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Decision Support Systems and Tools as Collaborative Web Platform for Sustainable Development of Landscapes

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1 ABSTRACT

Landscape development is increasingly characterized by collaborative processes involving multiple stakeholders of heterogeneous groups. An essential prerequisite for effective collaboration and sound decision-making in landscape development is the understanding of participating stakeholders of required landscape information and the interrelationships between factors influencing landscape development. The tools for representing, processing, analyzing and combining spatial data have evolved and diversified enormously in the last 30 years. This has influenced also the set of media that is applied in participatory planning workshops. Current technology offers great opportunities to allow broad access and to support deeper understanding of landscape processes by implementing web-based platforms. These comprise 3D landscape visualizations and spatial analysis functions. However, an analysis on how to prepare these platforms, their technical structure, their user interface, and the spatial data is missing.

In this paper we present a technical framework of a collaborative web-based platform that takes into account basic user demands for understanding and evaluating landscape processes. Further, we show an initial prototype of a user interface and its information content that was tested with stakeholders. The evaluation results show that the complexity and amount of information offered by the user interface should be customizable for different user groups. New approaches have to be developed to integrate realistic real-time visualizations into the system. Overall, for securing the final tool's effectiveness, it is essential that the technical development of the system is tight to its implementation in collaborative planning situations. These results provide helpful advice for targeted development of the collaborative web-platform system's components.

2 INTRODUCTION

The style of collaborative workshops in land use planning has undergone big changes during the last three decades. These are also related to the development of new communication techniques (Arciniegas & Janssen 2012). Workshop techniques 30 years ago based on large hard copies of maps combined with sheets of tracing paper maps for presenting characteristics of proposed plans or planning areas. With the implementation of Geographic Information Systems (GIS), a new communication tool was offered that allowed to present various map layers on a computer screen and could partially replace hard copies of (tracing) maps for examination (Longley et al. 1999). A next step, which is still under development, takes into account functions and services or the related policy configurations and connects them with related land use patterns. To reveal these relationships can facilitate a better integration of participating stakeholders e.g. in a planning process (Grêt-Regamey et al. 2013).

The workshop style also changed over the years from an emphasis on one-way communication to participation with active stakeholder involvement (Sieber 2006). Today, the major focus is on collaboration: stakeholders shall actively work together to identify a landscape development strategy that is sustainable and acceptable for the majority of the stakeholders (Arciniegas & Janssen 2012). But how can we use the existing technologies to support these collaborative processes? How can we prepare and provide spatial data that is accessible, understandable and useful for all participating stakeholders?

GIS-based 3D landscape visualizations have shown great potential as valuable communication tool in planning processes (Wissen Hayek 2011). Linking quantitative, spatially explicit indicators and realistic 3D visualizations of landscape change scenarios can facilitate the communication of relationships of factors that lead to certain landscape change. This allows to bring in different opinions on a topic and to create public interests (Wissen Hayek et al. 2012b). Furthermore, experiences show that interactive and participative tools help to understand coherence between prioritization of different indicators and possible land use change. For example, in Figure 1 participants of a workshop on wind farm planning choose the priority of economic viability, landscape aesthetics, nature protection, and noise emission. Depending on the indicators' priority, the amount of wind turbines differs. The interactive tool allows users to understand trade-offs between indicator values as well as between different demands of the landscape and landscape aesthetics (Grêt-Regamey et al. 2013).

Figure 1 – Real-time modeling and visualizing approach with slider control of selected indicators' priority

The variety of planning processes and the diversity of workshop settings and goals complicate the development of an all-purpose decision support platform. The effectiveness of such a platform depends on two major factors. First, it has to provide useful participatory GIS functions, comprising interactive elements of GIS-analyses producing indicators as well as of GIS-modeling producing scenarios of landscape change. Second, it needs to be suitable for participatory settings. With regard to the application, e.g. workshop or self-exploration, the content load and detail of information have to meet the users' demand. Particularly, if the user should understand the relationships between different indicators, overloading the interface is a problem, which can lead to lack of time for appropriate implementation of the tool and even deterrence (Salter et al. 2009). The problem of overloading the interface might be overcome by providing layman and expert modes with a customized offer of spatial information with a useful level of detail. However, there is a general conflict of required detail of information and suitable time investment in collaboration sessions. On the one hand, the need of detailed information on indicators is required to communicate what they state and how they are related to each other. On the other hand, these details need time to be understood. A multi-user-group interface might provide a solution for reducing the complexity of available information. However, with this interface type addressing more specific demands of different user groups might become more difficult.

In this paper we present a technical framework of a collaborative web-platform system that takes into account basic user demands for understanding and evaluating landscape processes. Further, we demonstrate a first prototype of implementing parts of this system, which was tested in a workshop and at an exhibition with different stakeholders. The prototype was designed to addresses basic user demands by implementing participative GIS functionality. This included a user interface design with certain interactive functions as well as preparing visual information content according to a defined level of detail and complexity. The evaluation results were analyzed in order to further specify user demands and to discover expected functions of the platform. They provide advice for enhancing the prototype of the collaborative web-platform.

3 THEORETICAL FRAMEWORK

In the early stages, GIS was used mainly for providing spatial information, but with increasingly active stakeholder involvement and the failure of tracing map paper sheets, a demand of interactive GIS was given. Participatory GIS is designed for improving stakeholder participation within group spatial decision-making (Carver 2003, Janowski 2009). Two function types of Participatory GIS must be distinguish: (1) Public

Participation GIS (PPGIS) focuses on an enhancement of public access to geospatial data and maps, providing possibilities for participatory learning and analysis by the general public, community groups and marginalized groups in planning and decision-making for their communities (Craig et al. 2002). In contrast, (2) Group Spatial Decision Support Systems (GSDSS) focus on supporting the identification of trade-offs, conflicts and compromises between stakeholder groups (Boroushaki & Malczewski 2010).

Our hypothesis is that to create an applicable and full-efficient decision support platform, both participatory GIS types (PPGIS & GSDSS) must be combined. Furthermore, the following functions should be available: general information on the planning topic and use of the platform, spatial analysis and evaluation functions, and interactive indicator-based decision support. In the following chapters these three functions are further explained.

3.1 General Information Content

For understanding complex topics and being capable of evaluation and decision-making tasks, first of all background information must be available and provided in a useful manner. In addition to texts, tables and graphs, maps are the basis for providing relevant information for spatial decision-making. Often stakeholders preferred maps as source of information for spatial decision-making, although they are not easy to understand and use (Janssen & Uran 2003).

Maps can show various and complex information in a spatially explicit way. They can present alternative solutions, scope for decision-making options or spatial patterns (Kraak & Ormeling 2003). Further, they can be used for developing scenarios and alternatives, e.g. by drawing in or modifying it (Carton & Thissen 2009), as well as to handle conflicts among stakeholders. In this way, they can support feedback loops in the planning process (Arciniegas & Janssen 2012; Andrienko et al. 2007). Another function of maps is that they provide base-layers (e.g. thematic and topographic maps) for the before mentioned functions (Arciniegas & Janssen 2012). In addition, map information can provide the input for GIS-based 3D visualization of alternative scenarios, which provide a common communication basis and support mutual concept development (Hehl-Lange & Lange 2005; Wissen Hayek 2011; Grêt-Regamey & Wissen Hayek 2013).

3.2 Spatial Analysis and Evaluation

GIS-based analysis is key for gaining information on the current landscape state or alternative development scenarios. Multi-Criteria Decision Analysis (MCDA) is an effective method to perceive the necessary trade-offs of different demands of the landscape. By weighting different criteria addressing economic viability, ecological or social quality of the landscape, and possible scenarios of landscape change are calculated. Integrating a MCDA in the workflow provides a method to evaluate, compare, rank, map and present the performance of decision alternatives on the basis of several criteria and/or objectives (Malczewski 2006, Grêt-Regamey & Wissen Hayek 2013).

Ideally, stakeholders with different backgrounds should choose criteria and indicators as well as their weighting themselves. In order to avoid mismatches and misunderstandings between the stakeholders' decision-making problem and the answers produced by the system, it is necessary that constraints are set with regard to the interactive modification of criteria and indicators in the user-interface (Uran & Janssen 2003). This might influence the required user-interface complexity.

3.3 Interactive Decision Support

Depending on the functions of an interactive decision support tool aimed at, a selection and combination of various interactive methods is possible. User-friendly interfaces are necessary to allow multiple users to provide input and generate real-time output for supporting to form an opinion and decision-making (Arciniegas & Janssen 2012). Interactive exploration and interactive allocation of map content is required to secure credibility and provide information for specific areas of interests. Furthermore, real-time output of analyses and landscape change models is important for dynamically exploring the spatial outcomes. Iteratively testing different input parameter settings and exploring results can facilitate the comprehension of spatial environmental effects. In this context, linking the quantitative, abstract modeling results to more qualitative 3D visualizations interactively is seen as a promising way (Grêt-Regamey et al. 2013, Wissen Hayek et al. 2012a).

4 METHODS

The goal is to develop a collaborative web-platform that integrates both types of participatory GIS (GSDSS and PPGIS). We elaborated a general technical framework for such a platform and tested parts of it in order to start its implementation. First, the technical framework is described. Then, the prototype of an interactive tool called "Landscape Impact Assessment Controller" is presented. Finally, the evaluation method of the effectiveness of the prototype is explained.

4.1 General technical framework

The various demands of different user groups call for a dynamic user-interface in order to provide a useful decision-support tool. We developed a technical framework that combines modeling and visualization functions essential for interactive landscape impact assessment by different user groups.

Resulting from the literature review (see chapter 3) essential functions are:

(1) The selection of indicators/parameters and their characteristics can be controlled interactively and the related landscape changes can be presented as spatial information. For example, the amount of economic incentives for farmers can be modified and as result the agricultural area that might be managed or abandoned are shown as abstract and realistic 3D visualizations at the area of interest. Thus, the user can identify trade-offs, limitations and restrictions with regard to the choice of the parameters' characteristics. Implementing this functionality requires a real-time user control of the GIS-model.

(2) The GIS-model scripts have to be standardized to make them accessible to different software and thus allows for linking different GIS-models. This standardization of indicator values and labeling, attribute labels, input/output data types, coordinate system, projection, etc. is also necessary for further processing of modeling results, e.g. in visualization workflows.

Figure 2 shows the schematic framework of a decision-support system. The system consists of five different servers and three workshop decision-support tools that are the front-end decision support platform interface and peripheral devices and software, such as mobile decision support apps.

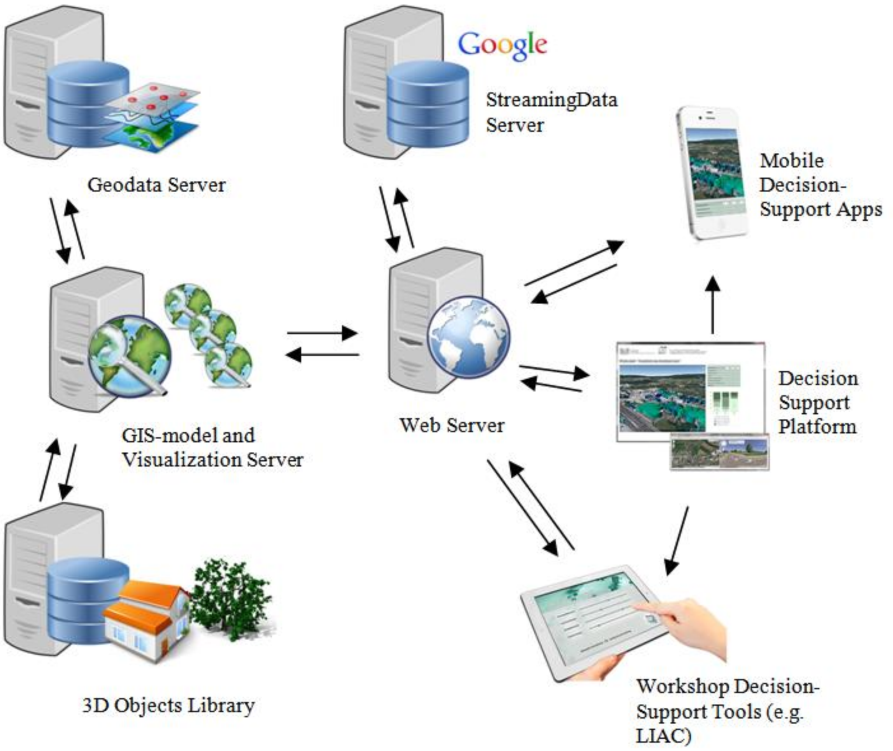

Figure 2 – Schematic framework of a Collaborative Web-Platform Decision-Support System for landscape planning

The web server is the core of the platform and serves as hub for all applications. All requests and replies pass the technical interface of the web server and are linked to spatial data and mapping information streams like GoogleEarth from the streaming data server. The users interact only through the web platform. Platform inputs, e.g. information requests are forwarded to the GIS-model server. This server runs the requested models and analysis modules (e.g. ArcGIS Server, R-Scripts), queries necessary data from the geodata server and sends the results back to the web server. Produced model outputs are also interpreted and linked to 3D objects and textures for 3D visualization. The resulting 3D visualizations are sent to the web server and displayed on the platform. This workflow is similar to existing ones (e.g. Pettit et al. 2013) with the difference, that we try to integrate a full controllability of models by adapted user-interface design.

3D landscape visualization of high detail requires the use of 3D objects for built and natural landscape structures and elements. The standardization of the input and output data of the spatial modeling processes allow for accessing the 3D objects automatically. However, in a library the 3D objects have to be structured in a meaningful way so that their access is secured. For example, a land use pattern of forest is defined by the forest type (e.g. deciduous, coniferous, or oak-hornbeam forest (Carpinion betuli)). This information should ideally already be available in the output of the GIS-model. The forest type defines the plant types of the trees, e.g. for an oak-hornbeam forest there are oak (Quercus robur) and hornbeam (Carpinus betulus), and further plants of the shrub and ground vegetation layer such as anemone (Anemone nemorosa), that are selected by data base queries. Finally, a realistic distribution of the individual plants of the forest type is necessary (Röhricht & Clasen 2006; Paar et al. 2008).

One major bottleneck is the time required for the real-time modeling processes. Saving produced model outputs to an archive on the GIS-model server allows for showing the results immediately on request. This archive option would allow users to share their evaluated scenarios among each other and discuss them for example in group rooms using the platform. The users feed the archive by using the platform and optimize the processing time by enlarging the amount of already processed model outputs. Of course, this procedure makes only sense for time-consuming models and analyses. A further option for achieving a real-time modeling approach is to implement interactive selection methods. Models and associated visualization workflows might then only be run for preferred perimeters. Perimeter selection could be carried out by a list of regional boundaries (e.g. administrative districts) or by designating a user specified perimeter by drawing a polygon on a map.

4.2 Prototype of the Landscape Impact Assessment Tool (LIAC)

In order to overcome the problem of different user capabilities and interface design complexity, we developed a first prototype of a decision support tool. A user-evaluation of the prototype should provide us with information on the users' demands and on useful designs of the user interface. Figure 3 shows the multilayer structure of the prototype of the "Landscape Impact Assessment Tool (LIAC)", which was designed to show the relation between indicators and the impacts of defining certain indicator values on land use. The tool is applied in a workshop setting. The target group for our web-platform are experts in land use and landscape development. The survey in the workshop revealed that participants were more heterogeneous than expected. To facilitate a "hands-on" experience for the participants, the thematic direction was leaned at a workshop series conducted in another study area in central Switzerland.

As indicated in Fig. 3, the main screen shows sliders with different optional value settings (low to high) for five indicators, which indicate different states of GIS-model parameters. The change of the indicator values is a direct input to a land use change model. A further option on the main screen is changing the view style to an "abstract view" in the second and third screen. In these screens the land use is shown either as a draped raster map on a digital elevation model or as realistic 3D visualization. Screen 2 presents a large view frame of the 3D visualization (realistic and abstract view mode), while screen 3 shows two close-up views of specified areas and an additional graph for information on land use values.

Considering the large amount of possible combinations of the indicators' values and resulting scenarios, visualization approaches that require many manual steps are not advisable. Furthermore, with a rising number of indicators the number of scenarios is increasing exponentially. A direct GIS-model link to the user-interface is one solution to produce scenarios in real-time with full controllability of the output. This was not implemented in the prototype yet. Instead, scenario outputs of a GIS-based land use model were prepared as visualizations and graphs, which were linked to the respective indicator value settings that were input to the respective scenario output. Criteria for the land use modeling of the rural, alpine case study area Andermatt in Switzerland were the degree of liberalization of the agricultural market, agricultural incentives for the farmers, farming income, provision of residential area and the degree of implementing a regulation for second homes in Switzerland. All these criteria have an effect on landscape development and interact with each other.

Figure 3 – Schematic screenplay of LIAC (Landscape Impact Assessment Controller), which presents land use scenarios that are defined through the interactive setting of indicator values in the controller interface

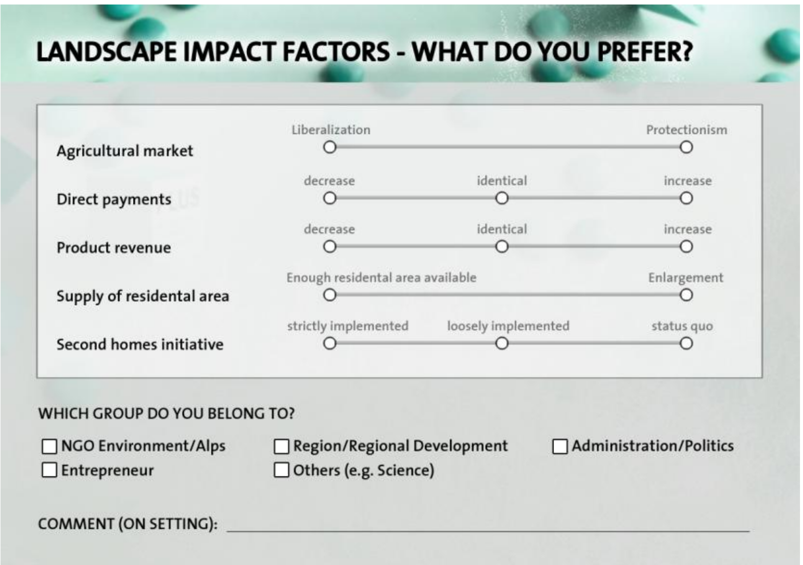

Figure 4 – Questionnaire of the survey carried out at an exhibition stand providing an overview on indicator characteristics and animating visitors to apply LIAC

4.3 Evaluation of the prototype

We applied the prototype in the case study area Andermatt in two different settings, at an exhibition stand and in a workshop situation, and evaluated it applying empirical methods. Visitors of the exhibition were animated to use LIAC by a small survey that also gave an introduction to indicators and their characteristics

(Fig. 4). About 30 participants explored the tool at the exhibition. The participants were a heterogeneous group including local inhabitants and representatives of Swiss and international governmental and non-governmental organizations from different departments. In open interviews we asked these users about their impression of the tool.

The about 20 participants of the workshop were international experts of land use management, spatial planning and nature protection from governmental and non-governmental organizations, private enterprises, and academic institutions. They were briefed on the prepared planning topic and the GIS models. In addition, the workshop moderator used LIAC to introduce the participants to the information content as well as the functionality and handling of the tool. The decision tool was controlled by a tablet PC that was synchronized to a projector screen presenting the chosen value settings of the indicators. The idea of this setup was to hand over the tablet to workshop participants for supporting their argumentation or explanations implementing the tool interactively. In a group discussion we received the users' feedback on the potential application of the tool and the quality of the user interface. Furthermore, we observed the users in both settings to record their reactions and if the controlling of the user-interface was easy to handle.

5 RESULTS

During a short personal and individual introduction of the available information, the participants at the exhibition "played" with the indicator settings of the LIAC tool to find out how the virtual landscape changes (Figure 5-A, -C, -D). Teenager used the tool more explorative than adults. However, all participants understood that the future land use patterns depend on the five indicators' value settings. The users recognized by themselves, how the indicators influence each other. Furthermore, they recognized on which scale the indicators can influence future landscape aesthetics. For example, less agricultural incentives for farmers effect an abandonment of fields and leads to an increase in forest in certain areas.

In the workshop the participants were rather interested in detailed explanations of the correlation between indicators than in a self-exploration of the tool (Figure 5-B). In conclusion of the group discussion the participants appraised the tool as innovative and useful as discussion basis in a workshop. However, participants stated that the interface offered too much information on the three screens. Furthermore, they asked for more user control on the models to verify effects and impacts of priority settings. Additionally, the participants mentioned that an interactive navigation through the 3D visualizations would have been desirable to see changes in detail, to have a better overview of the site, and better impressions of the view of the landscape.

Figure 5 – Application of iPad controlled LIAC in self-exploration situations and a workshop situation (Photos by T.M. Klein)

6 DISCUSSION & CONCLUSION

The fast developing technical possibilities of providing spatial data in various types of forms and in different types of accessibility offer sophisticated means for supporting public participation in spatial planning.

However, combining the available tools to a coherent and powerful system that can facilitate collaboration of heterogeneous stakeholder groups effectively is a major challenge. We focused in this paper on how to prepare a collaborative web-platform and presented a possible technical structure. Stakeholder feedback on a prototype of a user interface and spatial data presentation provided helpful insight for further development of the system.

Generally the stakeholders were interested in the new means. The users stated that a tool with interactive control of input parameters for generating scenarios of landscape change could help to understand complex landscape issues and offer a new basis for discussion in workshop situations. Even with rather general scenario information the prototype enabled participants to identify relationships of the five indicators controlling the land use change model. But we received also information on missing functions of the tool, which should be available to meet the users' demands.

Obviously younger participants (aged < 20 years) had less fear of contact with the interactive application than older ones. A reason might be that these young people are so called "digital natives" that grew up with the digital technologies (Lange 2011). Through interacting with digital technology from an early age (e.g. mobile devices, smart phones), they should have a good concept of these tools. The higher reservation of older participants might, however, be ascribed to a more critical examination of the technical means due to larger expert and case knowledge. Their requests for more information on the GIS models indicate that their focus was clearly on the meaning of the tool to provide reliable and thus useful information.

The first feedback of the users of LIAC shows that there is a need for a customized user-interface design depending on the user group. In particular the knowledge and capability of the users is crucial for defining a useful complexity of the user-interface design. Overstraining users might be avoided by a customized restriction of interactive parameter control and offer of information for the specific groups. Increasing the accessibility of GIS models seems necessary for a satisfying use of decision support tools by experts. This option might also support an even improved understanding of correlations between indicators and between prioritization of certain demands and resulting landscape changes.

The necessary investment of time for the users to understand and to control the tool as well as for processing the provided information turned out to be problematic. The required time might even increase with rising complexity of the interface and of the offered information content. The available time in the workshop was not sufficient to give the individual user the time he required. This experience reveals that the design of applications has to be developed in parallel with the tool to secure its meaningful implementation. Probably trade-offs must be taken into account due to a reduced complexity of the user-interface depending on the respective application situation (workshop vs. self-exploration).

Beyond user-related requirements we also discovered technical problems that have to be solved. Manual workflows for visualization are not feasible anymore if the amount of landscape change scenarios increases exponentially and if these scenarios can be defined interactively by the users. Furthermore, the degree of realism of the visualizations has to match the landscape development topic, e.g. vegetation types might have to be recognizable if the focus is on the ecological effects of agricultural management or landscape aesthetics. Hence, visualization workflows have to be redesigned to create sophisticated – and from the users expected – visualizations with a sufficient visual quality and appropriate level of detail in an automated way. In order to allow for analyses and visualization of output for any location on demand a generic, automated approach is necessary. This would ensure that the decision support platform is highly flexible and spatially independent.

Overall, it is hard to cover all aspects and demands and develop a useful user interface according to the ideas of different user groups. Particularly, it is challenging to satisfy all users. Generating a user interface that allows for adapting the amount of information, and thus its complexity, might be a constructive approach to meet the users' needs. Of great importance is an iterative approach for the development and testing of web-based platform system. Hence we aim at progressing by stages and with a particular focus on the interfaces to meaningful information provision in planning situations.

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