”. The matrices of all participants were then combined in a single matrix, which represented the average ranking of the group.

The impact matrices indicate characteristic qualities for each element, such as “Impact Strength” and “Involvement” (Scholz and Tietje, 2002). Both measures are based on the sum of all impacts that one element has on all others (sum of rows = “active sum”), and that one element experiences from all others (sum of column = “passive sum”). The “Impact Strength” is calculated by dividing the active sum by the passive sum for each element;

it identifies the elements that have strong impacts on other elements and are also prone to external impacting. If the ratio is >1 , the element has an active role in the system, if it is <1 , the element is strongly influenced by other elements. The “involvement” is calculated by multiplying the active and passive sums of an element and shows how strongly an element is interlinked with the system.

To benefit from particular insights of each satellite group, each group was asked to explicitly assess the regional system from their own perspective by selecting the elements most relevant to them and by their ratings. Consequently, the set of elements considered most relevant and the rankings differed substantially between satellite groups, and provided – with a certain overlap between all groups – more detailed information for particular fields.

3.4. Scenario development

Due to the ability to account for uncertainties, the scenario technique is an adapted and well-established method to illustrate potential future development of highly complex systems (de Jouvenal, 1967; Kahn and Wiener, 1967). Scenarios are described as “hypothetical sequences of future events” (Kahn and Wiener, 1967). As such, they can describe the dynamic development of complex systems, representing plausible sequences of events over a period of time. Scenarios do not predict, instead they acknowledge fundamental uncertainties with regard to future development. By developing different scenarios, possible system evolution is investigated by elaborating logical sequences for future changes in the system with respect to these uncertainties (Swart et al., 2004; van Notten et al., 2003; Wiek et al., 2006).

3.4.1. Scenario setting and principal uncertainties

To develop scenarios for any issue, the settings have to be explicitly defined and expressed. A clear question has to be formulated, and the principal uncertainties of the investigated scenario issue have to be identified. Also, the temporal and spatial frame allowing the investigation of this question has to be formed.

The analysis of the public discourse and group discussions within satellite and advisory group managed to reveal issues of great relevance to the local community and the associated uncertainties. As mentioned earlier, we concentrate only on the issue of changes in mountain agriculture in this contribution, although altogether three issues have been addressed, based on the participatory system analysis developed within the ALPSCAPE project. Here, we assume substantial changes in agricultural policies and liberalisation of markets and concentrate on the uncertainty of consumer behaviour in the scenario analysis, while noting that the system analysis would allow us to establish a more complex system of uncertainties and their interaction. However, using scenario analysis in combination with integrated modelling, the focus of the models, their sensitivities and uncertainties of each modelling process as well as the interfaces between models have to be accounted for, as they limit scenario complexity.

Moreover, the spatial and temporal settings of the scenario have to be established. The regional focus of our study as well as the system boundaries of the models set the spatial scope to the administrative boundaries of the Davos region. The time horizon and the differentiation between scenario phases as a sequence of events are constituted according to the scenario issue of investigation.

3.4.2. Qualitative elaboration of scenarios

For scenario specification, the most relevant elements and their development in accordance to the scenario issue are re-selected, re-sampled and re-arranged. To identify these elements, impact matrices and system graphs of the satellite groups are used. As mentioned earlier, special attention was given to the outcomes of the satellite group “agriculture”, which convened farmers and food processors, but also professional users of local agricultural products, such as hotels, for the agricultural scenarios.

To gain a coherent set of the most relevant elements for the scenario, some of the elements had to be aggregated and re-grouped. Based on these elements, a scenario-specific system graph was developed which displays the interrelations within the set (Fig. 7). Based on this graph, a scenario table was established in which the evolution of each element identified as relevant for the scenario issue and being of relevance in the simulation modelling can be qualitatively described over all scenario phases (Table 1).

At this point, the number of interactions between elements and the number of possible scenarios can vary considerably depending on the study design. But, as mentioned earlier, due to the limitations in the numerical models, only two scenarios on agricultural change were consistently developed to then be simulated by the models.

3.4.3. Parameterisation and quantification of scenarios

The qualitative scenarios were further prepared for numerical simulation through parameterisation and quantification of the elements. Based on Table 1, the suitable input parameters were selected from the list of all possible input parameters to the numerical modelling framework (Fig. 2) to describe the evolution of the elements.

Characteristic values for these input parameters were then derived for the simulation of scenarios. In the case of the agricultural scenario, parameter quantification and numerical simulation were tightly connected processes. Fig. 4 shows the workflow through the models involved and shows that the Local Agriculture Model and the Land Use Allocation Model deliver outputs that are further used for scenario simulation in other models. Primary input for the numerical simulation are limited to the input parameters of the Local Agriculture Model (Fig. 4).

3.5. Communication of the modelling results

The communication of the simulation results is considered to be the second interface between numerical modelling and local actors’ knowledge in the participatory process (Fig. 2). In this

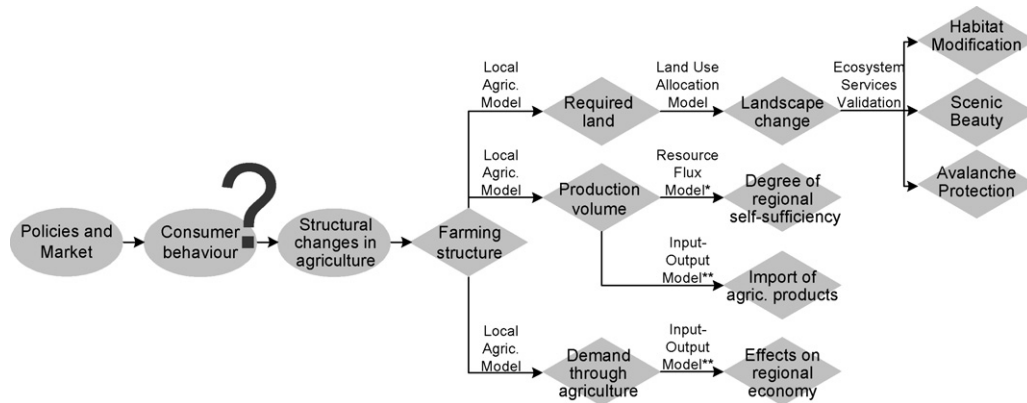


Fig. 4. Workflow of parameter quantification and numerical simulation as used in the scenario “Decrease in subsidies for mountain agriculture and liberalisation of markets”. The ovals indicate scenario assumptions and the diamonds indicate numerical input and outputs. Note that outputs of the Local Agriculture Model are used as inputs to all other models. (* Assumption that only the regional market is delivered; ** consumer baskets remain the same).

project phase, research feeds back to the local community, thus requiring adequate means of communication. Members of the advisory group and the satellite groups underlined this requirement by expressing their doubts about their ability to understand the outcomes of the numerical modelling.

Besides the organisation of further workshops and other public events, which allow face-to-face presentation of the results of the scenario analysis, we used “enhanced” storylines (Fig. 2) to communicate the results by combining qualitative and numerical aspects of the scenario analysis. Similar to a conventional scenario storyline (e.g. Arnell et al., 2004; Schoemaker, 1993), the “enhanced” storyline uses the advantages of a narrative (e.g. Guhathakurta, 2002). It employs narrative language that local actors are familiar with and sets elements into context, such as scenario assumptions, i.e. the qualitative estimates for elements that are not subject to modelling or principles of the numerical modelling framework. The enhanced scenario storyline also incorporates the indicators derived from the numerical simulation and demonstrates clearly parallels and differences between the scenarios (Box 1).

4. Results

The described procedure produces multiple phases of results, i.e. the system analysis based on the participatory workshops, the elaboration of the scenario specifications, and the simulation results. Within the scope of this contribution, they are not treated equally, but the system analysis and the scenario specifications are considered intermediate results.

4.1. System analysis

Each satellite group developed a system graph from their impact matrix, including the elements and impacts identified as most relevant by the individual group. Altogether 60 elements were identified by the satellite groups and aggregated differently, depending on the satellite group’s background. The two original impact matrices of the satellite groups “Schools” and “Agriculture” are shown as examples in Fig. 5. To ensure the readability

of the system graphs, the number of impacts included in the graphs was limited to impacts rated greater than 2.7.

Comparing the results of the two groups, the different perspectives become obvious. The impact matrix of the satellite group “Schools”, for instance, shows high impact strengths for the elements “landscape” and “tourism” and a strong impact of agriculture on the landscape. From the viewpoint of the group “Agriculture”, public subsidies have a strong effect on the agricultural use of land, and strong linkages are drawn between landscape attractiveness, tourism and demand on agricultural products.

Attempts to formally integrate the results of all satellite groups into one single system graph were not feasible because of the large number of elements and different aggregation levels used in each group. Consequently, a more intuitive, concept-driven approach to scenario development was followed (Scholz and Tietje, 2002; Wiek et al., 2006). All impact matrices and system graphs, although not formally combined, were nevertheless valuable for checking scenarios for consistency and to avoid contradictions.

4.2. Scenario specification

From the public discourse and the discussions within the advisory and satellite groups, decrease in subsidies for mountain agriculture and liberalisation of markets were considered major threats to the region (Stremlo et al., 2003; Wiek et al., 2006). The future of mountain agriculture is clearly not understood as a mere existential problem of a minority, but rather expected to affect the landscape, its attraction, possibly also (summer) tourism, and the ecological and cultural assets of the region.

If subsidies for mountain agriculture decline considerably, the price of agricultural products will better reflect production and processing costs, and thus product prices will rise. Farmers will strongly rely on consumer adaptations, which are thus considered a principal uncertainty forming the basis of the analysis (Fig. 6).

Two different scenarios are placed along this uncertainty. Scenario A assumes that demand for local products will increase

Table 1

Sections 1 and 2 of the scenario table display the subset of element considered most relevant for the scenario and the qualitative description about their behaviour over three scenario phases

Relevant elements	Qualitative scenario specifications			
	Initial state in 2000	2011	Scenario A (no subsidies, but market)	Scenario B (no Subsidies, no market)
Agricultural policies and market	Area-related subsidies for mountain agriculture and protected national market	Decrease in subsidies and liberalisation of market	No subsidies	No subsidies
Consumer behaviour	Consumers use local agricultural products. Prices are slightly higher than for competitive products	Consumer prices rise rapidly for local agricultural products	Consumers are willing to pay increased prices for local, high-quality products	Consumers buy cheaper products from the lowlands
Farming structure	Divers farming structure mostly producing milk and meat. Milk is then processed and distributed by the local dairy	Many farms cannot meet the harsh competition and stop farming. Due to decreasing amounts of milk, the dairy closes down	Few large farms remain which can produce, process and distribute meat and milk cost-effectively. Additionally a few part-time farmers will produce, process and distribute meat	Mountain agriculture has stopped. No more farms
Landscape	Typical, historically grown cultural landscape with pastures and meadows	–	Decrease in agricultural land with forest expansion below the timber line	Loss of agricultural land with forest expansion below the timber line
Resource management				
Food	Local agricultural productivity satisfied about 30% of the local consumption of dairy and meat products	–	The milk production volume decreases due to reduction of farming activity while demand on local dairy products raise	As demand for costly local dairy products is marginal, production has almost stopped
Electricity	Several little power stations generate about 10% of the electricity consumed in the area	–	Agriculture requires less electricity as before	Hardly any consumption through agriculture
Regional economy	Tourism is the dominating economic sector. Agriculture employs 117 persons and processing industry another 30	–	With decreasing farming activity, employment in agriculture are reduced and all jobs in the processing industry are lost. Other industries are not strongly impacted	With a stop of farming, employment in agriculture and processing industry vanish. Other industries are not strongly impacted
Ecological situation	High biodiversity of mountain meadows and pastures	–	Decrease of habitat diversity, but improvement of forest boundary habitats	Loss of biodiversity on mountain meadows, forest boundary habitats improve
Protection from avalanche hazard	Forest at steep slopes reduces the chance of avalanche release. Forest above infrastructure and housing reduces the risk against avalanche hazards	–	With forest developing at steep slopes above settled areas, the protection function locally increases	With even more forest expanding at steep slopes above the settlement, the protection function might increase even more
Scenic beauty	The traditional agricultural landscape is assumed highly attractive and a resource for tourism	–	Character of scenic appearance becomes “wilder” with increasingly expanding forest	Scenic appearance is dominated by forest below the timber line

despite augmentation of consumer prices. Scenario B assumes that demand will reduce strongly, so that costly and non-supported products will not be sold in the future.

The time horizon of the scenario analysis is from 2000 to 2050. Within this period three phases are distinguished: a pre-event phase before 2011, an event-phase in 2011, and a post-event phase after 2011–2050. The new national agricultural policy will be implemented in 2011. From then on a complete

reduction of subsidies is expected for the scenario caused by decrease of public support for mountain agriculture and by liberalisation of agricultural markets. The cost-effectiveness of production and demand for regional products despite increases in consumer prices is therefore crucial for the development of mountain agriculture after 2011.

The system graph particularly adapted to the scenario of agricultural change (Fig. 7), showing the evolution of all ele-

Box 1. The enhanced scenario story combines the scenario assumptions and simulation results from numerical modelling

Assumptions

After 2011, mountain agriculture reacts to decrease of subsidies and liberalisation of markets. High production costs due to harsh production conditions in the mountain environment have to be covered by consumer prices. According to discussions with local farmers, mountain agriculture would stop to sell milk, but specialise in high-quality local products.

Depending on consumer behaviour, demand for local, high-quality, costly agricultural products can differ strongly. Scenario A assumes an augmentation in that market despite consumer prices, due to a general increase in environmental and regional awareness, Scenario B assumes that this market dies out due to high competition and low awareness.

Scenario A: No subsidies, but market for local products

With increasing demand on high-quality, costly agricultural products, a small number of large, fully-professional farms can meet the requirements of this market to work cost-efficiently. Smaller farms are only to adapt if they are not mainly reliable on income through their agricultural activities. We assume that 5 large farms with an increased number of cattle and 15 highly diverse small lifestyle farms remain within the area of Davos. The milk processing industry has to close down as the total volume of milk decreases and the farms process their milk to high-quality, costly dairy products, which they also distribute. According to a local agriculture model that provides us information on typical productivity and land requirements in the region based on recent practices, this development results in a strong reduction in agricultural land and production volume.

The results of an economic model, displaying the regional economic network based on the financial fluxes between different economic sectors in 2002, show that the reduction of agricultural activity is marginal for the local economy with the Gross Domestic Product decreasing by 1.5%. However, about 152 jobs in food production and processing are lost. This is mainly because currently the tourism dominates the local economy and agriculture plays a minor role.

According to a resource model, that displays resource availability and consumption within the region, strong effects are expected for the degree of self-sufficiency within the region. At the moment, regional agricultural production can supply 27% of dairy product and meat consumption. But with the decreasing total volume of milk, the region will rely on to about 92.5% on imports for these products.

The greatest impact is expected on the landscape due to abandonment. A landscape model shows an increase of forested areas by about 60%. This development reduces landscape diversity with impact on the regional biodiversity, although in the upper side valleys we can expect greater diversity to forest establishment. The abandonment of agricultural is also very likely to reduce the competition for land and to result in further housing development at the valley floors.

With changes in the landscape, also ecosystem services will change, including an increase in protection of avalanche hazard through forest expansion, an increase in open forest habitats (such as the forest grouse) and a reduction in scenic beauty due to further housing development.

Scenario B: No subsidies, no market for local products

If demand on high-quality local agricultural products is not sufficiently high, the complete stop of professional agriculture shows stronger impacts on the region. The degree of regional self-sufficiency for dairy products, which is still around 7.5% in Scenario A, is reduced to 0.1% and the region is fully relying on food imports. The number of jobs losses in agricultural production and food processing is expected to be 160, and thus comparable to Scenario A. The proportion of added value generated by the agriculture is reduced to 0%. According to the land use model, effects on the landscape include the expansion of forested areas even on the most favourable agricultural sites at the valley floor of the main valley, if no conservation measures are taken. Ecosystem services develop also similar as in Scenario A, but the impacts are stronger.

ments as cause–effect chains of the elements “Agricultural policies and markets” and “Consumer behaviour”. These two elements play the key roles according to the scenario setting. How they develop depends strongly on the constituted scenario assumptions.

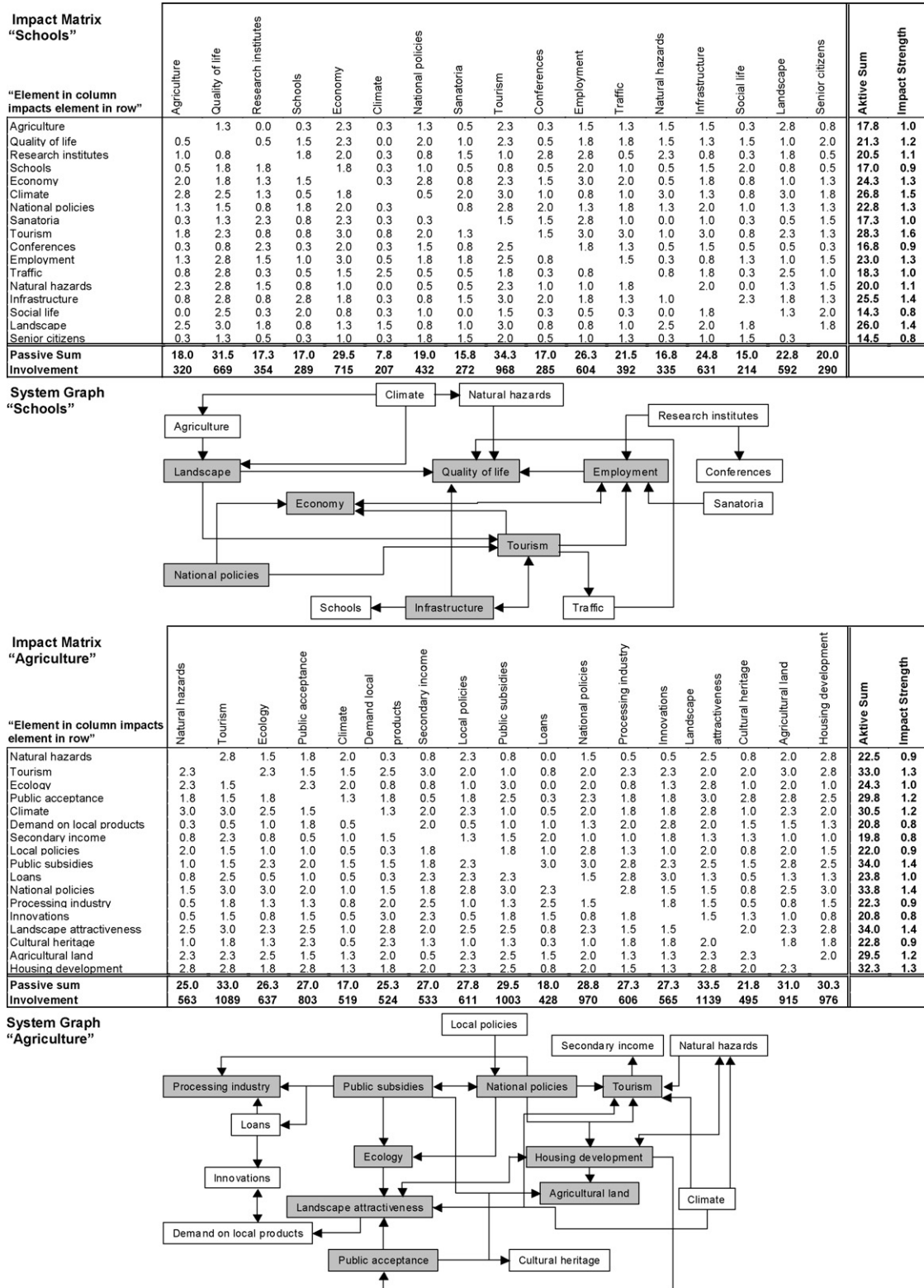


Fig. 5. The original impact matrices of the satellite groups "Schools" and "Agriculture" and the derived system graphs for both groups. The elements of highest "Impact Strength" are shaded in grey in the system graphs.

Following Fig. 7, the development of each element is qualitatively described in Table 1, which provides an overview of the evolution of the elements in all three scenario phases. Although not formally tested (e.g. according to Scholz and Tietje, 2002),

we were able to draw coherent qualitative scenarios from this table on the basis of a concept-driven, intuitive procedure and the impact matrices. These qualitative scenarios were thereafter discussed and accepted in the second workshop of the advisory

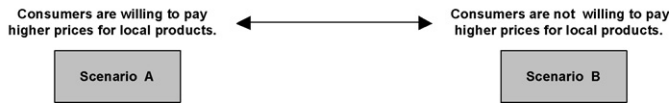


Fig. 6. Scenario space for the case study of decrease in subsidies for mountain agriculture and liberalisation of markets.

group in terms of their plausibility and integrity within the scope of the study.

The systematic, but qualitative elaboration of the scenarios in Table 1 built the basis for the elaboration of input parameters for the numerical simulation (Fig. 2).

Thus, the described evolution of elements in Table 1 was replaced by parameters and quantified with respect to the literature review (Lardelli and Lundström, unpublished data). According to the structure of the integrated modelling framework (Fig. 3), the parameters to be quantified in order to trigger the simulation include the input parameters for the Local Agricultural Model (grey shading in Table 2). In summary, the most important assumptions and scenario specifications were as follows.

Scenario assumptions and primary input values: We assume that structural changes in agriculture will take place after 2011 due to substantial changes in agricultural policy and consumer behaviour. Past experiences as well as discussions with experts on mountain agriculture and local farmers revealed that many farmers would have to stop their production. Farming structure would undergo a major shift with a decreasing number of medium-size professional farms. It is likely that large, fully professional farms with their own milk processing, and small farms concentrating on labour-extensive meat production with secondary, non-agricultural income will develop. For Scenario A assuming a vivid market for local agricultural products, we assume that five large, fully-professional farms and about 15 small part-time farms would remain within the region. For Scenario B, six part-time farms without any commercial distribution of their products are assumed.

4.3. Simulation results

The numerical modelling resulted in a number of quantitative outcomes including the simulation results of the Local Agricultural Model, the Input–Output Model, the Resource Flux Models, the Land Use Allocation Model and the Ecosystem Service Validation. These numerical results and their corresponding source models are given in Table 2, while the “enhanced” storyline sets the multiple results into context and briefly explains their meaning (Box 1).

4.3.1. Local Agricultural Model

The values derived from the scenarios specification and based on the assumptions summarised above are used in the Local Agricultural Model and represent the primary input to the model framework (shaded in Table 2). According to estimates on the agricultural structure, the Local Agricultural Model outputs the production volumes for dairy products and meat, as well as the agricultural land, which would be required for agricultural use.

In the case of a vivid market for high-quality, but costly local agricultural products (Scenario A), it predicts decreased milk and meat production to <20% and ~11.5% of the 2001/2002 volumes, respectively. The agricultural land is estimated to decline to ~32% of the intensively used agricultural land and to ~17% of the extensively used land in 1997. In the case of a complete stop of professional agriculture within the region (Scenario B), the outputs go down to zero. The outputs of the Local Agricultural Model were used further as input for the economic Input–Output Model, the Resource Flux Model and the Land Use Allocation Model.

4.3.2. Input–Output Model

The results of the regional Input–Output Model predict that the proportion of added value to the region through agriculture and processing industries declines from 0.2% to 0.04% for Scenario A and down to 0% for Scenario B. The reduction of the Gross Domestic Products amounts to 1.5% for Scenario A and 1.8% for Scenario B. Hence, the impact of a decrease, as well as a complete stop in agriculture show limited direct impact on the regional economy. This is mainly because agriculture plays a minor role already within the regional economy. For Scenario A, about 2.3% of full-time employment in 2001/2002 would be lost, which still adds up to about 152 jobs. For Scenario B, 160 full time equivalents are estimated to be lost.

4.3.3. Resource Flux Model

The Resource Flux Models predicts considerable decrease in self-sufficiency for food within the region due to reduced productivity in both cases. While the degree of self-sufficiency reached ~27.4% for dairy and meat products in 2001/2002, the expected production volume in Scenario A would only supply ~8.1% of the regional demand. For Scenario B, only ~0.1% of the region’s consumption could be satisfied and the region would rely almost completely on imports for these products. The self-sufficiency rate for electricity is hardly impacted by the agricultural scenarios. As electricity consumption declines only slightly with the reduction or stop of agriculture, the sufficiency rates rise by 0.08% for Scenario A, and by 0.1% for Scenario B.

4.3.4. Land Use Allocation Model

Based on the requirements for land calculated in the Local Agricultural Model, the Land Use Allocation Model suggests strong impacts on the landscape for both scenarios. Within the 50-year simulation period >1700 ha of abandoned land are estimated to be overgrown or forested for both scenarios. Forest expansion differs only by ~50 ha between the scenarios. It comprises a complete band of forest or at least overgrown land on all hillslopes below the tree line with very few spots of open grassland (Fig. 8). With this, the proportion of forest within the study area increases from 25.1% to 31.7% for Scenario A, and 32% for Scenario B. Both scenarios show almost identical forest expansion with rapid forest growth at valley floors. However, the simulations also indicate the ecological limitation despite generally favourable conditions at these sites. Remaining spots of unproductive grassland at valley floors (Fig. 8: Scenario B) can be ecologically explained through the distances of

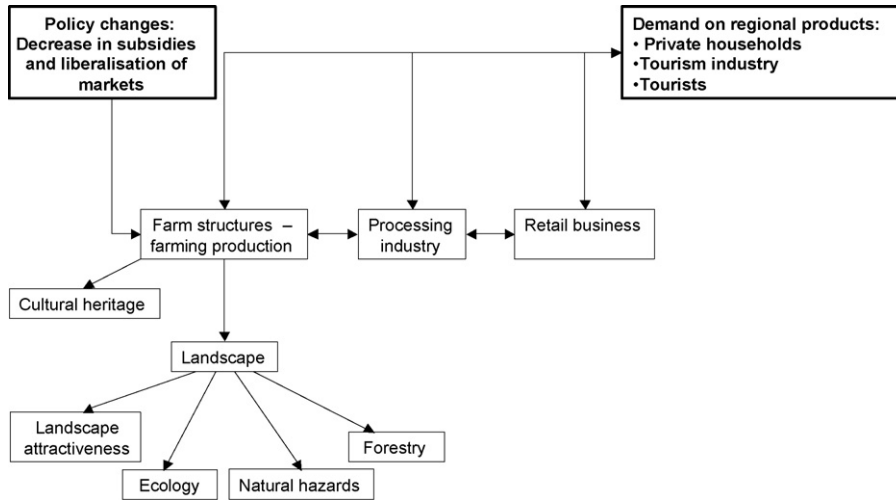


Fig. 7. Scenario-specific system graph in the case of decreasing subsidies for mountain agriculture and liberalisation of markets with high uncertainties in future demand.

seed transportation (e.g. Lässig et al., 1995). The forest-open land boundary which is considered an important indicator for scenic beauty (Franco et al., 2003) increases considerably for both scenarios. This is mainly due to the expansion of forest in the upper side valleys where no forests were present in 1997. For the remaining extensively used agricultural land in Scenario A, the simulation predicts large contiguous areas above the tree line. The formerly intensively used agricultural areas seem to be more likely abandoned than to be extensively used. Abandoned areas on valley floors are subject to rapid forest growth due to favourable ecological conditions, and a great proportion is likely to be used for further development of the settlement. This indicates that abandonment of agricultural land on valley floors is likely to favour an expansion of the settlement in future due to decreasing competition for land. Of course, spatial planning is restrictive at present, but we can assume that spatial planning will adapt to future situations in the long term and, if recent trends hold on, demand for secondary homes will remain high. For both scenarios the extent of unproductive grassland increases substantially. In 1997, ~9.5% of the study area was

covered with unproductive grassland; by 2050 a proportion of 30.2% would be reached according to Scenario A, and 39.0% according to Scenario B. Although landscape diversity increases at some locations, e.g. in upper tributary valleys, the Shannon’s Diversity Index calculated for the region indicates a reduction in landscape diversity. Although some species with specific habitat requirements can take advantage of this change in landscape, a decrease of biodiversity related to this predicted reduction of landscape diversity is also likely (Hietala-Koivu et al., 2004).

4.3.5. Ecosystem Service Validation

The impacts of land use changes were further validated by changes in ecosystem services (Grêt-Regamey et al., in press-a). The area’s flagship species capercaillie (*Tetrao urogallus*), which is used as an indicator of changes to wildlife habitat, benefits especially from an increase in open forested area, although an overall reduction in biodiversity has to be expected due to the reduction of landscape diversity (Hietala-Koivu et al., 2004). Furthermore, avalanche protection potential will increase due to increased forest area on steep slopes. The increase in forested

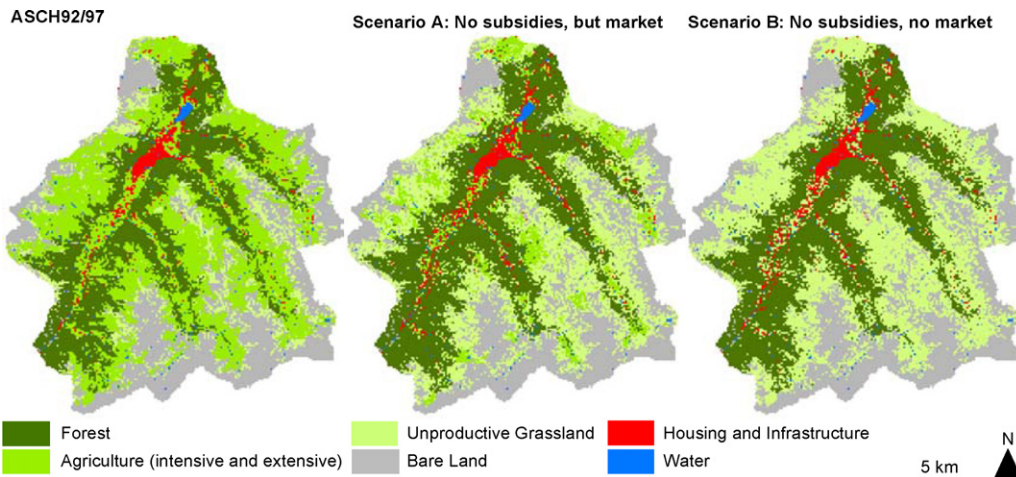


Fig. 8. Simulation results of the Land Use Allocation Model for Scenario A and Scenario B, and the initial situation in 1997 (Land Use Statistics 1992/97, BFS GEOSTAT).

Table 2
Parameterised and quantified scenarios with the according simulation results of the Local Agriculture Model (LAM), the Land Use Allocation Model (LUA), the Resource Flux Model (RFM), the Input–Output Model (IOM) and the Ecosystem Service Validation (EcoServ)

Relevant Elements	Input parameters and values for numerical modelling (Origin of the input parameter value → Type of model to be used)				Scenario outputs based on numerical modelling (Type of model) or based on qualitative scenario specifications			
	Parameters	2000	Scenario A No subsidies, but market	Scenario B No subsidies, no market	Parameters	2000	Scenario A No subsidies, but market	Scenario B No subsidies, no market
Agricultural policies and market	/	/	/	/	/	/	/	/
Consumer behaviour	/	/	/	/	/	/	/	/
Farming structure	Number of large, fully professional farms with milk and meat production, processing and distribution (→LAM)	2	5	0	Land requirements (LAM): Intensive agricultural use	998 ha	318 ha	0 ha
	Number of part-time farming with meat production, processing and distribution (→LAM)	0	15	6	Extensive agricultural use	8445 ha	1400 ha	0 ha
	Others of various sizes but without food processing and distribution (→LAM)	74	0	0	Production volume (LAM): Milk	5 Mio. kg	0.9 Mio. kg	0 kg
Landscape	Demand on land for intensive agricultural use	998 ha	318 ha	0 ha	Meat	252 000 kg	29 000 kg	0 kg
	Demand on land for extensive agricultural use (LAM→LUA)	8445 ha	1400 ha	0 ha	Land use pattern (LUA)	1997 (Figure 8)	Scenario A (Figure 8)	Scenario B (Figure 8)
					Landscape structure (LUA): Forest-Open Land boundary	6 064 km	6 919 km	7 022 km
					%-age of Unprod. Grassland	9.5%	30.2%	39.0%
Resource Management	Production volume for milk per month (LAM→RFM)	410 000 kg	100 000 kg	0 kg	%-age of Forest	25.1%	31.7%	32.0%
	Demand on local products per month (Scenario Assumption→RFM)	130 000 kg	200 000 kg	0 kg	Area (LUA): Close Forest	3545 ha	3386 ha	3801 ha
					Open Forest	773 ha	3581 ha	3831 ha
					Overgrown Area	2061 ha	1152 ha	554 ha
					Intensive Agriculture	998 ha	290 ha	42 ha
					Extensive Agriculture	8445 ha	2043 ha	329 ha
					Unproductive Grassland	2416 ha	7659 ha	9544 ha
					Housing and Infrastructure	566 ha	693 ha	703 ha
					Bareland and Water	6639 ha	6639 ha	6639 ha
					Self-sufficiency for dairy products (RFM)	27.4%	7.3%	0.1%
Regional Economy	Demand on other economic sectors (Scenario Assumption→IOM)	100%	20%	0%	Self-sufficiency for electricity (RFM)	10.08%	10.16%	10.18%
					Gross Domestic Product of the region (IOM)	627.7 Mio CHF	618.2 Mio CHF	616.2 Mio CHF
					Proportion of added value by agriculture of total added value in the region (IOM)	0.2%	0.04%	0%
					Total Employment (IOM)	6 474	6 322	6 314
Ecological Situation	Land use change (LUA)	1997 (Figure 8)	Scenario A (Figure 8)	Scenario B (Figure 8)	%-age of food products of all imports	13%	14%	15%
	Land use change (LUA→EcoServ)	1997 (Figure 8)	Scenario A (Figure 8)	Scenario B (Figure 8)	Landscape Diversity (LUA): Shannon's Diversity Index	1.59	1.48	1.25
Protection from avalanche hazard	Land use change (LUA→EcoServ)	1997 (Figure 8)	Scenario A (Figure 8)	Scenario B (Figure 8)	Habitat modification of the forest grouse (capercaillie) (EcoServ)	/	+5 300 CHF * year	+6 000 CHF * year
Scenic Beauty	Land use change (LUA→EcoServ)	1997 (Figure 8)	Scenario A (Figure 8)	Scenario B (Figure 8)	Change in risk against avalanche hazard (EcoServ)	/	+58 000 CHF * year	+86 345 CHF * year
					Change in scenic beauty (EcoServ): Due to forest expansion	/	+/- 0 CHF	+/- 0 CHF
					Due to further construction	/	-7 000 CHF * year	-6 200 CHF * year

The shaded zone indicates the prime input values.

area did not have a significant impact on people's preference for a view, but the likely expansion of the settlement on the previously agriculturally used land is considered to have a negative effect on scenic beauty within the region (Grêt-Regamey et al., in press-b).

4.3.6. Summary of the simulation results

The two scenarios elaborated on the issue focused on the consequences of differing consumer behaviour. A strict decrease in support of mountain agriculture without any re-modification of

this policy was assumed. In that regard, both scenarios were extreme, but could demonstrate that the effect of consumer behaviour is most likely minor compared to financial support. Even a positive development in the market of high-quality local agricultural products can most likely not compensate radical decrease to subsidies. Hence, in both cases a drastic decrease in subsidies for mountain agriculture would affect the region strongly. The result of such policy change would be immense changes in the landscape structure with consequences for ecosystem services, as well as a strong decrease in self-sufficiency. Compared to these indicators, the changes in the local economy are minor, although an overall loss in job opportunities of about 160 would have to be expected.

5. Discussion

5.1. Results of the scenario simulation

The scenario analysis addressed the impact of a substantial decrease in agricultural subsidies on the region of Davos. The chosen indicators derived from the numerical models showed the impact on the sustainability of regional development with a strong decrease in regional self-sufficiency, drastic changes in landscape structure with various impacts on ecosystem services, and direct effects on the local economy.

The relatively low direct impact on the local economy reflects the minor role of agriculture and the food processing industry compared to tourism in the contemporary economic structure. However, according to the outcomes of the satellite workshops and the participatory system analysis, the local actors assume a strong linkage between a decrease in mountain agriculture, subsequent landscape changes and the local economy. They assume that in particular through changes in landscape attractiveness the summer tourism could decline considerably and have a major impact on the local economy. Thus, also indirect economic effects are expected through agricultural abandonment and subsequent landscape changes which are not displayed in the recent modelling framework.

The ecosystem service “scenic beauty” addresses this aspects when the value of the landscape as a resource for tourism is estimated through a willingness-to-pay survey (Grêt-Regamey et al., *in press-b*) and results are applied to the simulated land use patterns (Grêt-Regamey et al., *in press-a*). According to these findings, the likely expansion of the settlement would reduce the value of “scenic beauty”. The difference can be interpreted as the amount that tourists are likely to spend less for their accommodation during a visit owing to a less beautiful view (Bebi et al., 2005; Grêt-Regamey et al., *in press-b*). In order to approximate additional indirect effects of a decrease in mountain agriculture on the local economy, we suggest estimating furthermore changes in tourist consumption patterns and number of tourists from these values. These could then be used to adapt the consumption volume of tourists in the Input–Output Model and would allow approximating indirect economic effects.

This example also shows that the qualitative system models are able to display a higher degree of complexity within the region compared to the numerical modelling which is strictly

bound to its limitations, and requires a lot of additional input data and effort to be modified.

5.2. Integrated modelling

The coupling of models proved to be highly instructive for assessing regional development in the Davos region. Alternatively, each of the numerical models could have been applied individually to the study area in order to identify sensitivities from the perspective of each particular model. However, combining the models through regional scenario analysis gave a more holistic perspective of the region and helped to better understand and evaluate different options of its long-term development based on numerical indicators. The scenarios and the dataflow between the models systematically adjusted their input parameters to the same assumed situation, drew interrelations between the individual models, and provided a common context for each simulation.

Differences in temporal and spatial scales, data aggregation of information and basic modelling assumptions have to be considered critically at the interfaces between individual models in any integrated modelling approach. In our case studies this applies, for instance, for the spatial resolution of the data available for the Land Use Allocation Model versus the ideal resolution for Ecosystem Service Validation, or the differentiation of land use classes versus the differentiation of economic activities within the Input–Output Analysis and the Resource Flux Model. In our case study, these interfaces could have been better elaborated and, thus, the explanatory power of the modelling been enhanced, if the target of the modelling approach had been better specified and narrowed down to a well-defined question at an earlier stage of the project. This, however, was difficult as the discussion with the local actors was intended to reveal the most relevant issues for the region.

Still, these potential sources of error and misinterpretation have to be taken serious in the interpretation of the simulation results and have to be communicated. They are best coped with by explicitly stating the fundamental assumptions and by documenting data transfers from one model to the other in order to make the interfaces between individual models as transparent as possible (Table 2).

5.3. The role of participatory involvement in scenario development

Participatory involvement can fulfil numerous functions within research projects (Antunes et al., 2006; Siebenhüner and Barth, 2005) and can cover a great range of group compositions, targets, organisational and institutional settings (e.g. Fischer, 2000; Rauschmayer and Wittmer, 2006; Santelmann et al., 2004; van den Beld, 2004). In the ALPSCAPE project, the involvement of local actors aimed for (1) ensuring the relevance and improving the regional scenarios through local system knowledge and (2) promoting capacity building within the local community.

The first intention of participatory scenario development resulted in a systematic collection of local system knowledge in the satellite group workshops in order to enable and improve

regional scenario development. From the viewpoint of knowledge generation, however, the participatory involvement could not contribute as much as expected to the development of the scenarios. One reason was that the outcomes of the satellite groups varied strongly in terms of elements included, and did not match up with each other to form one comprehensive system. The identified elements and system graphs produced during the workshops, therefore, had to undergo several steps of further re-selection and post-processing by the research team until qualitative scenarios could be drawn from them. If a complete set of, for instance, the researchers would have suggested 15 elements, this problem could have been possibly reduced, but might have had also the drawback of attenuating the group discussions. Instead of suggesting a prepared set of 15 elements, however, it might be valuable to suggest a pool of elements from which the most relevant 15 elements can be identified during group discussions. We see this as a possible and mutually beneficial compromise between leaving space for discussion and deriving system models, which can more systematically be combined.

Furthermore the participatory process could not contribute to the critical process of scenario parameterisation and quantification. The transformation of qualitative scenarios into sets of coherent input parameter values remained with the researchers, mainly because it would have required very specific and detailed knowledge of the numerical modelling framework. Still, the participatory involvement deepened and validated the existing system understanding of the researchers profoundly and ensured relevance, logic, consistency and validity of the elaborated scenarios as the researchers checked the consistency of the intuitively formulated scenarios with the outcomes of the satellite workshops, i.e. the system graphs.

The second intention was to address the key stakeholders and the local public through involvement into the project in order to improve the understanding of the region and discuss its long-term future options. Although the learning effect (e.g. van de Kerkhof and Wiczorek, 2005) has not been formally tested in the direct scope of the study, we strongly believe that the collaboration was profitable for both sides. First, the people involved in the advisory group represented key stakeholders and important decision-makers and therefore main addressees of the study. Second, many of these participants appreciated the project as an independent and in-depth study of the region and welcomed the outputs as an important knowledge base for their arguments. According to their feedback, they experienced the workshops as a unique platform to discuss long-term issues in a diverse surrounding. Finally, they showed great interest beyond the direct scope of the project, for instance, by inviting the research team to the local executive in order to present the research results and discuss them with policy makers. Out of this engagement, the research team was invited to actively participate in the elaboration of an overall concept for the future of the Davos region. The satellite group workshops served as a successful multiplier as additional local actors, not necessarily holding representative functions within the community, got involved.

In the course of the project it became obvious, that the target of capacity building and the strong response of key decision-

makers hindered us to insist on a closer collaboration in the scenario elaboration to a certain extent. To actually enhance the local actors' input to scenario elaboration, more sessions and a more stringent structure of the workshops would have been required. This, however, appeared unfavourable for the capacity building process, as key decision-makers in particular have tight schedules and are used to openly discuss.

In our case study, the chosen procedure was intended to support scenario development, but adaptations to better promote the capacity building process resulted in tradeoffs that weakened the input for scenario elaboration. In order to identify the most appropriate methodological approach for the particular project, we see the clear need to define the role of the participatory involvement and set the primary target for the process before starting the process (in agreement with, for instance, Rauschmayer and Wittmer, 2006; van den Beld, 2004; Wiek et al., 2006). Mainly qualitative approaches, including, for instance, not only future workshops (e.g. Jungk, 1994), mediation (e.g. Rajagopal, 1980), cooperative discourse (e.g. Renn, 2006), but also conceptual system modelling (e.g. Magnuszewski et al., 2005), might be most appropriate to raise issues, promote capacity building and develop solution strategies. Out of these qualitative procedures, the need might arise to focus on particular aspects numerically (e.g. Magnuszewski et al., 2005; Sendzimir et al., in press). In such cases, mediated or participatory modelling techniques are promising approaches (Bousquet et al., 2002; Castella et al., 2005; van den Beld, 2004). They might either enhance the process by adding model-based information on selective aspects (van den Beld, 2004), or build on participatory observations in order to establish agent-based models (Bousquet et al., 2002; Castella et al., 2005). In both cases, the participants have to be willing to work relatively intensely with the modelling team for instance because an urgent problem is addressed within the process. In our case study, we assume, the issues raised would have not been urgent enough to actually motivate also key stakeholders to collaborate on a more detailed, and more time-consuming level. If we had realised this in a very early stage of the process, more appropriate methods might have even increase the achievements in capacity building.

5.4. *Strengths and weaknesses of the case study*

Our case study bears typical strength and weaknesses of integrated sustainability research (e.g. Antrop and Rogge, 2006; Tress et al., 2005; Tress et al., 2003). First we want to point out on the strengths:

- *Potential of the scenario analysis in combination with the modelling approaches:* The scenario approach facilitated a meaningful application of all models within the same context. The logic of the scenario analysis greatly enhanced the systematic derivation of input parameters, and the communication of the simulation results to the local community, e.g. through a narrative.
- *The integration of qualitative participatory approach and the derivation of the quantitative set of scenarios for simulation:* Combining qualitative and numeric approaches is one of the

great strengths in integrated research. Referring to Kemp-Benedict's (2004; Tress et al., 2005) terminology, it allows to bring to together the complexity of qualitative approaches with the "complicatedness" of systems which is best handled by numeric modelling. However, on the interface between the two methodological traditions, our study suffered from a great loss of information, mainly as the limitations of the numerical models did not allow integrating additional aspects of future scenarios, which could have been elaborated from the outcomes of the satellite group workshops.

- *High acceptance of the study within the region:* The participant's reaction and the invitation to take part in the elaboration of an overall future concept for the Davos region indicate a high level of acceptance beyond the scope of the research project. We see reasons for that (1) in the early involvement of stakeholders of which some had already been engaged in the process of project design, (2) in the involvement of key stakeholders, such as local political authorities or key players in tourism, or other economic sectors, and (3) in the fact that the project leader was a well integrated member of the local community facilitating the communication between the research group and the local participants.

However, our case study bears also weaknesses that are quite common in the field of integrated sustainability research (e.g. Antrop and Rogge, 2006; Tress et al., 2005; Tress et al., 2003):

- *Need to clarify of a well-defined problem for the establishment of the integrated modelling framework:* Within the scope of the entire study, not only the issue of decrease in agricultural subsidies and liberalisation of markets were addressed, but also altogether three completely different issues. Although all issues were of relevance for the region, it would have been profitable from the perspective of knowledge generation to better narrow down the problem to be addressed through the modelling framework in order to improve the integrated model and enhance its explanatory power.
- *Too high expectations of the integration of models:* The research team expected to reach a higher degree of integration of the numeric models within the scope of the study. Despite frequent exchange between the researchers, the models were developed relatively separately. In the end, the systematic exchange of data between the models could be realised and the models could be applied for the same scenarios, but the explanatory power of their integration was not as high as initially expected. One reason for that can be found in the unclear definition of the end-users of the models and the initially un-realistically high expectations in the integration and operationalisation of the numeric modelling.
- *Too high expectations of the research team in terms of input and elaboration of the regional scenarios for simulation modelling:* The researchers hoped for a greater input in the parameterisation and quantification procedure. However, within the time schedule of the participatory process, this could not be realised. Due to the diversity and complexity of the models and the fact that the models were developed parallel to the participatory process, it was not possible to

communicate the possible input parameters in enough detail to involve the local actors in these processes as intensively as initially intended.

- *Time schedule of the participatory process and issues to be addressed:* It is often argued that participatory processes are time (and resource) intensive (e.g. Antrop and Rogge, 2006). This is certainly true, and to achieve a higher degree of collaboration, the participatory process would have required more time and resources also in our case study. However, apart from that project planning and resource aspect, the level of collaboration depends also strongly on the willingness and feasibility of participants addressed. In our case, the participants of the advisory group were mostly key stakeholders. They spent four evenings with us in workshops and discussions. Although not tested, it is doubtful that these key stakeholders, representing also the main addressees of the study, would have been willing to spend much more time on the project. The time-budget, they are willing to spend for such a process, might also depend on the issues to be addressed. The issue raised in our project was long-term regional development over a period of 50 years, and it triggered a profound discussion about the threads and potentials of the future development within the region. But the literature shows that more intense and time-consuming participatory approaches are more successful when urgent problems are addressed (e.g. Rauschmayer and Wittmer, 2006). Promising concepts to integrate modelling approaches, scenario analysis and participatory involvement, include participatory/mediated modelling (e.g. Castella et al., 2005; Hare et al., 2003; van den Beld, 2004) and the elaboration of quantitative or spatial input for numerical simulation in the participatory process as it was also our intention (e.g. Baker et al., 2004; Santelmann et al., 2004). Where such methods were successfully applied, the studies mostly focused on urgent problems of the community, so that common problem-solving and strategy-building were the primary goal of the collaboration (as suggested as a prime goal for transdisciplinary research in general by Klein et al., 2001), and the local participants were willing to spend a greater amount of time for the project.

6. Conclusions

From the methodological perspective, our case study could show typical problems in combining integrated multi-disciplinary modelling, scenario analysis, and participatory involvement. In the case study, the participatory process was intended to fulfil two functions. While the target of involving local actors to establish an understanding of the fragility of the region and trigger a discussion of its long-term future was indeed very well achieved, a number methodological problems had to be overcome to move from the outcomes of the satellite group workshops towards qualitative scenarios and finally to sets of input parameter values which could be used for the numeric simulation.

First, the participatory established knowledge base would have suggested integrating more aspects into the scenario analysis. But, mainly due to modelling limitations, the complexity had to be reduced in order to produce consistent sets of input

parameter values for scenario simulation. Second, we had to overcome the “bottleneck” between the qualitative and quantitative information. Although we cannot suggest any technique to “translate” qualitative data into quantitative modelling input, we consider the detailed documentation of this process a crucial step towards bringing together the realms of qualitative and quantitative data in integrated research. Third, we experienced a shift in priorities for the participatory process in the course of the project. While raising awareness on long-term future development was very successful and ended in the formal integration of the project team in a committee for the elaboration of an overall future concept for the region, we did not persist on the participatory, in-detail elaboration of scenarios as much as intended. Reasons for that were the concomitance of the model development and the participatory process, and the complexity of the models and the interfaces between them.

To improve the integration of qualitative participatory and quantitative, model based techniques, we recommend alternatively to

- (1) specify a well-defined problem and narrow down the issue to be addressed by the models which can then be approached in greater detail within the given timeframe;
- (2) use either well operating models when starting the participatory process, so that their potentials and limitations are clear, or develop the model directly during the participatory discourse in the tradition of participatory or mediated modeling;
- (3) consider the sole application of appropriate qualitative techniques with respect to the primary focus of the participatory process in an initial phase and eventually identify the need for additional information through numerical modelling within the process.

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References

- Alcamo, J., 2001. Scenarios as Tools for International Environmental Assessments. European Environment Agency, Copenhagen.
- Antrop, M., Rogge, E., 2006. Evaluation of the process of integration in a transdisciplinary landscape study in the Pajottenland (Flanders, Belgium). *Landscape Urban Plann.* 77, 382–392.
- Antunes, P., Santos, R., Videira, N., 2006. Participatory decision making for sustainable development—the use of mediated modelling techniques. *Land Use Policy* 23, 44–52.
- Arnell, N.W., Livermore, M.J., Kovats, S., Levy, P.E., Nicholls, R., Parry, M.L., Gaffin, S.R., 2004. Climate and socio-economic scenarios for global-scale climate change impacts assessments: characterising the SRES storyline. *Global Environ. Change* 14, 3–20.
- Aroca, P., 2001. Impact and development in local economies based on mining: the case of the Chilean II region. *Resour. Policy* 27, 119–134.
- Baccini, P., Bader, H.-P., 1996. *Regionaler Stoffhaushalt*. Spektrum Akademischer Verlag, Heidelberg.
- Baker, J.P., Hulse, D.W., Gregory, S.V., White, D., Van Sickle, J., Berger, P.A., Dole, D., Schumaker, N.H., 2004. Alternative futures for the Willamette River Basin, Oregon. *Ecol. Appl.* 14, 313–324.
- Bätzing, W., 2004. *Die Alpen - Entstehung und Gefährdung einer Kulturlandschaft*. Beck, München.
- Bebi, P., Kytzia, S., Lundström, C., Walz, A., Grêt-Regamey, A., Lardelli, C., 2005. NFP48 ALPSCAPE—Schlussbericht, Davos. Available at: http://www.slf.ch/lebensraum-alpen/pdfs/NFP48/final_report.pdf.
- Bousquet, F., Barreteau, O., d’Aquino, P., Etienne, M., Boissau, S., Aubert, S., Le Page, C., Babin, D., Castella, J.C., 2002. Multi-agent systems and role games: collective learning processes for ecosystem management. In: Janseen, M. (Ed.), *Complexity and Ecosystem Management: The Theory and Practice of Multi-agent Approaches*. Edward Elgar Publishers, Cheltenham, UK/Northampton, MA, USA, pp. 248–285.
- Brabec, B., Meister, R., Stöckli, U., Stoffel, A., Stucki, T., 2001. RAIFor: Regional Avalanche Information and Forecasting System. *Cold Regions Sci. Technol.* 33, 303–311.
- Carmichael, J., Tansey, J., Robinson, J., 2004. An integrated assessment modeling tool. *Global Environ. Change Hum. Policy Dimens.* 14, 171–183.
- Castella, J.C., Trung, T.N., Boissau, S., 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. *Ecol. Soc.*, 10.
- de Jouvenal, B., 1967. *The Art of Conjecture*. Weidenfeldt & Nicholson, London.
- Fischer, F., 2000. *Citizens, Experts and the Environment*. Duke University Press, Durham, NC.
- Flückiger, S., Schmid, T., Riederer, P., 1998. *Globale Entwicklungen und Naturkatastrophen - Eine gesamtheitliche Betrachtung am Beispiel von St. Niklaus VS*. vdf Hochschulverlag ETH, Zürich.
- Franco, D., Franco, D., Mannino, I., Zanetto, G., 2003. The impact of agroforestry networks on scenic beauty estimation—the role of landscape ecological networks on a socio-cultural process. *Landscape Urban Plann.* 62, 119–138.
- Fritz, O., Kurzmann, R., Zakarias, G., Streicher, G., 2003. Constructing Regional Input–Output Tables for Austria. *Austrian Econ. Q.*, 1–39.
- Greiner, R., 2004. Systems framework for regional-scale integrated modelling and assessment. *Math. Comput. Simul.* 64, 41–51.
- Grêt-Regamey, A., Bebi, P., Bishop, I.D., Schmid, W. Linking GIS-based models to value ecosystem services in an Alpine region. *Environ. Manage.*, in press-a.
- Grêt-Regamey, A., Bishop, I.D., Bebi, P. Predicting the scenic beauty value of mapped landscape changes in a mountainous region in using GIS. *Environ. Plann. B Plann. Des.*, in press-b.
- Guhathakurta, S., 2002. Urban modeling as storytelling: using simulation models as a narrative. *Environ. Plann. B Plann. Des.* 29, 895–911.
- Hare, M., Letcher, R.A., Jakeman, A.J., 2003. Participatory modelling in natural resource management: a comparison of four case studies. *Integr. Assess.* 4, 62–72.
- Hietala-Koivu, R., Lankoski, J., Tarmi, S., 2004. Loss of biodiversity and its social cost in an agricultural landscape. *Agricult. Ecosyst. Environ.* 103, 75–83.
- Hirsch Hadorn, G., Bradley, D., Pohl, C., Rist, S., Wiesmann, U., 2006. Implications of transdisciplinarity for sustainability research. *Ecol. Econ.* 60, 119–128.
- Hug, F., Baccini, P., 2002. Physiological interaction between highland and lowland regions in the context of long-term resource management. *Mount. Res. Dev.* 22, 168–176.

- Isard, W., 1998. *Methods of Interregional and Regional Analysis*. Ashgate Publishing Limited, Hants.
- Jungk, R., 1994. *Zukunftswerkstätten: mit Phantasie gegen Routine und Resignation*. Heyne, München.
- Kahn, H., Wiener, A.J., 1967. *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years*. Macmillan, New York.
- Kemp-Benedict, E., 2004. From narratives to number: a role of quantitative models in scenario analysis. In: Pahl-Wostl, C., Schmidt, S., Jakeman, T. (Eds.), *iEMSs 2004 International Congress: "Complexity and Integrated Resources Management"*. International Environmental Modelling and Software Society, Osnabrueck, Germany, Available at: <http://www.iemss.org/iemss2004/pdf/scenario/kempfrom.pdf>.
- Klein, J.T., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, R.W., Welti, M. (Eds.), 2001. *Transdisciplinarity: Joint Problem-Solving Among Science, Technology and Society. An Effective Way of Managing Complexity*. Birkhauser Verlag, Basel.
- Kok, K., Rothman, D.S., Greeuw, S., Patel, M., 2003. European scenarios: from VISIONS to MedAction, Maastricht. Available at: http://www.icis.unimaas.nl/medaction/downs/Deliverable_2.pdf.
- Kok, K., Rothman, D.S., Patel, M., 2006. Multi-scale narratives from an IA perspective: Part I. European and Mediterranean scenario development. *Futures* 38, 261–284.
- Kok, K., Rothman, D.S., Patel, M., de Groot, D., 2004. Multi-scale participatory local scenario development: using Mediterranean scenarios as boundary conditions. In: *Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multi-Scale Assessments*, Alexandria, Egypt. UNEP. Available: <http://www.millenniumassessment.org/documents/bridging/papers/kok.kasper.pdf>.
- Kok, K., van Delden, H., 2004. Linking narrative storylines and quantitative models to combat desertification in the Guadalentín, Spain. In: Pahl-Wostl, C., Schmidt, S., Jakeman, T. (Eds.), *iEMSs 2004 International Congress: "Complexity and Integrated Resources Management"*. International Environmental Modelling and Software Society, Osnabrueck, Germany, Available: <http://www.iemss.org/iemss2004/pdf/scenario/koklink.pdf>.
- Lässig, R., Egli, S., Odermatt, O., Schönenberger, W., Stöckli, B., Wohlgemuth, T., 1995. Beginn der Wiederbewaldung auf Windwurfflächen. *Schweizer Zeitschrift für das Forstwesen* 146, 893–911.
- Magnuszewski, P., Sendzimir, J., Kronenberg, K., 2005. Conceptual modeling for adaptive environmental assessment and management in the Barycz valley, lower Silesia, Poland. *Int. J. Environ. Res. Public Health* 2, 194–203.
- McGarigal, K., Marks, B.J., 1995. *FRAGSTATS 3.3: Spatial Pattern Analysis Program for Quantifying Landscape Structure*, US Department of Agriculture, Portland.
- Messerli, P., 1989. *Mensch und Natur im alpinen Lebensraum - Risiken, Chancen, Perspektiven*, Bern, Stuttgart.
- Naveh, Z., 2000. What is holistic landscape ecology? A conceptual introduction. *Landscape Urban Plann.* 50, 7–26.
- Nowotny, H., Scott, P., Gibbons, M., 2005. Re-thinking science: Mode 2 in societal context. In: Carayannis, E.G., Campbell, D.F.J. (Eds.), *Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters: A Comparative Systems Approach Across the United States, Europe, and Asia*. Praeger Publisher, Westport.
- Pahl-Wostl, C., 2002. Participative and stakeholder-based policy design, evaluation and modeling processes. *Integr. Assess.* 3, 3–14.
- Rajagopal, R. (Ed.), 1980. *Environmental Mediation and Conflict Management: A Selection of Papers Presented at the 5th Annual Conference of the NAEP*. Washington, DC, April 21–23, 1980, New York.
- Rauschmayer, F., Wittmer, H., 2006. Evaluating deliberative and analytical methods for the resolution of environmental conflicts. *Land Use Policy* 23, 108–122.
- Renn, O., 2006. Participatory processes for designing environmental policies. *Land Use Policy* 23, 34–43.
- Rockafellar, R.T., Wets, R.J.B., 1991. Scenario and policy aggregation in optimisation under uncertainty. *Math. Oper. Res.* 16, 119–147.
- Rotmans, J., van Asselt, M.B.A., 1996. Integrated assessment: growing child on its way to maturity. An editorial essay. *Clim. Change* 34, 327–336.
- Rotmans, J., van Asselt, M.B.A., Anastasi, C., Greeuw, S., Mellors, J., Peters, S., Rothman, D.S., Rijkens, N., 2000. Visions for a sustainable Europe. *Futures* 32, 809–831.
- Santelmann, M.V., White, D., Freemark, K., Nassauer, J.I., Eilers, J.M., Vache, K.B., Danielson, B.J., Corry, R.C., Clark, M.E., Polasky, S., Cruse, R.M., Sifneos, J., Rustigian, H., Coiner, C., Wu, J., Debinski, D., 2004. Assessing alternative futures for agriculture in Iowa, USA. *Landscape Ecol.* 19, 357–374.
- Schoemaker, P.J.H., 1993. Multiple scenario development—its conceptual and behavioral foundation. *Strategic Manage. J.* 14, 193–243.
- Scholz, R.W., Tietje, O., 2002. *Embedded Case Study Methods—Integrating Quantitative and Qualitative Knowledge*. Sage Publications, Inc., Thousand Oaks, CA.
- Schönwiese, C.D., 1994. Analysis and prediction of global climate temperature change based on multiforced observational statistics. *Environ. Pollut.* 83, 149–154.
- Sendzimir, J., Magnuszewski, P., Balogh, P., Vari, A. Anticipatory modeling of biocomplexity in the Tisza River Basin: first steps to establish a participatory adaptive, framework. *Environ. Model. Software*, in press.
- Siebenhüner, B., Barth, V., 2005. The role of computer modelling in participatory integrated assessments. *Environ. Impact Assess. Rev.* 25, 367–389.
- Soliva, R., 2007. Landscape stories: Using ideal type narratives as a heuristic device in rural studies. *J. Rural Stud.* 23, 62–74.
- Stremlo, M., Iselin, G., Kienast, F., Kläy, P., Maibach, M., 2003. *Landschaft 2020—Analysen und Trends. Grundlagen zum Leitbild des BUWAL für Natur und Landschaft. Bundesamt für Umwelt, Wald und Landschaft*, Bern.
- Swart, R.J., Raskin, P., Robinson, J., 2004. The problem of the future: sustainability science and scenario analysis. *Global Environ. Change Hum. Policy Dimens.* 14, 137–146.
- Tress, B., Tress, G., 2003. Scenario visualisation for participatory landscape planning—a study from Denmark. *Landscape Urban Plann.* 64, 161–178.
- Tress, B., Tress, G., Fry, G., 2005. Integrative studies on rural landscapes: policy expectations and research practice. *Landscape Urban Plann.* 70, 177–191.
- Tress, B., Tress, G., van der Valk, A., Fry, G.L.A. (Eds.), 2003. *Interdisciplinary and Transdisciplinary Landscape Studies: Potential and Limitations*. Delta Series 2, Wageningen.
- van de Kerkhof, M., Wiczorek, A., 2005. Learning and stakeholder participation in transition processes towards sustainability: methodological considerations. *Technol. Forecast. Social Change* 72, 733–747.
- van den Beld, M., 2004. *Mediated Modelling: A System Dynamics Approach to Environmental Consensus Building*. Island Press, Washington, DC.
- van den Berg, L.M., Veeneklaas, F.R., 1995. Scenario building: art, craft or just a fashionable whim? In: Schoutte, J.F.T., Finke, P.A., Veeneklaas, F.R., Wolfert, H.P. (Eds.), *Scenario Studies for the Rural Environment*. Kluwer Academic Publishers, Dordrecht.
- van Notten, P.W.F., Rotmans, J., Asselt, v.M.B.A., Rothman, D.S., 2003. An updated scenario typology. *Futures* 35, 423–443.
- Vested, H.J., Jensen, H.R., Petersen, H.M., Jørgensen, A.M., Machenhauer, B., 1992. An operational hydrographic warning system for the North Sea and the Danish belts. *Continental Shelf Res.* 12, 65–81.
- Vester, F., von Hesler, A., 1980. *Sensitivitätsmodell. Regionale Planungsgemeinschaft Untermain, Frankfurt a.M.*
- von Ballmoos, M., Bebi, P., 2003. *Raumentwicklung und Nachhaltigkeit in der Landschaft Davos*. Geomatik Schweiz, pp. 661–664.
- Walz, A., Bebi, P., Purves, R.S., 2004. Land-use simulation for small regions in the Swiss mountain area—comparison of two modelling techniques. In: *Proceedings of the GIS Research UK 12th Conference*, Norwich, UK, pp. 356–359.
- Wiek, A., Binder, C., Scholz, R.W., 2006. Functions of scenarios in transition processes. *Futures* 38, 740–766.