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Approaches to integrating indicators into 3D landscape visualisations and their benefits for participative planning situations

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Abstract

In discussing issues of landscape change, the complex relationships in the landscape have to be assessed. In participative planning processes, 3D visualisations have a high potential as an aid in understanding and communicating characteristics of landscape conditions by integrating visual and non-visual landscape information. Unclear is, which design and how much interactivity is required for an indicator visualisation that would suit stakeholders best in workshop situations. This paper describes the preparation and application of three different types of integrated 3D visualisations in workshops conducted in the Entlebuch UNESCO Biosphere Reserve (CH). The results reveal that simple representations of a complex issue created by draping thematic maps on the 3D model can make problematic developments visible at a glance; that diagrams linked to the spatial context can help draw attention to problematic relationships not considered beforehand; and that the size of species as indicators of conditions of the landscape's production and biotope function seems to provide a common language for stakeholders with different perspectives. Overall, the of the indicators the functions required to assist in information processing. Further research should focus on testing the effectiveness of the integrated visualisation tools in participative processes for the general public.

Keywords: 3D visualisation; Landscape indicators; Participation; Integrated visualisation tools; Landscape management

1. Introduction

Current planning processes aimed at the management of landscape change should include local stakeholders in order to enhance the acceptance of the outcome and the implementation of measures (Healey, 1997; Fürst, 2005). One problem of participative planning processes is communicating the relevant planning information among all the stakeholders in an understandable way (Demuth and Fünkner, 2000). For an integrated analysis of landscape change, the characteristics of landscape conditions such as the productivity of the soil, water supply and retention, climatic regeneration as well as geological and biological diversity or the scenic view have to be evaluated. In practice, indicators are used to measure the impact of landscape change on these conditions with regard to economic, ecological and social requirements (v. Haaren, 2004).

Traditional planning tools such as maps, diagrams, tables or texts often fail to communicate the results to lay people (Tress and Tress, 2003; Appleton and Lovett, 2005). Compared to these tools, GIS-based 3D landscape visualisations show a high potential for contributing to a better understanding of the information (Orland et al., 2001; Al-Kodmany, 2001; Heißenhuber et al., 2004). By integrating indicators, 3D visualisations offer the opportunity to link all the dimensions, the visual and non-visual parts of the landscape, and may even provide a new planning tool (Bishop and Lange, 2005). However, only single studies exist that are suggesting possible designs of integrating indicators in these visualisation tools (e.g., Hehl-Lange, 2001). Beyond, the impacts of the integrated tools in real planning situations have not been tested yet.

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To link visual qualities to production, ecological, cultural and amenity functions was one objective of the EU project VisuLands—Visualisation Tools for Public Participation in the Management of Landscape Change (http://lrg.ethz.ch/visulands). In the VisuLands project, tools were developed to improve understanding of what people consider important in the visual landscape and to assist in the assessment of different landscape development scenarios. This paper describes the research into how to represent landscape indicators in 3D visualisations, and their application in public participation processes. First, three ways to display indicators in 3D landscape visualisations are classified with respect to the type of visualisation and interactive requirements. Second, results from psychological and media-pedagogical research on using images for information communication are applied in the design of 3D visualisations with regard to human information processing. Third, based on the principles derived from the literature review, integrated 3D landscape visualisations are used in real planning situations to collect feedback from end users with regard to understanding and utility. The results reveal what qualities the respective designs and the mode of interactivity of the three types of integrated 3D visualisations had for the participants' information processing and for the planning process. Thus, they should provide a component for a standardised 3D visualisation method for landscape indicators.

2. Literature review

2.1. Integrating indicators into 3D landscape visualisations

Today, rapid development in computer technologies has extended the possibilities of visualisation in landscape planning enormously: geographic information systems (GISs) make it possible to base visualisations on real-world geo- and vegetation data and advanced rendering methods allow the photorealistic representation of scenes in real-time. Interactive landscape visualisations may facilitate the communication of landscape related issues by raising people's attention, by demonstration, by putting them in context, and by the construction of mental models (Dransch, 2000). Technically, virtual landscapes are composed of the terrain, a geotexture, which is usually created from satellite data or orthophotos, vegetation and built structures (Lange, 2001), possibly extended by water, animals, people, atmosphere and light (Ervin, 2001).

Different types of landscape visualisations can be distinguished with regard to the level of realism, ranging from abstract to realistic representations of the landscape (Lange, 2001), and secondly, with regard to perspective and scale, ranging from an overview to close local views. Third, the ability to interact with landscape visualisations is important for their use as a communication tool. Different levels of interactivity are available (Schroth et al., 2005), so that changes of the visual landscape can be assessed by experts as well as community members in an intuitive way by switching between alternative scenarios and timeframes (Lange et al., 2003). If parallel windows are used, the landscape model can be linked to abstract scientific visualisations, e.g., diagrams, by hyperlinking objects in the landscape to them. Finally, real-time movement makes it possible to view the landscape model from different perspectives and to zoom into areas of interest or zoom out to the overview.

For a comprehensive landscape assessment, ecological, economic, social and aesthetic criteria have to be evaluated. Aesthetic can be assessed by the visual landscape quality expressed mainly by visual elements (Nohl, 2001) that can be displayed in the 3D visualisation. However, in evaluating ecological and socio-economic aspects, complex systems have to be analysed (v. Haaren, 2004). These systems cannot be mapped themselves and therefore, must be illustrated by indicators, i.e., measurable characteristics reflecting the state of the system. Visualising smaller entities of the whole system that indicate the extent of specific functional relations or their spatial dimension for a particular issue are challenging but have proven to be practical (Hehl-Lange, 2001). Three different types of indicator visualisation in three dimensions are classified in this paper with regard to their representation and interactive features.

First, thematic maps show objects or topics that are not part of the topography, e.g., economic or social data on economy (Hake et al., 2002). Cartographic projections of thematic maps onto the terrain as an overlay are suitable for showing indicators in relation to elevation, slope or orientation (Sieber, 2001). Traditional two-dimensional thematic maps usually have a rather low level of realism, i.e., they abstract reality considerably. However, different target groups prefer different representations, e.g., it has been suggested that realistic representations are more suitable for lay people (Buziek et al., 2000). Therefore, one great potential of interactive visualisations is that they allow diverse target groups to view, combine and explore the underlying geodata individually.

Second, non-visual processes with respect to the geological or biological impact of a landscape change can be uncovered indirectly by visual indicators. For example, the ecological needs of different plant species can be used as an indicator value for the sensitivity of and adverse effects on a biotope (Böcker and Stöhr, 2004). Thus, vegetation species can demonstrate harmful consequences of a landscape change on the landscape's ecological quality that are not necessarily visible at a glance. The question is how these indicator species could be meaningfully visualised in more realistic looking 3D models for different stakeholders. In using interactivity, time series seem to be an appropriate feature for the representation of landscape change.

Third, most of the economic and social indicators are hard to express, as they are neither visual nor spatially explicit. Their assessment is not formalised yet with regard to landscape assessment and the relationships are rather complex (v. Haaren, 2004). Socio-economic data can be shown in additional windows with abstract scientific visualisations, e.g., diagrams or tables, which are linked to the realistic landscape model by hyperlinks. In this way, the spatial relationship between data and location becomes explicit. However, empirical knowledge about the effectiveness of this approach is still rare.

The three identified approaches of indicator visualisation were further elaborated to enhance their potential for communicating specific information. Therefore, the individual cognitive dimension of presenting and using visual information as well as modes of interactivity and their potential in the communication of indicators were investigated.

2.2. *Individual cognitive dimension of presenting and using visual information*

Successful information delivery in the participative planning of landscape change should rely on the principles of communication theory (Orland et al., 2001). The communication process is characterised by information, the extraction of information from a medium and the individual information processing that leads to the comprehension of the message (Luhmann, 1987). This means that individual cognitive performance is finally responsible for the information delivery's degree of completeness. Therefore, the theoretical background of image reception, cognition and functions of images as an aid in learning can build a framework to explain the effects of visual information on the recipient and to derive advice for an effective design of the information in 3D visualisations (Wissen et al., 2005; Wissen, 2007).

Cognitive theories are based on an information processing paradigm that explains the attraction of interest to and the processing of media messages (Bonfadelli, 2004a). The idea is that people confronted with new information activate a cognitive pattern to integrate the new impressions (Scheufele, 2001). Assisting in the consecutive phases of this information processing, the design of images functions mainly to motivate and thus focus the attention of the viewer to support the extraction of information by pointing to relevant attributes, contextualising information, facilitating scenario building, and assisting in the comprehension of the message by giving links between the reality and the cognitive concept of an issue that has to be built up or extended (Weidenmann, 2002a; Bonfadelli, 2004a). In cartography, Buziek et al. (2000) summarises the implications of the major cognitive approaches by Neisser (1976), Paivio (1986) and Pylyshyn (1981) for the use of dynamic and interactive features in visualisation. Buziek et al. (2000) shows that such features are a means to highlight specific visualisation objects, to support the perception of space, and to facilitate learning processes. A brief overview of recommendations drawn from literature for the presentation of the information in images that help fulfil these functions is given in Table 1.

Conclusions from the fields of media-psychology and media-pedagogic point out that perception, recognition and cognition are multi-sensory patterns of events (Luders, 2001; Faßler, 2002). For this reason, many factors have to be taken into account when trying to optimise the design of 3D visualisations for information communication, and a simple mechanical application of design and application rules would not be sufficient either. The research results instead provide an orientation aid to refer the different principles to each other so that the 3D visualisations can be designed to accommodate the psychological principles of information processing (Schnotz, 2002).

3. Overview of case study site and methodological issues

3.1. *Social-empirical testing*

A social-empirical research design was set up to provide a structure for collecting and analysing end-users' feedback on the utility of the integrated visualisation tools. Because the impact of the 3D visualisations had to be assessed in the complex context of participative landscape planning, it was not possible to control all the influencing factors in a quantitative experiment. Therefore, an explorative case study analysis with a mix of qualitative methods was seen as most suitable (Flick et al., 2003).

The data was collected over three thematically different series of workshops related to landscape development and with different groups of stakeholders. Two of these workshop series are discussed here in detail, the third had a slightly different participatory setting. The methods for data collection comprise observation of and group discussions with the workshop participants, as well as in-depth interviews with key actors. In order to ensure an objective observation, two researchers conducted independent observations, following structured observation guidelines, and compared the results afterwards. These have been documented in protocols and, when possible, on audiotape. Later, the interviews were transcribed on the basis of these tapes. The data was then analysed by coding and clustering, using a combined method of grounded theory and qualitative content analysis (Strauss, 1998; Diekmann, 2005). The coding was applied by two researchers, who then compared the results. This approach of carefully combining different data sources, researchers, and methods should lead to more comprehensive results as conclusions are based on different levels and thus can be more extensive than with one access only (Kelle and Erzberger, 2003; Flick, 2004).

3.2. *Case study site—Entlebuch UNESCO Biosphere Reserve*

The Entlebuch UNESCO Biosphere Reserve (UBE) was chosen as the case study site for testing the integrated visualisation tools because the Biosphere management had

Table 1
Results from the literature review on possible functions of 3D visualisations as an aid to human information processing and recommendations for the presentation of the information to fulfil the functions

Function	Design recommendations for representation and interactivity
Triggering the attention of the viewer (cognitive and affective) and raising his awareness which enhances his chance of perceiving the information	High attention • Visualisations that integrate new aspects of already known issues (Bonfadelli, 2004a; Klimsa, 2002; Weidenmann, 1994) • Areas with a lot of information presented (Hearnshaw, 1994; Schierl, 2001) Attention can be evoked by • Dynamics (Buziek et al., 2000) • Conciseness (Bonfadelli, 2004b) • Closeness and relevance; comprehensibility; credibility (Weidenmann, 2002b; Bonfadelli, 2004b) • Emotional contents (Strzebkowski and Kleeberg, 2002) • Opportunities to interact with the representation (Buziek et al., 2000) • Originality (Meckel, 2001) • Colour and size (Weidenmann, 2002b)
Pointing to the relevant attributes to help the viewer in the extraction of information	Organising complex issues/providing for transparency by • Objective simple designs (Weidenmann, 2002a) • Didactical presentation of the elements, e.g., with chosen display detail and perspective; colour and size distortion (Weidenmann, 2002a; Schnotz, 2002)
Contextualising the information to aid the viewer in getting familiar with a situation	Providing for • An overview on the area of investigation and data for comparison (Dransch, 2000) • Realistic and complex situations (Weidenmann, 2002b) • A combination of realistic and abstract elements to be suggestive about the situation (Weidenmann, 2002a)
Giving links between the reality and the cognitive concept of an issue to assist the viewer in the development of his perception	Providing for • A medium level of reality and a medium degree of complexity (Lewalter, 1997) • Symbolic images (Weidenmann, 1994) • A design according to the representation form (e.g., topographic information or spatial arrangements in an abstract design; appearance of elements in a realistic design) (Weidenmann, 2002b) • Interactive navigation between overviews and focused zooms to help the viewer developing his own mental model (Buziek et al., 2000) • An arrangement of different information windows to increase access to the desired information (Weidenmann, 2002b)

already initiated various collaborative planning forums (Schroth et al., 2006). The site is located in central Switzerland, in the main valley between Lucerne and Bern, and is famous for its cultural landscape of national and international significance. The diverse, agricultural landscape contains important habitats for plants and animals, e.g., karst areas, forests and unique moorlands. As with similar regions throughout Europe, the Entlebuch area faces problems in maintaining its agricultural farms and in losing inhabitants, which in turn can cause major impacts on the landscape over the long term. Biosphere reserves are sites recognised under the UNESCO's Man and the Biosphere Programme that innovate and demonstrate approaches to conservation and sustainable development (UNESCO, 2006). Therefore, the Entlebuch serves as a model region and a 'living laboratory' where solutions for these problems are developed in participative planning processes.

3.3. *Characterisation of participative planning at the case study site*

Healey (1997) observed a paradigm shift, the so-called "communicative turn" in planning participation. In addition to Healey's (1997) most influential book *Collaborative Planning*, Forester (1989) has determined the discussion in planning theory, while both authors refer to Habermas' (1981) *Theory of Communicative Action* as the basis of their arguments. Forester (1989) adopts Habermas' theory to planning in order to understand planning as a communicative process and to derive ethical norms for communication in planning, i.e., comprehensiveness, objective truth, normative correctness and subjective truth, in other words: transparency and credibility. Because transparency and credibility are key principles in collaborative planning, it is necessary to assess the indicator visualisations not only with regard to their communication functions (Table 1), but also how far they enhance transparency of the process. From his analysis of current planning processes, Forester concludes that communication in this specific context is biased by structural inequalities and he sees the role of planners in transferring Habermas' ethics to planning as a way to facilitate a consensus-oriented communication. Like Forester, Healey (1997) also refers to Habermas (1981) and she emphasises that today, planning is shaped by a multi-stakeholder society. She asks how planning could achieve sustainable results in such a context and her answer is a planning approach that she describes as "collaborative planning", characterised by the sharing of power, group learning, transparency and a consensus-oriented style of communication. All the workshops and forums established in the Entlebuch area attended to the suggestions of Forester and Healy in practice and provided a very good basis for testing the visualisation tools and gathering feedback on their usability.

3.4. *Access to the planning situations and choice of 3D visualisation scenarios*

Landscape development is a central topic in most of the projects carried out in the Entlebuch because a beautiful and ecologically stable landscape is recognised as the basis for a healthy life, and, furthermore, provides natural capital for tourism and a powerful mechanism for promoting regional products (Ruoss et al., 2002). These are crucial aspects as one third of the local people work in the tourism and agriculture sectors. Among the most important regional employers are the cable car companies in Soerenberg and Marbach (Schnider, 2005).

Access to real planning situations was made possible by one of the Biosphere's regional managers who coordinated scientific research and education in the Entlebuch Reserve. He arranged for the VisuLands team to apply the integrated 3D visualisations in different workshops. All of the workshops described in this paper were facilitated by him and took place locally. The workshops followed a standard workflow shown in Table 2 that was elaborated for the participatory processes in the Entlebuch Reserve (Schmid, 2004). The application of the 3D visualisations was integrated in this workflow. In all cases, the content of the indicators was discussed beforehand with the experts involved and the facilitator conducting the workshops. In the following, the application and effects of the integrated 3D visualisations used in the two case studies are described in detail.

4. Case study 1: tourism

4.1. *Concept*

At that time, the main problem for local tourism in the Entlebuch area was the lack of an up-to-date infrastructure in comparison to its national and international competitors. Therefore, the owners of cable car and skiing facilities, as well as some hoteliers, were planning new investments. According to the principles of the Biosphere Reserve, the investments were aimed at a sustainable regional tourism development, but a long-term strategy that would ensure synergetic effects among the different investments was missing. Therefore, the Biosphere management invited all relevant local stakeholders, including the investing cable car owners, hoteliers, a local farmer engaged in agro-tourism, and representatives of the Tourism Board, to an open forum on the future objectives for tourism in the area. In this context, the attractive landscape was addressed as one asset of local tourism and how tourism shapes the landscape was discussed as well. Although the forum did not address the general public, it was open to other stakeholders. The workshops of the forum were facilitated by a member of the Biosphere management and aimed at group learning and a consensus-oriented communication (Healey, 1997). The outcome of the workshops, i.e., the future tourism strategy, was relevant insofar as it will provide guidelines for the allocation of new investments and infrastructure, but attendance was not obligatory.

However, a first workshop conducted in 2003 without any visualisation support, suffered from the lack of innovation and the facilitator suggested using landscape visualisations. The research team agreed to include the forum in its case study, because the issue was landscape related and the organisation of the forum was a good example of collaborative planning. The second workshop, held at the local agricultural school in May 2004, was supported by interactive landscape visualisations, attended by eleven tourism stakeholders (10 men, one woman) and three researchers, and facilitated by one of the Biosphere managers. In comparison to the rather common use of visualisations at the end of a planning process, the landscape visualisations were introduced at a very early stage to support the development of scenarios (cf. Lange and Hehl-Lange 2006).

4.2. *Methods*

A shared observation guideline assisted each of the three participating researchers in looking for triggers that would

Table 2
Standard workflow with different phases in the moderation of a workshop

Factual phases	Introduction	Collecting	Choosing	Editing	Planning	Conclusion
Emotional phases	Orientation	Working				Finishing

Source: Schmid (2004, p. 85).

indicate an impact of the visualisations. Triggers included gestures towards the display, verbal references to the image or an emotional response like laughter. The content of the overall discussion was documented in a protocol while screenshots and photos showed the setting and the visualisations. After the forum discussion, a 10-min group discussion was held in order to establish a group position on the visualisations. This group assessment was compared with the individual assessments of the impact of the visualisations. In addition, questionnaires were given out. As a third element of data triangulation, the facilitator was interviewed in depth.

In the May 2004 workshop with 11 stakeholders from the tourism sector, a discussion on the current condition outlining the strengths and weaknesses took place. The chances of the current tourism supply and the possibilities for new supplies were also analysed. The two topics of winter and summer tourism supplies in the Entlebuch region were evaluated consecutively. At the beginning of the workshop, the facilitator introduced the 3D visualisations to the participants as instruments that can deliver relevant data for the discussion. The VisuLands team was responsible for showing the visualisations on demand and explaining their content. In this workshop, two different kinds of integrated visualisation tools could be applied, i.e., thematic maps and linking diagrams to the 3D visualisation. Visualisations of indicator species were not used because the vegetation was of minor importance. In the following section, the course of the second workshop is presented with the focus on the use of indicator visualisations.

4.2.1. Thematic map on basis of an elevation analysis

Traditionally, winter skiing around the village of Soerenberg (1165–2350 m above sea level) has been the major tourist activity in the area. Therefore, most of the initial discussion in the first workshop focused on winter tourism and it was stated that safe snow conditions are of great importance, as is long-term quality, and an infrastructure that meets demand. One of the key results of the first workshop was the identification of climate change as a key driver of change because the skiing areas of Soerenberg are lower than those of the competitors and will be one of the first to suffer from global warming.

In preparing the second workshop, the facilitator asked for visualisations of scenarios from climate research that would show the average elevation at which snow will sufficiently be available for skiing over the winter season, i.e., this average "snow line" worked as aggregated indicator for the economic prospects of winter sports. On the basis of studies by Föhn (1990) and Elsasser and Bürki (2003), a snow line (coloured green) at an elevation of 1500 m was chosen through an elevation analysis of the terrain (Fig. 1). Personal communication with one of the researchers in climate change and tourism in Switzerland supported the assumption that Soerenberg will be among the first places to suffer from climate change, although no local climate model that incorporates the topography exists for the area. The use of the LandXplorer software (http://www.3dgeo.de) made it possible to change the elevation on demand and the intention was to use this feature to show different scenarios in a transparent way.

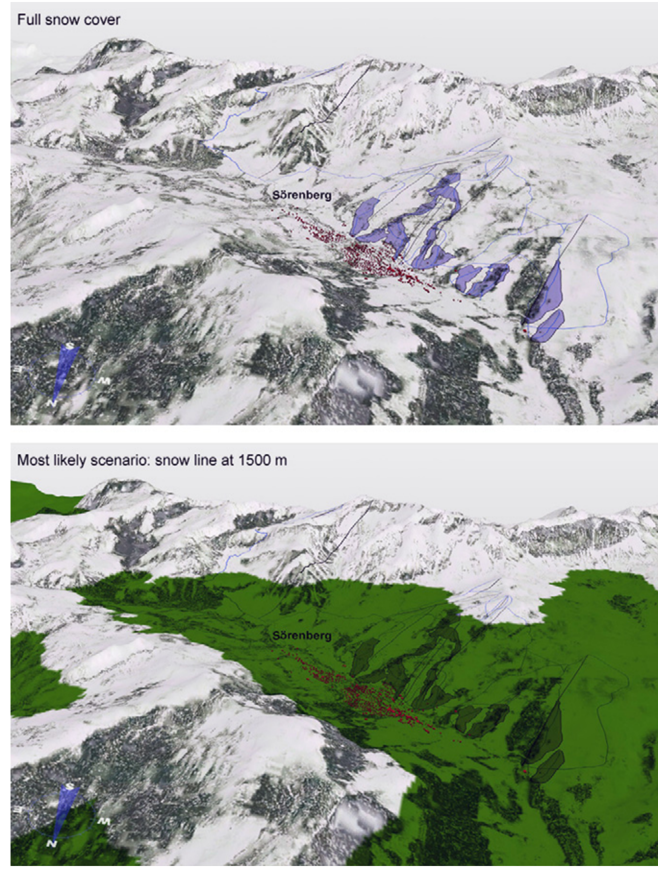

Fig. 1. Average level of sufficient snow conditions for skiing (snow line) in comparison to the existing infrastructure: The green areas are below the average level, black lines represent the ski lifts, the blue areas are covered with artificial snow and the village is shown in red. The second variant represents the most likely climate change scenario (3D visualisation: VisuLands 2005; geodata courtesy of GIS Canton Lucerne).

Combining the snow line with the realistic 3D terrain model and showing it from an overview perspective should draw the participants' attention towards the consequences of climate change. Highlighting the area of Soerenberg and the local skiing facilities should establish closeness and address the participants' everyday experience. In order to represent uncertainty visually, the areas without snow got an abstract, transparent green colour in contrast to the past situations with snow that were rendered rather realistically. The levels of realism and complexity should not only be suggestive of the situation but were also intended to assist the viewer in forming an evaluation and building a personal opinion of this rather abstract issue with regard to local conditions.

4.2.2. Linking the number of overnight stays to the location of hotels

After the discussion of global warming as a key driver of change, the discussion focused again on the decline of the

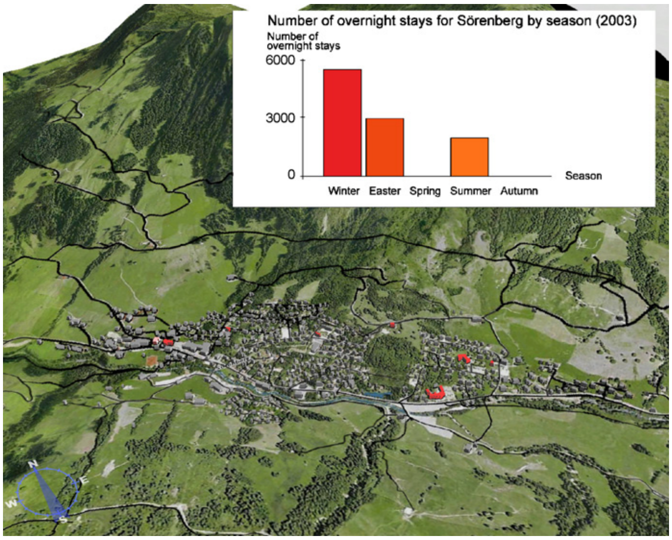

Fig. 2. Link of the 3D visualisation of the village of Soerenberg with a diagram on numbers of overnight stays over seasons. The red objects represent the hotels (3D visualisation: VisuLands 2004; geodata courtesy of GIS Canton Lucerne).

infrastructure. The GIS layer with the location of chalets (holiday houses, in grey), bed and breakfasts, hostels, and hotels (red) in Soerenberg was laid onto the terrain model with the buildings in the form of extruded boxes (Fig. 2). The red colour should direct the attention to the overall number and spatial distribution of accommodation for short-term tourists. The overview perspective of a rather realistic landscape and the abstract building models should help in contextualising the information without getting too complex.

As an economic indicator, the number of overnight stays in the region in 2003 was shown in a diagram in an extra window and linked to the short-term accommodation objects in the model. The diagram was designed with rather simple highlighting to indicate the main use of accommodations in winter, the smaller peaks at Easter and in summer, and the long vacancies during spring and autumn.

4.3. Results and discussion

Overall, data was collected from three different perspectives—the observers (protocols, observation guidelines), the forum participants (individual questionnaires, shared group discussion), and the facilitator (in-depth qualitative interview). For the analysis, these data sources were transcribed and related to the visualisations. Altogether, the data was processed in a content analysis, summarising the observed visualisation impacts and comparing the inside view of the participants with the observations by researchers and facilitator. In the following, the impacts on the planning process and outcomes are extracted. The results are assessed with regard to the visualisation functions from Table 1 and the need for transparency (see the requirements of collaborative planning).

4.3.1. Thematic maps

In the workshop, the facilitator chose a future level of probable safe snow conditions of 1500 m in 50 years. Although the numbers had been known before, the visualisation caused some discomposure and astonishment, indicating the emotional effects of the 3D visualisations. This means that the design was rather useful for triggering the attention of the participants and addressing them emotionally as they revealed the effect of the change on the local situation. The relevance of the information was stressed by this approach and it raised the participants' awareness. One participant recapitulated that "the green will be without snow". The high degree of abstraction of the climate change scenario assisted in the extraction of the main message, although one participant assessed it as too simplified. Thereby, participants were motivated to contribute their own view of the issue and their local knowledge. This is an indication that the visualisation was compared with the individual's cognitive concept of the shown facts. With regard to information processing, the design turned out to be very suitable for transferring the message of the scenario. The topic was further elaborated in the discussion by exchanging knowledge on factors and their effects. Thus, the relevance of the indicator was assessed collaboratively.

As a direct impact of the visualisations, the focus of the discussion shifted from the enhancement of winter sports to the diversification of tourist opportunities towards hiking, educational trails and farm holidays, and, making better use of the landscape as an asset. In conclusion, it can be suggested from the meeting minutes that the elevation analysis was the turning point of the discussion and the facilitator confirmed that it had a very strong impact on participation. Nevertheless, it should be noted that one participant felt uncomfortable working with the 3D images and stated in later conversation that he felt slightly manipulated because the image had such a strong impact. Another participant expressed his doubts on the credibility of the visualisations, because local conditions like exposition were not considered specifically. These experiences are in accordance with findings by Dockerty et al. (2005) and Sheppard (2005), who identify the downscaling process for national data on climate change to locally engaging scenarios as one of the biggest challenges in visualising climate change.

However, such detailed forecasts based on local models are not necessarily required in "what-if" scenarios, which aim to facilitate the discussion of hypothetical futures: How do the stakeholders respond if climate change will have an impact? Nevertheless, it is suggested that clarifying the relevance of the "what-if" scenarios in comparisons to forecasts or other more precise methods is necessary to present the assumptions in a transparent way. The collaborative and interactive development of the visualisations seems to be the right approach to making the assumptions more transparent, but there was not enough time in this workshop to go through the alternative scenarios in detail, and the interactive analysis could have been used more as well.

Did the visualisations have a long-term impact (Nicholson-Cole, 2005)? There are strong indications that the visualisations did have an impact on the planning outcomes. From follow-up meetings with local stakeholders, it appears that the owners of the local skiing infrastructure installed the new facilities at higher elevations with regard to the discussion and the visualisation. In addition to winter tourism, the diversification towards a stronger focus on summer tourism was not only a consensus but a variety of new offers for summer tourists have now been established.

4.3.2. Linking diagrams to the 3D visualisations

Overall, the representation of the indicators by hyperlinking was understood by all participants and eight of the eleven participants favoured linking the landscape visualisations to statistical indicator data. The facilitator mentioned that all participants were familiar with the data but showing them in combination with the 3D visualisations "put more stress on them and they might have got an official character." This means that the indicators were noticed more consciously and in context because of the visualisations, thereby increasing transparency and credibility of the assumptions.

Looking at the uneven distribution of overnight stays for winter in contrast to other seasons, the participants recognised the open potential for summer tourism. With regard to the uneven distribution of holiday houses and hotels, the stakeholders identified a lack of hotel space. It became clear that this lack of hotel space makes it impossible to host large groups, e.g., conferences or bus tourists, who usually travel in groups of about 30 people. Cause-and-effect chains were elaborated in the discussion and taken into account in the tourism development concept by calling for additional hotel space.

The chosen design seemed to assist the stakeholders in the workshop very well in the comprehension and assessment of the factors shown. As this group was used to abstract designs, the results may not be transferable to other stakeholders who are not so familiar with abstract presentations.

5. Case study 2: agriculture

5.1. Concept

The characteristic landscape of the Entlebuch region has been shaped by agriculture, in particular, cattle breeding and dairy farming. However, the future development of this area depends on political and economic driving forces, such as the liberalisation of the agricultural market and declining subsidies that will increase the pressure on existing farm management practices. A decline in grazing will cause major changes in the landscape with negative impacts on local socio-economic and ecological conditions. Therefore, within the framework of the EU project: Lacope–Landscape Development, Biodiversity and Co-operative Livestock System (www.lacope.net) local farmers of the Entlebuch Reserve, administrative representatives, experts, and scientists worked together on a concept for future management systems on the alpine farms. The outcome of the collaboration was thought to show measures that take into account very specific regional characteristics but their implementation was optional for the individual farmer and not tied to legal documents. The major aim was to elaborate sustainable land use practices on the alpine farms that would be suitable to keep the dynamic of forest and pastures in a balance and thus the landscape open. For this task, landscape functions, e.g., the production and habitat functions, should be integrated into the assessment of possible land use changes. Indicators to assess these landscape functions should match the interest of the stakeholders, be applicable on the alpine farms, and be calculable on the basis of the available GIS data set. In this case, the vegetation types on the alpine farms were seen as a valuable data set for deriving the indicators.

The vegetation on the pastures is an important resource for the productivity of an alpine farm. The productivity of a pasture can be determined by the specific fodder quality of the vegetation types. A declining fodder quality is mainly expressed by the percentage of weeds in the respective type (Landwirtschaftliche Lehrmittelzentrale, 2004). For the assessment of the biotope function, the intactness of the respective vegetation types can be used as an indicator expressed by plants and plant associations. Therefore, plant species were chosen as an indicator for both the economic and the ecological condition of the pastures at different time periods of the agricultural trend scenario.

5.2. Methods

The Lacope team organised the workshops and recruited the participants. In a strong collaboration with the Lacope team, the concepts for the integrated 3D visualisations for two of the workshops were developed. The first workshop, in November 2004, was attended by eighteen stakeholders (fourteen agricultural specialists (i.e., farmers) and four representatives from public offices) and three scientists (agricultural experts) working on the Lacope project, who discussed the concrete impact of possible future landscape developments and the consequences for alpine farms. The group met again in a second workshop in June 2005, but this time only eight stakeholders and two scientists were present. They dealt with the developing solutions to optimise the management of the alpine farms, taking economic and ecological aspects into account. Using the integrated 3D visualisations in a workshop series, it was possible to enhance their design by applying the research results of the earlier workshop.

The stakeholders described a restructuring of the alpine farms according to the agricultural trend scenario.

As a consequence thereof, the view of the landscape would change drastically as a lot of open areas would be subject to a succession to forest. This scenario was to be prepared with 3D visualisations of all three types in order to show the consequences of the changes on single areas for an in-depth assessment.

First, the qualitative scenario had to be translated into a GIS database. A basic problem was that such detailed statements on regional landscape change require a large number of parameters that could not be collected in the given time. Moreover, as the simulated landscape processes grow more realistic, the parameter's uncertainty also grows larger. In addition, the results become difficult to interpret (Fritsch, 2002). As a compromise, simplified estimates were used to identify landscape processes, keeping in mind that the model's limited spatial validity had to be communicated.

Quantifiable criteria for pastures with high potential for land use change to extensive grazing or abandonment were derived from literature, e.g., the distance between farm building and pasture, the height above sea level, the slope, the soil moisture expressed by the vegetation types, and the current type of management (Pezzatti, 2001; Gotsch et al., 2004). In the next step, these criteria were translated by a spatial analysis of the digital terrain model and a query of the thematic data using ArcView 3.3 (www.esri.com) into a spatially explicit GIS database for the farms under discussion in the planning workshop. As numerous ecological and economic variables cannot be anticipated with sufficient certainty beyond 30 years (Lederbogen et al., 2004) and as the perceived relevance of distant consequences of changes is rather low for most people (Nicholson-Cole, 2005), a time horizon of 30 years was defined. A time period of 5 years was chosen to demonstrate economically relevant changes due to management alternatives in the short run and two other time frames from today, each of 15 years, should reveal the impact of the development on the vegetation and thus the view of the landscape.

Causal chains were built, including knowledge on vegetation ecology, and were used to allocate the changes in the land cover in the selected time frames according to the agricultural trend scenario. An example for such a causal chain is: If grazing pressure declines, then extensive pastures on a rather wet fen will be avoided by cattle. This will cause the initiation of a succession process to forest that would start with dry grass and tall forbs in the first stages. On extensive pastures in dryer areas, grazing weeds and groves would come up in a time frame of 5 years, followed by an area-wide growth of spruces (*Picea abies*).

5.2.1. Visualising indicator species of fens

To enable an assessment of the view of the landscape, the intactness of the vegetation types, and their fodder quality, rather realistic representations of the landscape changes were prepared with the software Visual Nature Studio (VNS; www.3dnature.com). The programme allows GIS shape files to be imported and can distribute different plant models in the polygons. The vegetation types were mapped following a simple mapping key useful for vegetation mapping in an agricultural management context. The size of the key plant species of each vegetation type, e.g., *Eriophorum latifolium, Ranunculus acris, Ranunculus aconitifolius*, and different clover species (*Trifolium*) indicating fens, was exaggerated. Additionally, indicators for the direction of long-term development, e.g., rush species (*Juncus* sp.) and *Veratrum album* as indicators for effects due to changes in the grazing intensity were shown. Thus, the viewer's attention should be drawn to these indicators without disturbing the represented view of the landscape (Fig. 3). For a better orientation, viewpoints were chosen that are easily recognisable due to landmarks, e.g., by showing the Schrattenfluh, a large karst mountain in the area, in the background. In the first workshop, the distribution pattern of the plants in the polygon and some of the plant species shown were criticised as incorrect by the stakeholders. These aspects were improved in the 3D visualisations used in the second workshop.

In both workshops, these visualisations were used to activate the subsequent discussion. In the first workshop, they were part of an impulse presentation whereas in the second one, they were presented in a loop of a sequence that presented each image for six seconds so that the participants were able to see them several times and then make their thoughts or comments known.

5.3. Results and discussion

The effects of the integrated 3D visualisations used in the two workshops are based altogether on four observation protocols, two group discussions, and four in-depth qualitative interviews, i.e., three with the facilitators (in the first workshop, the facilitator team, comprising the regional manager and a scientist of the Lacope project, was interviewed together, in the second workshop, they were interviewed separately) and a telephone interview with one of the representatives of public office who focuses on nature protection. The data analysis followed the same methods as in the case study described in Section 4.2.

5.3.1. Visualising indicator species

In both workshops, the specific visualisations received rather intuitive responses from the stakeholders. These emotional reactions can be traced back to their identification with the area shown, also recognised by the facilitator. Overall, this can enhance the motivation to deal with the subjects shown.

The exaggeration of the indicator species in some of the visualisations was criticised. In one image, the pasture was said to look like a fairy tale due to the distribution of too many of the indicator species. One farmer said that pastures like those represented do exist but not in their area. In another visualisation, the transition between two vegetation types was very sharp because of the GIS

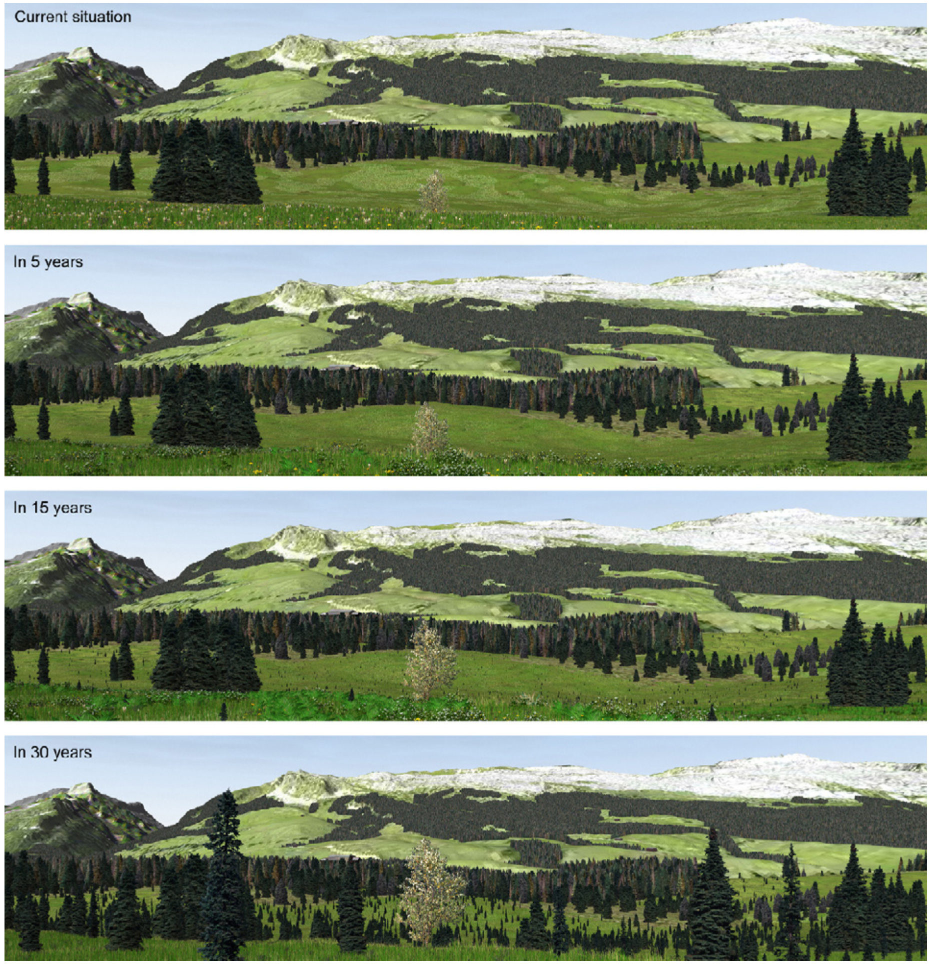

Fig. 3. Realistic renderings demonstrating the impact of a management change on the habitat quality through the use of indicator species on vegetation level (3D visualisation: VisuLands 2005; geodata courtesy of GIS Canton Lucerne).

polygons and from the chosen standpoint it looked awkward and rather unrealistic. Therefore, standpoints showing landscape elements in a perspective where they are not recognisable at first glance should be avoided and exaggerations carefully applied. On the other hand, the participants were of the opinion that exaggerations in these kinds of visualisations are good for raising the awareness of lay people who are not familiar with the area with regard to problematic issues. The actual effectiveness for lay people should be analysed in further studies.

Lively discussions on the accuracy of the content followed the presentations. The stakeholders responded according to their own experience and thus they revealed different opinions on the development of the vegetation. The farmers mentioned that deciduous trees would come up in the first succession stages, whereas the foresters were of the opinion that spruces would occur area-wide. Rush species were said to be indicators for an overuse of wet pastures. Indicator species occurring in cases of under-grazing were listed by a representative of the nature protection office. Although the represented vegetation change in the 3D visualisations was not correct in every detail, the feedback shows that the stakeholders recognised the indicator species. The visualisations pointed out their use in promoting the exchange of experience between stakeholders with different perspectives. The method of showing new aspects in the form of indicator species in known development processes was said to be very useful for this task. With regard to the effectiveness, these 3D visualisations could be enhanced by integrating more local knowledge and specialists' experiences. Their use could lead to more meaningful discussions between stakeholders, e.g., on problematic developments with regard to the maintenance of biotope functions due to apparently small management failures, thus communicating certain measures and their intended aims more comprehensively. In addition, the farmers stressed that they got a stimulus for their thoughts on the future landscape and possible land use.

The stakeholders in the workshop knew the development used for the visualisations very well but seeing it as a time series brought a new aspect. Verbal references and gestures indicate that the interactive temporal presentation assisted them in recalling or even anticipating experiences, in turn motivating them towards active participation in the discussion on possible solutions. In other words, the time series communicated the dynamics of landscape change and highlighted how the visual landscape will change in this scenario. Referring to some of the indicator species, discussions on cause-and-effect chains took place, e.g., mistakes made in management practice that led to the occurrence of the rush species, revealing interest for a deeper analysis to find solutions to solve the problem. Visualising indicator species might therefore be useful for simple initial assessments to alert stakeholders to aspects of change that should be subject to further investigation.

6. Conclusions

Overall, all three ways of integrating indicators into 3D landscape visualisations have shown to be effective in assisting the analysis of landscape change when using them as an introduction to the working phase of participative planning workshops. These results correspond to the conclusions by Lange and Hehl-Lange (2005) that landscape visualisation can facilitate the communication between professionals and the public and increase the scope of participatory workshops. The chosen designs fulfilled the functions required by assisting in information processing by raising awareness, contextualising information, and encouraging a critical comparison with one's personal perception as well as the further analysis of a topic. The interactive spatial analysis was flexible enough to respond to the fact introduced by the facilitator and to show the possible impact of a climate change scenario on local tourism. The visual analysis supported the facilitator's attempt to open the discussion on more balanced tourism strategies for winter and summer tourism and there are strong indications that it had an impact on the outcomes as well.

Interactively linking the spatial distribution of accommodation with diagrams on their average utilisation, animated the stakeholders to set up cause-and-effect chains that drew attention to problematic relationships that should be considered in a further analysis. Data known beforehand but not included in the considerations were thus used for the assessment.

Visualising indicator species seems to provide a common language for different stakeholders to discuss problematic developments from different perspectives and to alert stakeholders by offering a simple initial assessment. The dynamic presentation of indicator species in a time series especially proved to support the understanding of landscape change. By drawing attention to how slow processes evolve on the vegetation level, they helped stakeholders to recall experiences, which in turn brought up local information very useful for a more comprehensive assessment of the development shown in the visualisation.

Finally, the approaches to integrating indicators into 3D visualisations could only be tested with collaborative stakeholder groups. As public participation addresses the general public, their effectiveness should be tested with interested citizens, the passive public, and children or young adults. We suggest that the three approaches be further developed for other planning settings and participant groups. For different participatory settings, other approaches with simpler representations and interactivity will have to be found.

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