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Google Earth based visualisation of Land Use scenario studies

R. van Lammeren [1] , J. Houtkamp [2], S. Colijn [3], M. Hilferink [4] , A. Bouwman [5]

[1] Wageningen University, Centre for Geo-Information Ron.vanLammeren@wur.nl
[2] University Utrecht, Content and knowledge engineering joske@cs.uu.nl
[3] University Utrecht, Content and knowledge engineering scolijn@nobel.nl
[4] ObjectVision bv. mhilferink@objectvision.nl
[5] Netherlands Environmental Assessment Agency Arno.Bouwman@pbl.nl

Abstract

In this paper we present the outline and usability of Google Earth visualization of Sustainable Outlook (GESO), a tool to prepare a multi-layered visualization of land use changes. The land use changes are the results future outlook studies of the Netherlands Environmental Assessment Agency. GESO aims an effective, easy and low cost way to study Sustainable Outlook data via an interactive 3D visualization that integrates the land use icon and landscape feature approach as presented in previous studies.

The concept, implementation and usability of GESO are explained, concluded and discussed. The paper starts to explain the context of GESO and the intention to visualize 3-dimensionally land use changes (Al-Kodmany, 2001; Borsboom- van Beurden, 2006; Lammeren, 2005). Out of this context the concept of GESO architecture is presented. Amongst other functions it combines two Dutch authorized datasets, national DEM and the national topography, into a semi-3D dataset. Secondly the tool transforms these semi 3D data, the Sustainable Outlook results, linked with 2D- and 3D-objects, into KML files. The KML files, to be viewed by Google Earth, offer the user different levels of detail via multi-layers and combinations of current and future land use. The multi-layers do offer traditional grid based colours, textures and 3D-icons.

The usability and impact (Sheppard, 2001, Mahdjoubi (2001), Hudson-Smith, 2005) of the multi-layered visualisation has been tested via a test group, of 45 persons in an experimental setting. The results of the test show that the use of the multi-layered approach scored in line with previous research findings. Regarding the correctness of answers, as representation of cognitive function, the grid based colours and textures score a little better. However the 3D icon visualization scores better with respect to the affective and stimulating function. The test results are discussed with respect to the intentions of the Environmental Assessment Agency.

Key words: 3D visualization, land use data, usability, affective function, cognitive function, Virtual globe, kml/kmz, 3dshapes, landscape icons, landscape feature

Introduction

The Netherlands Environmental Assessment Agency (PBL) produces scientific studies on future land use that support Dutch policy-makers on different administrative levels. The results of these studies are offered to the policy makers as (digital) reports including maps of current and future land use. The Sustainable Outlook is one of these products that has to be delivered every four years (Milieu en Natuurplanbureau, 2007). It is intended as a source to discuss the impact of possible middle and long term (maximally 30 years) land use changes on the physical environment especially the landscape, including scenery and the biotic and abiotic characteristics. The land use transitions for the Dutch land area are based on scenario story lines that form the context for simulation of land use development via the dedicated modelling software Land Use Scanner (Hilferink, et al. 2001). The result of the Land Use Scanner are geo-referenced raster data sets that cover the full extent of the Netherlands that present land use in the near future. Each raster cell spans 100 by 100 meter and one land use class. The maps created from these datasets do cover also the full extent of the Dutch area, have legends of maximally 19 classes of land use (nominal scale), are colour printed on A4-size, and presents the land use classes in a particular year according a specific scenario.
The maps must support policymakers in detecting and understanding land use changes and their impacts on the physical environment. However such impacts are hardly interpretable from these maps. Currently a change of colour hue in these maps only depicts the transition to a different type of land use. For example the effects of low density residential development on open landscapes or the effects of scale enlargement in agriculture have to be interpreted by the policy makers themselves.

The PBL noticed usability problems regarding these maps (Borsboom-van Beurden et al, 2006). The processing of information by end users (the policy makers) seems far from optimal, regarding understanding and interpreting the meaning of the maps. This hindrance has to overcome when finally the end user must find differences and detect changes between the current and future situations as well as between different future situations. Given the recent developments in 3D visualisation PBL started a number of projects to search for a better communication platform to policy makers (Hudson-Smith, 2005). The first project took off in 2004. Two challenges were to be met. Firstly the nominal land use map had to be transformed into a 3D visualisation. Secondly the 3D visualisation should be available by an interactive environment.

An iconic representation of the concerned land use types, called land use icons, (Van Lammeren et al, 2005) had been defined and were constructed by 3D Studio Max [1]. In this first attempt grid data on future and current land use were transformed via a Virtools [2] application into 3D scenes by using the land use icons. This Land Use icon approach implied that landscape features essentially for mental mapping and navigation (Lynch, 1960, Al-Kodmany, 2001) were not included and represented at all. Users of this 3D scenes couldn't cognitively relate the 3D representation of Sustainable Outlook results and the Dutch landscape as they known (Sheppard, 2001).
To overcome this problem another approach had been put forward that enriched the Sustainable Outlook data presentation with selected objects from topographical data by which landscape features of importance for user orientation. This landscape feature approach had been implemented via ArcGIS [3] (Momot 2004).
Both approaches turn to have pros and cons. The Land Use Icon approach succeeded in the delivery of highly realistic results via 3D scenes, interactivity and simple

conversions. Despite this achievement, the synthetic character of the results, the lack of landmarks and the artificial grid-based spatial structure were seen as major drawbacks, leading to a missing link with the cognitive map of end users (Sheppard, 2001, Sheppard et al, 2008). Either the slow rendering for the full extent of the Dutch landscape didn't make it appealing to users. The benefit of the Landscape Feature approach seemed to improve the link with the cognitive maps of users. The drawback could be the limited visualisation of the grid cells that represent the expected land use change and consequently the landscape transition.

Since 2005, considerable progress has been made with respect to underlying data sets and technical improvements. At the Netherlands Environmental Assessment Agency, new data have been acquired as the Actual Elevation Model of the Netherlands (AHN) [4] and the National high resolution topographical data (top10Vec) [5]. Additionally, 3D presentation software has progressively developed. Virtual Globes (Google Earth [6], NASA WorldWind [7] and Microsoft Virtual Earth [8]) have found their ways into the Web 2.0 society. These Virtual Globe viewers offer navigation, interaction and exchange of data via the Web. The link of these Virtual Globes to 3D object modeling (eg. SketchUp [9]) and GIS software via respectively Collada objects and KML exports creates an enormous potential (Rodrıguez Lloreta, 2008).

Taking these previous experiences and new developments into account this paper presents in the following section a multilayer 3D visualization application based on the combination of both the Landscape Feature and the Land Use Icon approaches. This application must support the link with the cognitive maps of users and for that offer a better and faster understanding of the Sustainable Outlook data. Considering the latter objective the third section of this paper focuses also on some usability experiences.

GESO: concept and application

The conceptual design intends to address the following user scenario. A policy maker starts up Internet to find out the latest scenarios – story lines and model outcomes - for land use in the near future. Via a web viewer, in this case Google Earth, the policy maker is able to look at the intended land use changes. Via navigation over and through the Dutch land area as presented by recently collected high resolution aerial photos and added 3D presentations of land use classes (fig 1a) the user will have an impression of land use changes within the landscape. Depending on the height of the user viewpoint the land use visuals will change in graphic and geometric details. On the lowest viewpoint (man eye's view) 3D-objects related to new and current land use classes can be seen (fig 1.b). On higher viewpoints (bird's eye view and higher) the 3D-objects will change into textures and colours. Based on this types of navigation and interaction the user has to detect changes and their impacts.
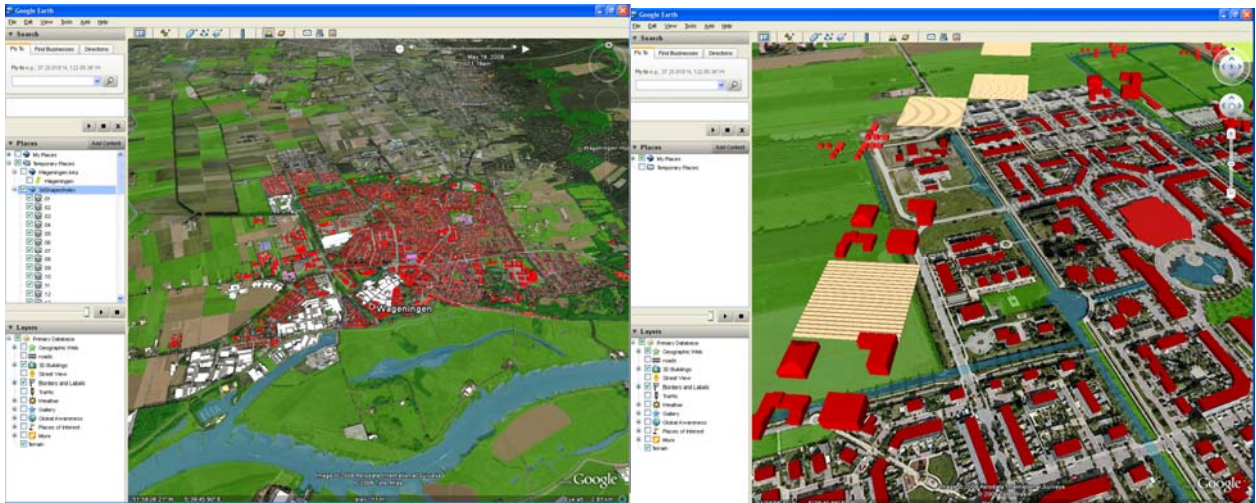
Figure 1.a Current Land Use   Figure 1.b 3D-Icon visualisation of land use

Figure 1.b Iconic representation of Land use change

Via GESO this user scenario becomes reality. GESO is an acronym of Google Earth visualisation of Sustainable Outlook data. GESO, an open source application, creates visualisation-formats (KML/KMZ) for the whole area of the Netherlands out of three authorized data sets, which could be viewed via Google Earth (version 4.2.x).
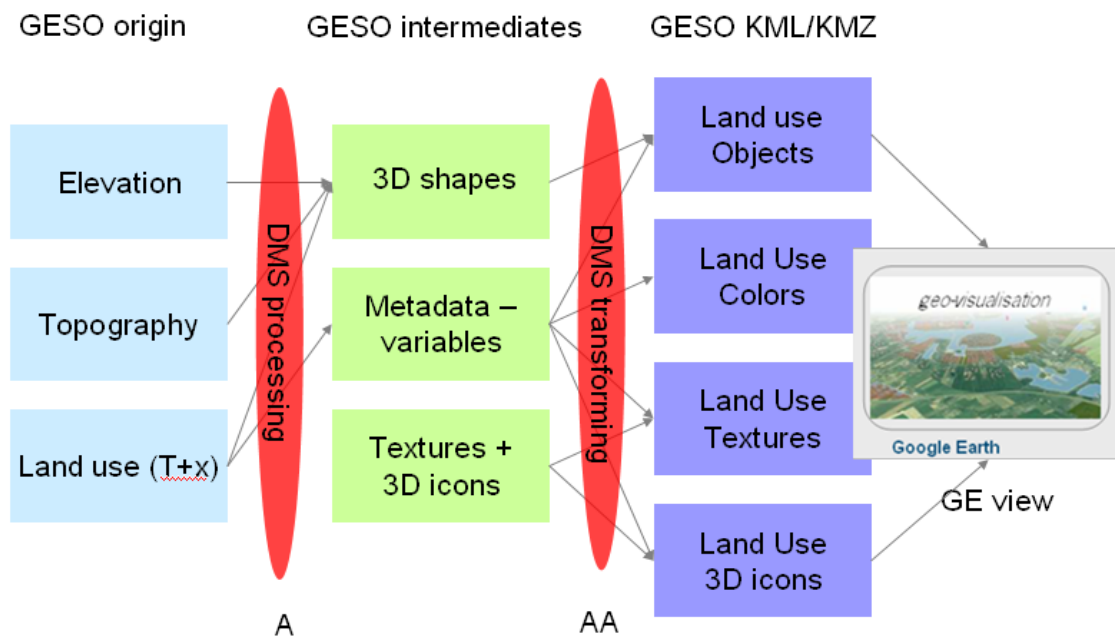

Figure 2 GESO conceptual design

The GESO concept (fig.2) includes the multi-layered data (purple boxes – GESO kml/kmz) to view by Google Earth (GE view). The data consist of KMZ/KML files that represents graphic entities that have been generated by transformation functions (red polygon AA). For the generation of KML/KMZ some intermediate files (green boxes – GESO intermediates) are needed. 3D shapes to construct 3D objects for the current land use, Metadata to define colours for current and future land use and libraries of 3D icons and texture objects. The 3d shapes have been derived from the elevation data combined with topography data via an analysis and alter functions (red polygon A). The authorized data (blue boxes – GESO origin) like the Dutch elevation data (AHN [4]), the high resolution Dutch topographic data set (Top10vec) [5] and the Sustainable outlook results as generated by Land Use Scanner form the main input for creating the multi-layered visualisation.

Extending the Google Earth default data supply GESO creates graphic entities in KML/KMZ format like 3D-objects of Top10Vec building objects to visualize the current landscape, 3D models of the land use icons, texture and colour files. The last three entities are helpful to visualize the future land use and landscape and are properly geo-referenced (WGS84) and a data structure (KMZ,KML) that supplies data to Google Earth in such away that the user will benefit of the Google Earth's data scalability and navigation principles. The latter item means that higher viewpoints offer lower levels of graphical detail. Lower viewpoints give 3D details of high detail. High detail means 3D geometry and high resolution textures (Lammeren, 2005). For the construction of 3D icons the interoperable format of Collada has been used. This format is shared by many 3D modelling software packages including SketchUp and 3D StudioMax.

If all KML/KMZ files are generated the Google Earth tab Places will make the 17 land use class layers visible (fig. 3).
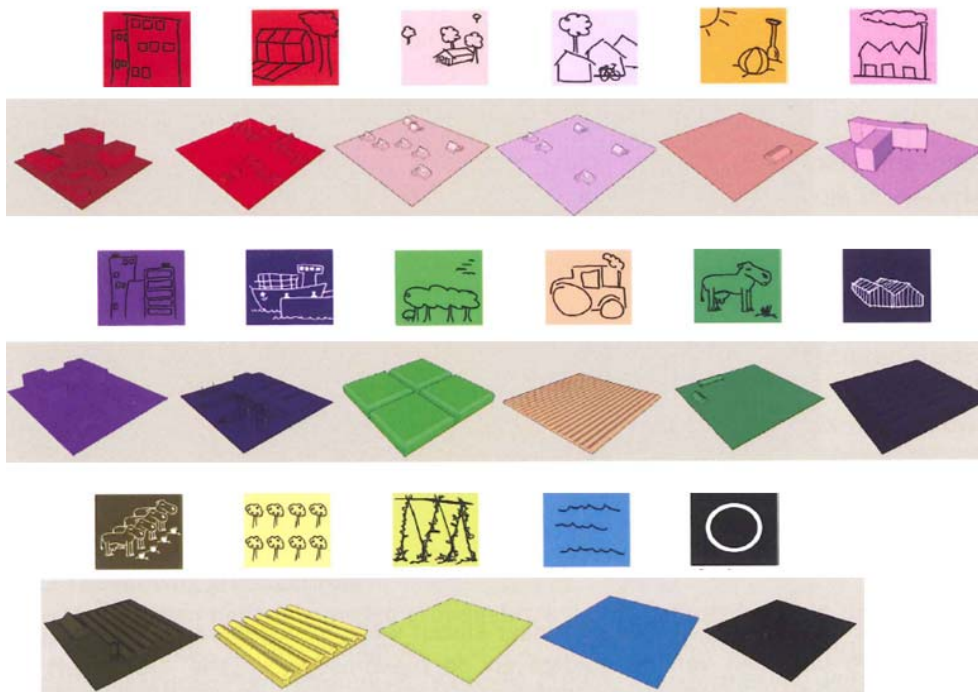

Figure 3: First, Third and Fifth rows show textures.
Second, Fourth and Sixth rows show 3D-icon of the same land use classes
Colours do have identical meanings

In the same way the current land use may become available via the 3dShapes layers (figure 4a). All the land use changes of that scenario will be visualised upon the default aerial photo background as offered by Google Earth. In fact there could be four modes (figure 4b – 4d shows three of them).
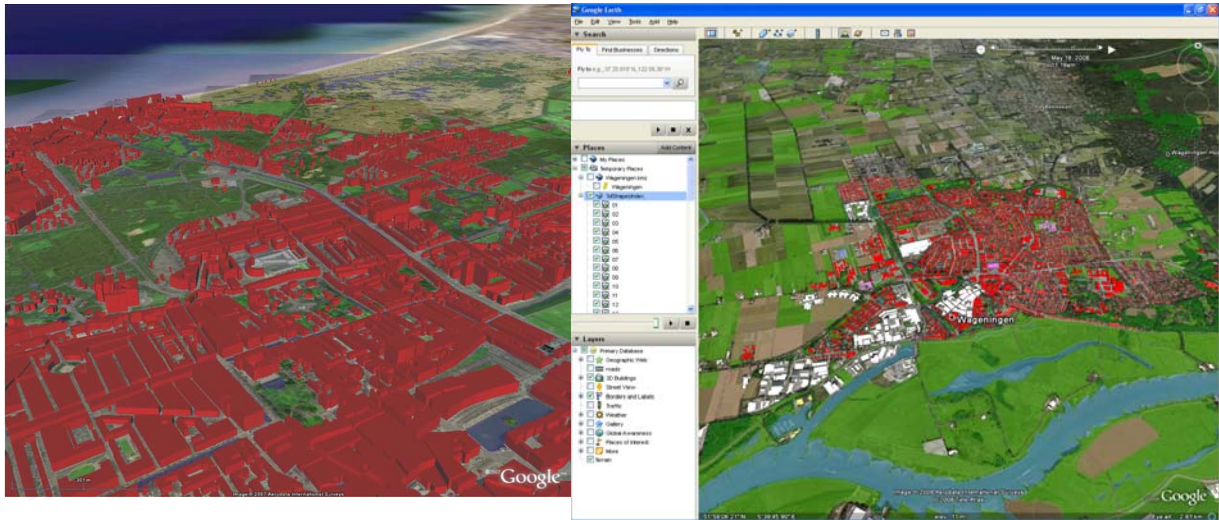

Figure 4a 3D objects current land use

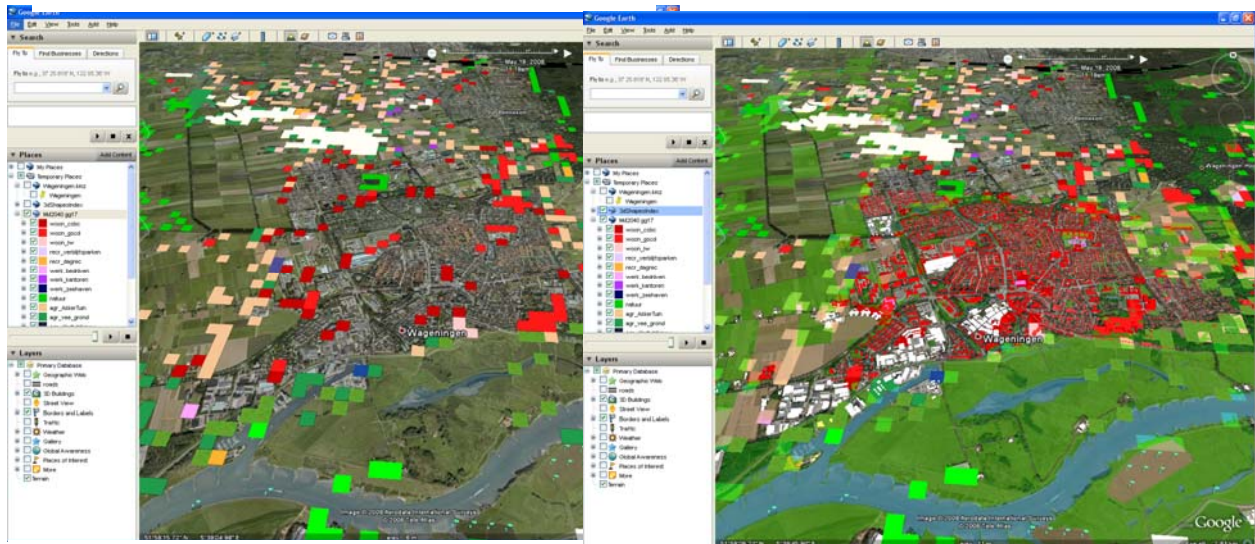*Figure 4b Visualisation current land use*

Figure 4c Colour based Future land use

Figure 4d Current and future land use

Usability: methodology and results

A first step has made by creating files to visualize three-dimensionally land use changes more directed to landscape features and structures as may expected. A next step checks if such multi-layer geo-visualisation approach really offers solutions for the problems at hand. From literature it is known that 3D visualization offer more insight and understanding of spatial relations (topology) and dimensions (geometry) (Bos et al, 1999) especially when users could navigate (Mülder et al, 2007). More details, like materials, lightning, reflection and atmospheric conditions (photo-realistic), offer better ways for recognition to support understanding and affective connotation (ref.). The latter could lead to more esthetical and subjective qualifications. If the presentation fits better to the daily visual references (Bishop et al, 2003) then it will improve communication. Responses are much more precise (Van den Brink et al, 2007) and the variety of different presentation techniques makes comparison easier (MacEachren et al, 2005).
However a more user centered (Fuhrman et al, 2005) usability study addresses the question "What conditions has a 3D visualization of future land use chances to meet to support the request of policy makers for an unambiguous, fast and simple interpretation."

To answer this question we postulate a number of hypothesis on the meaning and understanding of the multi-layered visualisation (Colijn, 2008). The following hypotheses will be discussed in this paper: If the visualization offers more information then users will make less mistakes by, respectively will use less time for, the judgment of the land use distribution [a]; if land use is more realistic visualized then it will be more persuasive and it increases experience [b]; if textures are used instead of colours or 3D-icons then differences in land use classes will be understood faster and unambiguous [c].
These hypotheses have been tested via an experimental setting with 45 test persons (average age 32,5; sd 11.4) consisted of two groups, students and researchers The test persons had to fill in at the start of the test a questionnaire with eight personal questions (eg age, gender, computer skills). Then they had to perform four tasks by using Google Earth and the multi-layered KML set by which visualization of changed land use was offered via colours [i], textures [ii] and 3D-icons [iii]. This part of the test had to put forward task performance data like speed of handling, quality of answers, intensity of interaction (toggling of layers, zooming, panning and changes of viewpoint). After the task performance the users had to answer an appreciation questionnaire of 42 Lickert scale based questions and three open questions to recommend improvements. This questionnaire addresses the GE-interface and the graphic attributes of the visualized data. Finally the test group had to answer an experiences questionnaire of 7 questions. Each question started with a screendump of GE (figure 5). Based on this screendump the test person was offered sub-questions to assess the quality of the physical environment.

Figure 5 Still related to an experiences question

Based on the results of this experimental setting the following results have been found after processing these by descriptive (average and distribution) and explanatory (eg. one way Anova, Chi^2-test, PCA, Cronbach's Alpha, Tukey post hoc-test) statistics. The first hypothesis is rejected regarding "making less mistakes" statement clause because there were no differences found between the three [i, ii, iii] visualization types (F=0.0660, p=0.522), however the 3D-icon visualisation offers the most information and the colour based less. Regarding "using less time" "statement clause it seems that there are no significant differences between the three. However the texture based visualisation differs positively little (table 1, row 1). The second hypothesis [b] seems to be acceptable because the test results of the questions related to this topic show up to be answered more unambiguous in case of [i] then for the same questions related to [i] respectively [ii]. Also the number of task related results seems higher for [iii] visualization then for [i] and [ii] (table 1, row 2).

Visualisation		Row 1 Average Score	Row 2 Number of Answers	Row 3 Variance
i	Colour	4.78 (0.91)	657	1.92
ii	Texture	4.78 (0.83)	679	2.06
iii	3D Icon	5.09 (0.81)	687	1.46

Table 1

The third hypothesis is rejected too, because there were no significant differences between the three visualization types (F=0.228, p=0.797), however the 3D-icon visualisation scored a little better (table 1 row 3).

Conclusion and discussion

Regarding the objectives of the GESO project we conclude that the Sustainable Outlook data could be three-dimensionally visualised via the Google Earth interface for the whole

of the Netherlands. The GESO-application offers the whole of the Netherlands as extent, four levels of detail by default and visual differences between changed and unchanged land use classes within one view, as well as the representation of current land use and areal photo's as a reference. Colours, textures and 3D-icons have been defined and digitally created to present land use changes on several levels of detail. As a reference to landscape features and structure the default Google Earth aerial pictures of the Netherlands have been used as a visual background.

According the usability test and especially the experiment to proof three hypotheses it turns out that 3D-icon visualisation shows no significant improvement of information exchange and understanding. The more traditional colour based visualisation results show lees mistakes, but the 3D-icon type shows to be more persuasive and increases experiences. The users significantly found the 3D-icon visualisation more attractive (F=3.041, p=0.046) and prefer the aesthetics (F=3.067, p=0.057)

Other research results show similar outcomes. Many researchers (Appleton and Lovett , 2002; Bishop and Rohrmann, 2003) concluded that an higher level of detail support a better mental representation of a landscape and for that similar responses. Studies into more photorealistic visualisation do also support the idea that more realistic visualisation improve the affective function by which people will be more convinced of their personal understanding and they do easier assess and respond.

According to Sheppard (Sheppard and Cizek, 2008), every new powerful technology has a potential of misuse. Because virtual globes are universally accessible, the chances of misuse are much greater. Miscommunication is easily possible. "The realism, perspective views, and social meanings of the landscape visualizations embedded in virtual globes invoke not only cognition but also emotional and intuitive responses, with associated issues of uncertainty, credibility, and bias in interpreting the imagery." (Sheppard & Cizek, 2008). In that respect it keeps worthwhile to refer usability results to the conceptual model of Mahdjoubi and Wilthshire (2001) who introduce three functions of visualization in spatial planning: stimulating, affective and cognitive.

GESO functionality does address all three functions as shown above, but considering the usability study there are still many items left for discussion. In the first place using GE and the multi-layered Sustainable Outlook by this test group means a more stimulating, affective and cognitive supporting tool in comparison with the hard copy maps. However the test group didn't consist of policy makers which could be an important pitfall considering the results. Especially it is know from other studies that the meaning and understanding of visuals could by users vary greatly depending on the knowledge domain, the roles and the tasks they have to perform (MacEachren et al, 2005).
So far GESO results have only be tested for the stimulating, affective and cognitive functions regarding understanding and meaning of the three visualisation layers in case of spatial details. These have not been tested for landscape features and structures! The way that users detect more efficiently and effectively differences between several temporal states of land use and by that changes is still a next research challenge to meet by using GESO *. This research topic needs some adaptation of the GESO in the direction of a research tool like user tracking (positions, paths and time expenditure) as well multi window for additional information and instruction.

* GESO is developed in DMS language (open source). The 3D icons have been made via SketchUp (royalty free software) or via 3DStudio Max and transformed into SketchUp models. Besides, the 3D icons may be shared via the 3D model database of the SketchUp community. Currently the multi-layered data is not available via the GE web service. There are many opportunities to develop such a full web service via offering it by the open Google Earth community [10] or via an intranet like Google Earth Enterprise license [11]. This web service could be improved via the dedicated kml generation application that is available under a GNP GPL (open source) license [12]. The 3dShapes data generated by the GESO project partners is available under the CC-BY-NC-SA/3.0/NL license [13] conditions and to be downloaded from [14].

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