Understanding Landscape Changes and Cultural Ecosystem Services in a Retro(per)spective

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Abstract

The historical analysis about the evolution of landscapes is crucial in evaluation processes for landscape planners and regional planning authorities to shape multifunctional landscapes (WALZ 2008). On the other hand historical knowledge can support the awareness of the people who are direct users of the landscape. The goal of our study is (1) to survey if 3D visualizations can contribute to a better understanding of landscape changes in a retrospective. Next we would like (2) to show the practical contribution of 3D visualizations for a holistic understanding of Cultural Ecosystem Services (CES) trends. We demonstrate that 3D visualizations (still and motion pictures / animations) help extend both traditional (e.g. historical maps) and modern (e.g. GIS-based) mapping methods towards a more holistic understanding of complex landscape situations / changes and their impact on CES-trends that can be supportive for developing future scenarios in planning practice.

1 Introduction

The integration of the Ecosystem Services (ES) concept into landscape planning, management and decision making processes is currently providing new challenges for multiple disciplines in ecology, conservation, as well as landscape modeling and design sciences (DE GROOT et al. 2010; GRÊT-REGAMEY et al. 2013; DAILY et al. 2009). Especially the incorporation of Cultural Ecosystem Services (CES) seems to be difficult (CHAN et al. 2012). Ecosystem Services (ES) are defined by the Millennium Ecosystem Assessment as "benefits people obtain from ecosystems" that contribute to human well-being (MEA 2005). These contain provisioning services such as food and water; regulating services such as flood and disease control; supporting services, such as nutrient cycling; cultural services such as "cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism" (MEA 2005, p. 58-59). In our study we focus on Cultural Ecosystem Services (CES) which can be described as the "non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA 2005, p. 4). Among the most prevalent issues in the context of ES Assessment are the questions of (1) how to visualize and communicate ecosystem and landscape services to relevant stakeholder groups and (2) how the social and economic relevance of ES can serve as a basis for decision-making processes (DE GROOT et al. 2010). 3D visualization tools and techniques can provide a possible solution to these questions and serve as a remedy for visualization challenges in this perspective.

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CES constitute the outcome of complex and dynamic relationships between ecosystems and humans in landscapes over long time period (FAGERHOLM et al. 2012). However CES are often motivators for owning land as well as helping tools for raising public support for protecting ecosystems (PLIENINGER et al. 2012) because of its hard operationalization they are faded into the background in the ES framework and so in decision making processes. By analyzing complex trade-offs related to the development of multifunctional landscapes, the involvement of sociocultural aspects in landscape evaluation are indispensable. By presenting influential issues of CES such as aesthetic values opposite to regulating or habitat services, interactive 3D visualization tools related to GIS-based modeling might become vital (DANIEL et al. 2012).

In the analysis about the condition and trends of ES on the sub-global level, land use change has been identified as the most important driver (MEA 2005). According to WALZ (2008) there is a strong connection between land use changes, landscape function changes that provide ecosystem services of particular landscapes. All these components have big influence on the changing landscape scene as a result of human-ecosystem interactions. Within this issue 3D visualizations are highly relevant for interpreting CES-trends in a retrospective. According to the German Nature Conservation Act, the values of the historically grown natural and cultural landscapes have to be protected in order to a sustainable maintenance of the "diversity, characteristic features, beauty" and recreational value of nature and landscape (BNATSCHG 2009, §1, Art.4). Thus the evaluation of landscape scenes in a retrospective becomes especially relevant. In terms of this we analyse "past landscapes" in terms of land use as well as landscape scene changes. Due to the fact that past landscapes often serve as guiding principles in landscape planning and nature conservation (e.g. renaturation, revitalization projects, long-term environmental monitoring etc.) the analysis of CES-trends can help to understand the reasons and drivers behind landscape changes. 3D visualization of past landscapes can support the definition of guiding principles. This can also contribute to public participation processes as well as the awareness of decision makers. As confirmed by VON HAAREN et al. (2005) and WISSEN (2009) 3D visualizations become vital in evaluating landscapes by upgrading the communication between all stakeholders. The DLA Conference offers the discussion of these new problems by experts of geodesign as a "set of techniques for planning built and natural environments in an integrated process involving stakeholder participation and collaboration" (GOODCHILD 2010).

To summarize all the mentioned aspects above, the aim of this study is (1) to show the relevance of 3D visualizations for the interpretation of landscape changes, as well as (2) to apply 3D visualizations and 2D-maps for the analysis of CES-trends in a retrospective.

2 Research Area

In this study, we analyze landscape changes of Hainberg in the urban forest of Göttingen in a retrospective to assess their impact on cultural, aesthetic, recreational and educational values. The study area (around 1200 ha), located at the Eastern part of the City Göttingen (Lower-Saxony) belongs administratively to the Forestry District of Göttingen. The case of Göttingen's Hainberg serves as an appropriate setting for analyzing land use changes and trends of CES in particular, as its landscape has changed vastly over the past 150 years. As

such it developed from an agriculturally-coined area into a forested landscape given the activities of several influential stakeholder groups such as private entrepreneurs, policy makers, and non-profit organizations. Showing significant changes in the landscape scene we have chosen three time intervals representing different land use conditions before (1790-1878), during (1879-1910), and after (1911-2013) afforestation processes.

3 Material and Methodology

3.1 Input data

A wide range of historical data such as literature about the afforestation of Hainberg (MERKEL 1897), old guidebooks, historical maps (each of them 1:25000) from 1794 (Kurhannover Surveying Map), 1878 (Prussian Surveying Map) Topographic Map of 1910 and 2002 have been acquired from the Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN) that have been digitalized within a prior work (PREUTENBORBECK 2009). Digital Elevation Model (NLWKN) as well as Digital Orthophotos from 2011 (City Göttingen) served as a further basis for the 3D Visualizations in Biosphere 3D (www.lenne3d.de). Furthermore historical images such as copper engravings, old paintings and old photographs have been collected from the City Museum of Göttingen.

3.2 3D Visualizations with Biosphere 3D

The presentation of afforestation processes and culturally important buildings required software with high vegetation LOD, diversity of 3D-plants, 3D-objects, interactivity, as well as compatibility with ArcGIS. These criteria have been fulfilled by the interactive software Biosphere 3D. The visualization process in detail is presented in figure 1.

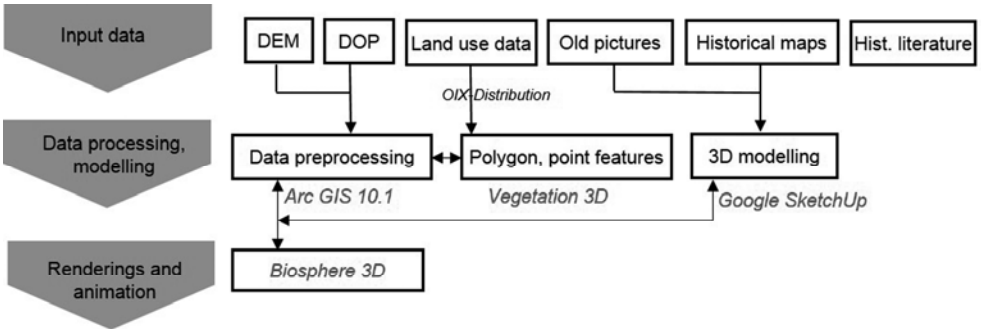

Fig. 1: Working process from the input data to 3D visualizations in Biosphere3D.

Visualizing historical landscapes by working with historical data served us many challenges because of data inaccuracy. To solve this problem we used a triangulation of maps, and historical images from more perspectives to get a more realistic and truth visualization.

3.3 Web-survey

According to ROTH (2006) further research should be done to examine the effect of landscape representations such as 3D-visual landscape simulations in the Internet. He demonstrated that web-based surveys are an objective and reliable tool for collecting valid data on visual landscape assessment. In terms of this an internet survey has been conducted to evaluate the preferences of interdisciplinary researchers and landscape experts for interpreting land use changes over time. We used the software Questback EFS Survey 10 for this issue. The goal of the survey was to show how researchers as well as practitioners working directly / indirectly with landscapes, landscape history – but not necessarily with 3D visualizations – assess historical materials such as (a) descriptions, b) historical maps, c) old pictures / paintings as well as computer-based representations such as (d) GIS-maps, e) constant 3D Visualizations f) animations in terms of their validity. We presented each of the six methods about the status before, during, and after afforestation, that is shown in figure 2.

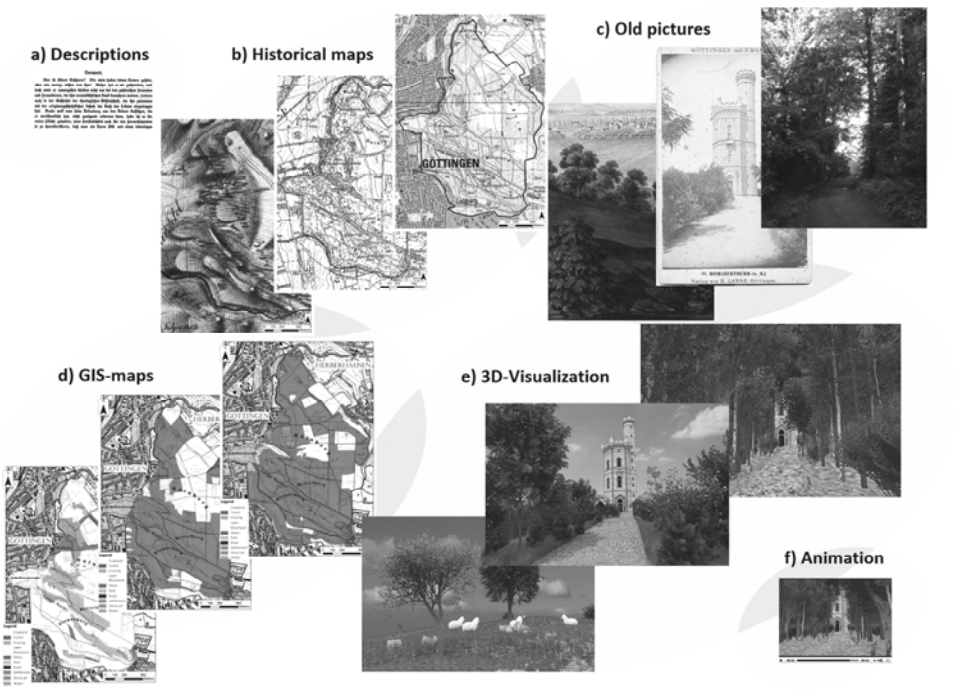

Fig. 2: Six Methods for interpreting land use changes as presented in the survey. The constant 3D visualizations (e) as well as the animations (f) were made in Biosphere3D.

After the introduction of the topic as well as annotation of the relevance of the study the following seven question groups have been formulated:

1. Origin of the Disciplines; 2. Annotations for all six methodologies explaining landscape changes; 3. Assessment of six methodologies; 4. Landscape preferences; 5. Evaluation about the quality of 3D visualizations; 6. Application field of 3D visualizations; 7. Best method for intermediation of land use changes.

The invitation has been sent via email and could be downloaded within the time span between 07.10.2013 – 15.11.2013 from the following link: http://www.unipark.de/uc/forstwissen/f986/?code=333b1e3e26293dbf. The advantages of the survey were (1) that the interviewees could break up whenever they wanted and start from the same point they finished; (2) researchers from different regions could be achieved. After closing the questionnaire a histogram frequency analysis has been done with the software STATA and Microsoft Excel. The qualitative questions have been evaluated with a deductive method of qualitative content analysis by highlighting keywords of the answers. The keywords have been ordered to context groups and have been quantified to show the tendencies of the answers (figure 5).

3.4 From a 2D to the 3D level

As a second issue of our study, we demonstrate the practical application of 3D visualizations in terms of their contribution to a holistic understanding of CES-trends. Using an indicator catalogue and modern mapping methods as developed by SZŰCS et al. (forthcoming), we identified trends of different CES. Here we extend this work by adding 3D visualizations to the current concept – therefore elevating the discussion of landscape changes from 2D to 3D level (figure 3). For a better understanding we briefly describe the procedure from the numeric data to 3D visualizations:

For the analysis of CES trends in three time intervals seven case studies have been chosen in the research area according to the criteria of data availability, motivation of building, spots providing CES such as public parks, viewing platforms etc. These are: 1. Bismarckturm, 2. Molkengrund, 3. Eulenturm, 4. KWP & Rodelbahn, 5. Weisse Wand & Lange Nacht, 6. Schillerwiese, and 7. Rohns.

As defined by the MEA (2005) CES have been differentiated into the following six subservices relevant for Göttingen's Hainberg: aesthetic-, educational-, recreational-, cultural heritage-, inspiration-, and cultural values. Then 23 significant indicators have been defined to specify the trends of the six CES-subcategories that have been evaluated based on historical materials such as literature, historical maps, old photographs, paintings as well as copper engravings (see figure 3 Indicator catalogue). Next an appropriate mapping method has been developed for showing CES-trends locally in the seven case studies. This has been done depending on the quality and the quantity of the available subservices as pie charts, projected on land use maps for each time interval. Thus the assessment of land use changes and CES-trends in parallel is possible (see figure 3 CES mapping). As a next step we continued with the 3D visualizations of the seven case studies based on the historical images as well as historical maps as described in the chapter 3.2 to show the reflections of CES trends in the landscape scene as a result of land use changes.

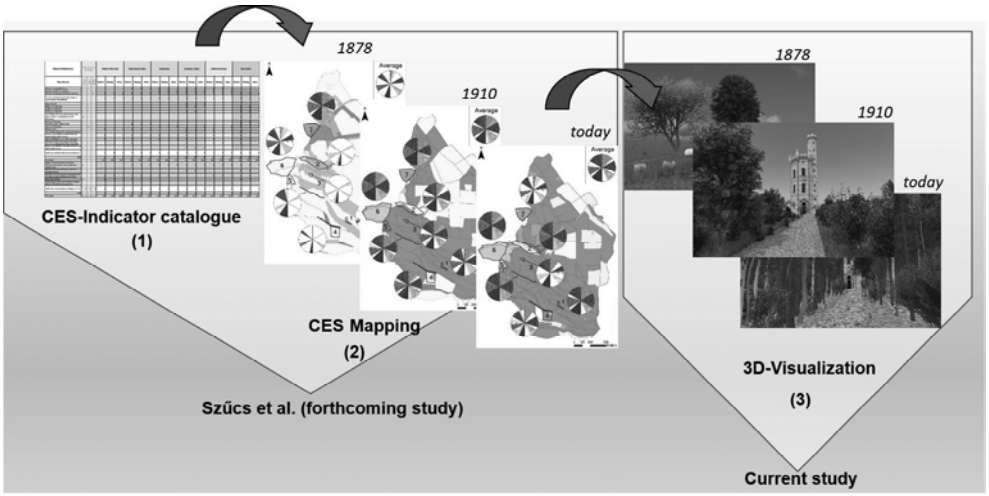

Fig. 3: Conceptual framework of the study from the numeric to the 2D and 3D level: (1) by assessment of CES subservices; (2) mapping CES-trends and land use changes as well as (3) visualizing distinctive changes of the landscape.

4 Results

We invited 76 experts, from whom 53 participants could accomplish the survey. From these 48 experts (participation quote of 63,2%). filled out the questionnaire completely. The average time for filling out the questionnaire lasted 18 minutes. Among the participants – coming all from different parts of Germany – from multiple disciplines there have been indirect users of visualization techniques (n=24) – from the disciplines of history (32%), humanities (4%), economic sciences (9%) – as well as direct or potential users of visualizations (n=29) – such as archaeology (2%), natural sciences (17%), engineering (6%), landscape and regional planning (7%), nature conservation (19%), geography (2%) and IT (2%).

After showing the six methods for interpretation of landscape changes we asked the interviewees in the question group three to rate them in a four scale system depending on the grade of authenticity. Figure 4 illustrates that 3D visualizations (47%) and animations (43%) have been named as the most authentic method in terms of their comprehensibility of showing landscape changes. Digital maps (49%) have been named as the second comprehensive one.

However on the question-group 7: “Which methodology would you personally choose to explain transformations of landscapes”: digital maps (55%), pictures (55%) have been chosen as first, then literature (51%) historical maps (40%) visualizations (36%) animations (36%) followed. The most frequent combination for the adequate interpretation for landscape changes was the overall use of all six methods.

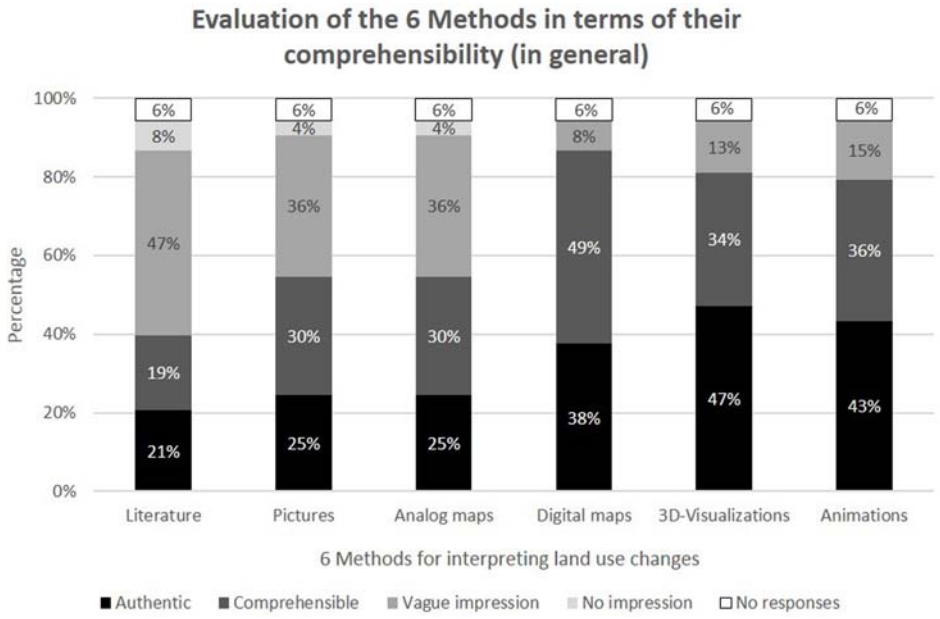

Fig. 4: Evaluation by rating the six methods about their comprehensibility for interpreting landscape changes.

In the question group No. 6 we further inquire whether or not 3D visualizations help contribute to a more holistic understanding of land use changes. 68,9% of the direct users – mostly from natural sciences and nature conservation – as well as 66,6% of the indirect users – mostly historians – have answered with "Yes" on this question.

As next the interviewees had to declare about the advantages and disadvantages of 3D visualizations. Here the most frequent answer was "the better understanding of landscape changes" that facilitates our hypothesis (figure 5). The next repeated argument was to get an insight into the "overall context" of the landscape as well as to increase "imagination" that other historical materials do not allow.

Additionally correlations were also proven between the different methodologies, the experts have been chosen. The study showed that digital maps have been chosen most frequently in combination with 3D visualizations (31%) as a method for interpreting landscape and land use changes. On the other hand 22% of the people were choosing analogue maps and 3D visualizations. All in all the combination of a historical image and the digital maps were the most frequently (48%) chosen pairs, that were mostly preferred by historians. This means that the method-combination of geographical and visual information were essential for the interpretation of landscape changes.

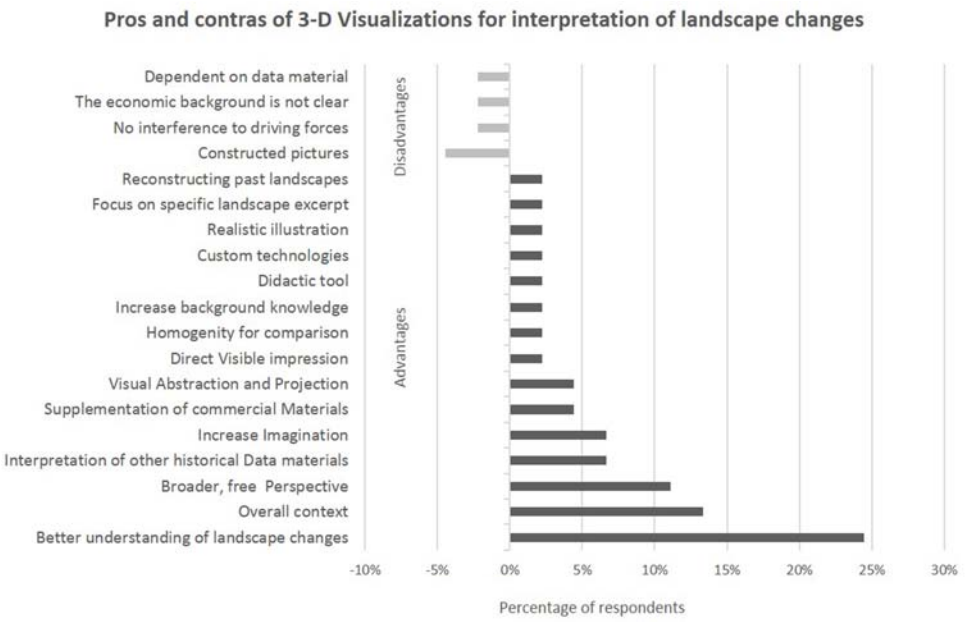

Fig. 5: Qualitative analysis on the question: "Where do you see the advantages of 3D visualizations on the contrary to other methodologies?"

In the same question group we asked the participants if they think that "3D animations are necessary for illustrating landscape changes, or fixed 3D images are sufficient enough for this issue?" The interesting outcome of this question was that 41% of the direct users have answered with "Yes" and 50% of the indirect users have been answered with an eventual utility of 3D animations that indicates the interests in other disciplines definitively. To justify this answer they emphasized aspects like "more authentic effects" "broader perspective" and "better interpretation for decision makers as well as for laymen".

In question No. 5 on the quality of visualizations, the most important aspects were highlighted such as resolution (n=35), 3D-buildings (n=35), landscape structure (n=30), vegetation (n=29), authenticity (n=25), perspective (n=24), animation (n=21), background (n=21).

Question group 6 focused on the application field of 3D visualizations by having a multiple choice. The following practical scopes have been named (in a descending order): museums (83%), exhibitions (79%), teaching (69%), landscape planning (67%) as well as there have been named other applications (each 19%) like multimedia, web applications, archaeological reconstruction, landscape evaluations, renewable energies in landscapes, environmental didactics, tourism, architecture, mediation, public participation.

All in all the results of the questionnaire reveal that 3D visualizations serve as a remedy with respect to land use changes and historical processes (e.g. reforestation, reconciliation, urbanizations).

5 Conclusions and Outlook

The advantages of 3D visualization techniques have already gained in importance across many cases, including landscape management issues (PAAR 2006) and participatory processes (WISSEN 2009; VON HAAREN et al. 2005). However, its utility for retrospective analyses connected to CES-trends has not been discussed yet. Recently there are various efforts to include CES assessment by establishing a conceptual framework for that (CHEN et al. 2012). In this sense there is a need to develop new approaches to demonstrate, communicate, and discuss CES and their trends as a background for landscape changes. We demonstrate that historical knowledge about landscape development is crucial for the public to help understanding of landscape evolutions. On the other hand it encourages the maintenance of stakeholders in the planning of forthcoming landscapes as well as increase public awareness of the historical and ecological meaning of different landscape features.

In this study we focus on the importance of 3D visualizations for understanding landscape changes in a retrospective for opening a new perspective of CES-assessment. This combination of these two aspects – retrospective and perspective function – help understand the true value of 3D visualizations in the context of landscape management. First, our questionnaire showed that 3D visualizations help extend the explanatory power of conventional mapping methods (retrospective function). Second, because of the broader perspective, understanding the overall context to observe the evolution of landscapes from different perspectives that historical materials do not allow (perspective function).

Our main conclusion is that 3D visualizations (still and motion pictures / animations) help extend both traditional (e.g. conventional mapping) and modern 2D (e.g. GIS-based mapping) methods towards a more holistic understanding of complex landscape situations / changes and their impact on CES-trends. 3D visualizations are crucial to fully understand the changing bundles of cultural services in both space and time. Supporting and promoting the imagination of policy-makers and the people in place may eventually provide a profound basis for decision making processes. The results therefore provide guiding principles for future landscape activities towards multifunctional landscapes that might be supportive for developing future scenarios in planning practice. For public participation processes the involvement of 3D visualization can help to provide the discussions on the same level. In terms of a suitable landscape management more empirical assessment is needed about the inhabitants' needs referring to cultural, educational, aesthetic and recreational values that are strongly connected to CES, landscape provide in our surrounding.

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