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MAPPING LANDSCAPE OPENNESS WITH ISOVISTS

9.1 INTRODUCTION

Today's fast changing society and environment resulted in the creation of new cultural and natural landscapes and in the deterioration of traditional landscapes (Antrop, 2005). New developments such as urban and infrastructure projects and the industrialisation and expansion of large-scale agriculture are resulting in new landscapes which are superimposed on traditional landscapes. The main difference between new landscapes and traditional landscapes is expressed by dynamics in speed and scale, as well as the changing perceptions, values and behaviour of their users (Antrop, 2005). As a result, the visual appearance and peoples perceived quality of landscapes are changing (Nohl, 2001; Antrop, 2004). As a consequence the extent to which people identify with the landscape may decrease and therefore people's well-being is at stake. This is not limited to landscapes with outstanding beauty, but in particular applies to everyday landscapes where people live and work (Council of Europe, 2000). Without interference of policy makers or planners, the visual quality of everyday landscapes will decrease because landscape changes are mainly economy-driven (Bell, 1999). The need to protect and enhance landscape quality is now widely recognised and has been put on European and national political agendas (Council of Europe, 2000; Wascher, 2000; Piorr, 2003; Antrop, 2004; Dramstad, Tveit et al., 2006). There is an increasing demand for decision support systems that offer information on the visual quality of landscapes in order to monitor and evaluate the impacts of ongoing developments (Tress, Tress et al., 2001; Scott, 2003).

Although a significant amount of scientific research has been done on visual landscape issues, policy makers are still calling for information that is more useful and relevant to policy-making processes and that can make these processes more effective (McNie, 2007). As McNie (2007) has indicated, there is often a mismatch between the information that is produced by scientists and the information that is required by policy makers. In particular, policy makers may need information that is not available or not useful, or they may not be aware of existing information that is of use to them.

So what do policy makers require from decision support models for monitoring and evaluating visual landscape quality? Two recent developments are of particular interest. The first is that policy makers have come to realise the need to include the perception of people in the decision-making process. This aspect of visual landscape assessment is included in the definition of landscape in the European Landscape Convention: “Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000). This definition implies that people’s perception of the landscape should be included in policy making. The second is the increasing dependency of environmental policy making on a third wave of Geographic Information Systems (GIS) (Roche and Caron, 2009), which can combine and analyse many datasets in a transparent way. These developments have created a demand for a new generation of decision support tools that are both realistic and technologically advanced.

In recent decades, significant advances in computers and increasing access to high-resolution geodata have led to an increasing deployment of GIS in assessing visual landscape variables, using reproducible methods, over wide areas. Some of the first examples of mapping visual qualities using GIS are presented by Steinitz (1990) and Bishop and Hulse (1994). Mapping the environment based on people’s perception poses interesting challenges for geographical information science because it requires expertise in both GIS analyzing techniques and the psychology of how people experience landscapes (Brabyn, 2008). The ability of GIS to represent individual views of landscape introduces the opportunity to explore subjective and personal views within a spatial environment, potentially coupling the quantitative processing capabilities of GIS with a wide range of social and psychological methods (Aspinall, 2005). Geographic information systems (GIS) provide a way of representing large amounts of data on landscape in a comprehensible format. As such, GIS enables the assessment and analysis of landscape quality in a scientifically sound, and practically useful manner (O’Shea, 2006). In particular, GIS provides the possibility of making the decision-making process more transparent, standardised, and replicable (O’Looney, 2000). In order to be useful for decision makers, GIS tools need to be flexible, easy to use, and adaptable (Geertman, 2002). Because of the tremendous growth in accessible and affordable geo-data, the role of GIS has increased within the decision-making process.

The present research is aimed at developing a procedure to describe the visual landscape, which takes advantage of improvements in measurement techniques, developments in GIS and availability of high-resolution topographic data. The procedure is developed for policy making and spatial planning purposes, and provides information about one specific aspect of the visual landscape, *landscape openness*. In the remainder of the chapter, first the concept of landscape openness is explained, then a method to model landscape openness is proposed. Subsequently, a procedure to use this model for policy making purposes is demonstrated. Finally the results of an evaluation of the procedure with policy makers are discussed.

9.2 LANDSCAPE OPENNESS

Openness is an aspect of the visual landscape that is strongly emphasised in theories relating to perceived visual quality and landscape preference (Herzog, 1987; Coeterier, 1996; Tveit, Ode et al., 2006). The quality of openness depends on biological, as well as cultural and personal factors. Theories emphasising the biological aspect are evolutionary theories such as the prospect-refuge theory (Appleton, 1975), in which prospect is the degree to which the environment provides an overview, which is directly related to landscape openness. According to this theory, people display a preference for certain configurations that combine enclosure and openness. Due to their evolution in the savannah, humans tend to prefer environments that offer various options for cover while at the same time allowing an overview of large spaces. Thus, a balance between open and enclosed landscapes appears to be preferred to either confined or exposed spaces (Strumse, 1994; Buijs, Jacobs et al., 1999; Hagerhall, 2001). Another evolutionary-based theory is the preference model developed by Kaplan et al. (1989). The model assumes people will be attracted to the landscape if human abilities to process information are stimulated. The model consists of four components: coherence, complexity, legibility, and mystery. Openness is a key aspect of the components (Herzog and Kropscott, 2004) and was found to be a predictor of landscape preferences. Kaplan et al. (1989) compared four domains of predictors of landscape preferences. They found that openness, which was rated by respondents based on photographs, was one of the most powerful predictors. Notably, in the study by Kaplan et al. (1989) openness was found to be negatively related to landscape preference, whereas other studies have revealed positive relations between openness and landscape preference (e.g. Rogge, Nevens et al., 2007) The quality of openness not only depends on biological factors, but also on other factors such as shared cultural values and personal learning experiences, which guide and filter people's perceptions (Gifford, 1987; Bourassa, 1990).

The preferred degree of openness may differ across various dimensions. For example, from a general user perspective, half-open landscapes tend to be most preferred because these provide opportunities for understanding as well as exploration (Appleton, 1975). From a cultural perspective, however, extreme degrees of openness or enclosure can be highly valued because these are markers of cultural values such as uniqueness and historical importance. Policy makers often take cultural values as a starting point for planning and decision making. They take a point of reference in the past to determine the current cultural value of landscapes. In The Netherlands for instance, 1900 has often been taken as reference year because it pre-dates the large-scale landscape developments of the twentieth century, such as urban sprawl, heath land reclamation, and land consolidation (Koomen, Maas et al., 2007). Based on such a reference year, a high degree of openness is preferred for one landscape type and a low degree of openness for another. An example of varying preference is the landscape of the Netherlands, where one of the core qualities is a certain degree of openness.

9.3 MODELLING LANDSCAPE OPENNESS

By making use of advances in GIS and high-resolution geodata, physical objects can be modelled in detail. Models of openness have been developed based on physical objects, but here a perception-based approach is presented. The meaning of 'perception-based' in this chapter is that in contrast to a model constructed with objects alone, a subject or perceiver is added, on which the output of the model for openness is based. More precisely, the model is based on visual perception. To model landscape openness, the visual landscape – in particular the visual space – is simulated with the visible space. One way to model openness, which links perceptual factors with spatial information, is provided by the concept of the isovist, which has had a long history in architecture and geography, as well as mathematics. Tandy (1967) is generally acknowledged to be the originator of the term *isovist*. An isovist is the space visible from a given viewpoint with respect to an environment. Benedikt (1979) has further developed the concept of isovists and introduced a set of analytical measurements of isovist properties. The appeal of the concept of an isovist is that it provides an intuitively attractive way of thinking about a spatial environment, because it describes the space 'from inside', from the point of view of individuals, as they perceive, interact with, and move through the space (Turner, Doxa et al., 2001). A similar concept has been developed in the field of landscape architecture and planning, using the term *viewshed*. Although there are various methods to calculate both the isovist and viewshed, a typical difference between the two concepts is that the isovist represents the space that can be 'overviewed', while the viewshed represents (parts of) objects that are visible. Other differences, such as taking into account the vertical viewing angle and terrain height, which are typically only included in the viewshed, are no limitations for isovists per se. The possibilities of isovists and viewsheds have been investigated by many scientific studies for various purposes (Fisher, 1991, 1996; Batty, 2001; Llobera, 2003; Franz and Wiener, 2005; Stamps, 2005).

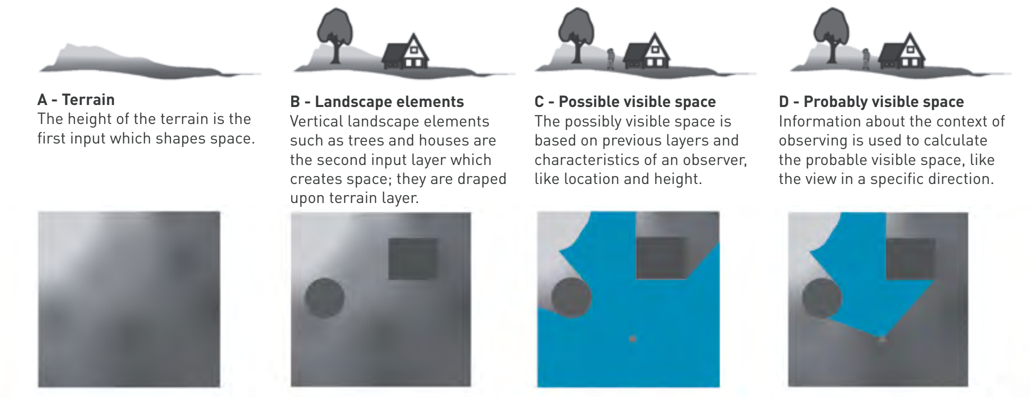


Figure 1

Aspects of landscape and space: terrain (A); landscape elements (B); possibly visible space (C); probably visible space (D)

In this research ArcGIS and Isovist Analyst are used to measure the visible space by calculating isovists (Rana, 2002). The software calculates isovist polygons from two input datasets: a point layer, which represents locations of observer points, and an obstacles layer, which represents the physical environment (figure 1A and B). Visual limitations are simulated by parameter values, which limit the size of the isovists. Figure 1C shows the possible visible space from one viewpoint, based on the terrain height, the landscape elements and the observer height. Besides the location and the eye level of the observer, other characteristics like the angle of view also determine the visible space. This probable visible space (figure 1D) is related to the context and viewing characteristics of people during various activities. The limitations on the field of view may be different for each activity. The isovist polygons for each observer point are constructed by first calculating a number of radials, which are straight lines from the observer point to the first obstacle and therefore represents lines of sight. The radials are calculated every n degrees. A disadvantage of this calculation method is that only the horizontal viewing angle is taken into account, and therefore does not detect a difference between for example a house of 7 metres high and a tower of 50 metres, while this difference is expected to affect the degree of openness. A solution for this limitation would be the calculation of three dimensional isovists, such as proposed by Culagovski (2007).

9.3.1 Validation

The isovist and related concepts are applied in many situations, for example for landscape planning and policy making (Weitkamp, Bregt et al., 2007). In general, there is a lack of actual validations of such numerical and spatially explicit information to assess openness. Although the use of the isovist to estimate perceived openness is an intuitively attractive representation, the many assumptions and simplifications when modelling the perceived landscape openness require a validation.

Three isovist variables were selected to compare with perceived openness, based on the literature (Van der Ham and Iding, 1971; De Veer and Burrough, 1978; Stamps, 2005; Tveit, 2009) and based on the ease of detecting their equivalents in the field. The first is the minimum line of sight. The second is the maximum line of sight which emphasises the importance of distance for the perception of openness. The third is the average line of sight, which is strongly related to the size of the field of view. In short, these three isovist variables and their perceived equivalents in the real world can be summed up as: minimum radial and shortest line of sight; maximum radial and longest line of sight; and average radial and average line of sight.

A field experiment was carried out to test the correspondence between the three isovist variables and perceived openness in the field. Thirty-two Dutch students were asked to rate the openness of the landscape for thirteen field locations, which cover the full range of openness in the Netherlands. A questionnaire was created in which the participants were asked to rate the openness of the landscape on a scale from 1 (low) to 10 (high). They were also asked to estimate the average line of sight, maximum line of sight, and minimum line of sight (in metres).

One way to examine how the isovist variables are related to perceived landscape openness is to calculate how much of the variation of openness can be explained by a combination of the variables. With openness as the dependent variable and the average radial, maximum radial, and minimum radial as predictors, multiple regression analysis was performed. This resulted in two models. The first, with the average radial as the predictor, with an R^2 of 0.84. The second with the average radial and the maximum radial as predictors, with an R^2 of 0.91. In general, the minimum radial did not contribute much to the model (the average radial was dominant), but for individual locations, the perception of openness could change with a landscape element close to the observer while retaining similar values for maximum radial and average radial.

The relationship between perceived space and measured space is most often described by a power function (Wagner, 1985, 2006). The maximum radial and the average radial showed very high correlations with perceived openness, whereas the correlation of the minimum radial was lower. When values of the isovist variables reached above a certain value, further increase did not affect the openness rating. For example, if the maximum radial was higher than 3500 metres or the average radial was higher than 1000 metres, the perceived openness remained fairly constant (on a scale from 1 to 10, between 9.2 and 9.8). Again, the minimum radial did not contribute much to the model, but for individual locations, the perception of openness could change with a landscape element close to the observer but with similar values for maximum radial and average radial.

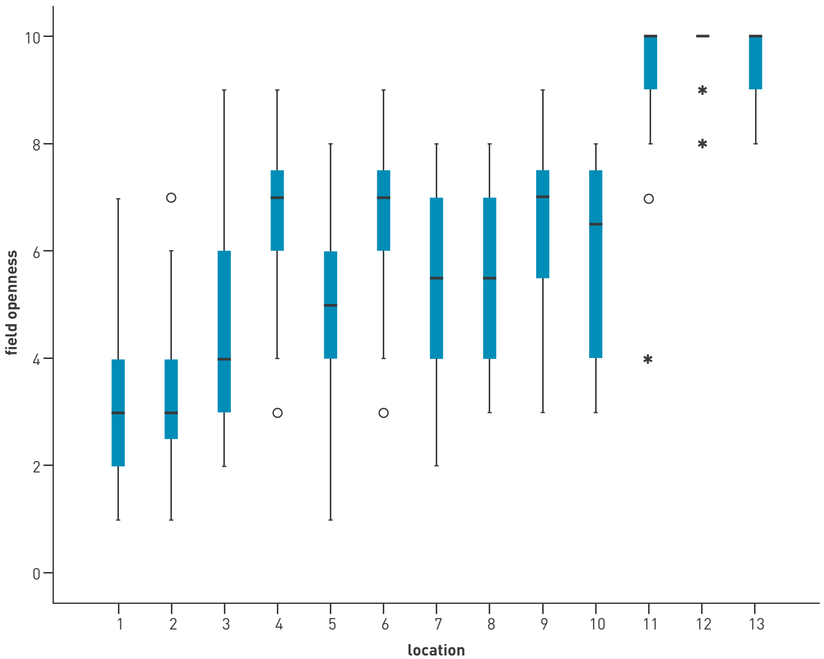
The most important difference between measured and perceived distances is that the measured distance only yields one result, whereas perception of distance varies within a group of people.

Because openness ratings are actually made by individuals, the reliability of individual ratings is an important aspect of the data analysis (Palmer and Hoffman, 2001). To obtain more information about the variation within the group of participants, the Intraclass Correlation coefficient is calculated. This measured the extent to which participants agreed when rating the openness of the 13 locations. The average of the scores of the 32 participants were highly reliable (the Average Measure Intraclass Correlation value was 0.99), suggesting that despite the participants' individual differences, the scoring process was successful in identifying different levels of openness. The Single Measure Intraclass Correlation is the reliability one would get if using just one participant. In this case, this value was 0.76. Landscape openness is a descriptive characteristic that can be rated in a fairly objective way and therefore there is high consistency between those rating.

The range of openness ratings of the 32 participants is illustrated with a box plot in figure 2. The locations with average openness values (between 4 and 7) tended to show more variation than very high or very low rated openness. The three locations with the highest average openness ratings (11, 12, and 13) showed the lowest variation. Location 12 had a very uniform

Figure 2

Box plots of rating of field openness by 32 participants for 13 locations. An increasing location number (x-axis) corresponds with and increasing isovist value



rating except for two outliers. The locations were predicted to have an increasing value of openness based on the isovist calculations. However, locations 4 and 6 had higher values than location 5, and locations 7 to10.

In summary, most of the variation in perceived field openness is explained by the average radial and the maximum radial of the isovist. There are however individual rating differences, but in particular, on group level, there are high correlations between isovist values and perceived openness ratings. When taking into account that differences between landscapes were relatively small (all Dutch landscapes), for European landscapes it will be easier to detect differences, and therefore even better correlations are expected. In short, the isovist appears to be a good indicator of perceived landscape openness.

9.4 PROCEDURE

With the use of isovist measurements, a step-by-step procedure was developed for policy makers to simulate landscape openness based on perception and expert knowledge. The design of the procedure is based on a literature study about landscape perception, and conversations with landscape researchers, policy makers and planners.

9.4.1 Create the observer layer

The first step is to create an observer layer. The observer layer represents the locations from which people may perceive the landscape. Since the majority of people perceive the landscape from a road, a road network should be selected. In order to decide where on the road the viewpoints are located, a mode of perception has to be defined. This can be either a static or dynamic mode of perception (Weitkamp, Bregt et al., 2007). The mode of perception reflects what people can see related to a certain activity. Accordingly it includes information about the observer as a subject, rather than as a physical object. Three main sampling strategies are distinguished to locate the viewpoints: individual point sampling, sequence points sampling and network point sampling. The first sampling strategy reflects perception of openness from individual locations, for example from a lookout (figure 3, step 1B). This is a static mode of perception. These individual points can be predefined by policy makers and planners or randomly selected on the road network. The second sampling method reflects perception from a sequence of locations (figure 3, step 1C). This is a dynamic mode of perception in which people perceive transitions and variations in landscape openness. The chosen distance between the points may depend on the expected perceived intensity of changes of openness: the more complex the spatial configuration, the shorter the distance between points should be. The distance may also

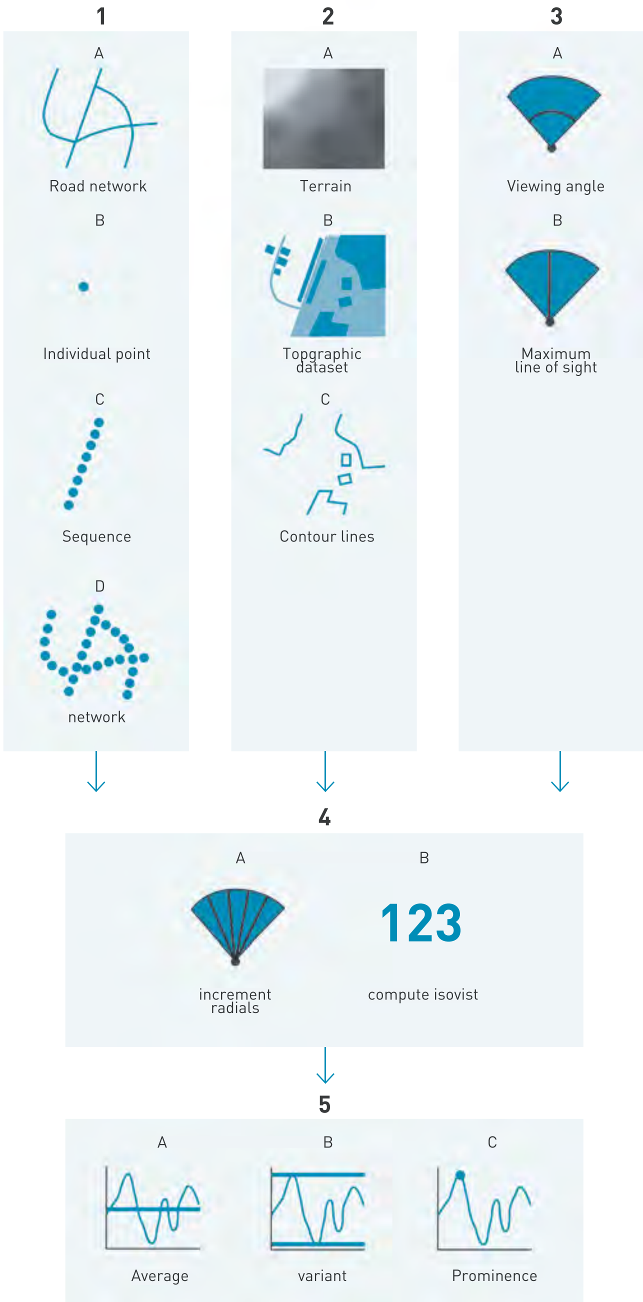


Figure 3

Step-by-step procedure for measuring visibility

The numbers and letters are explained in the main text. A black letter means that the sub-step is required; a grey letter means that the sub-step is optional. A connected box means that the previous step is necessary to execute it; a non-connected box does not need a previous step to be executed.

depend on people's activity in the landscape. For a walking tourist the distance should be shorter than for a person driving to work by car. The third sampling method reflects perception from a network of roads (figure 3, step 1D). These points may be either a collection of individual points (first sampling method) or a collection of sequences of points (second sampling method). The total collection of points does not reflect the locations visited during one activity, but is a summary of multiple activities. This is in contrast to point sampling and sequence sampling, where there is a direct relationship between perception and locations of points. This sampling method may reflect a static perception of openness, using predefined or random sampling, or a dynamic perception of openness, using regular or irregular sequencing points.

9.4.2 Define the physical space

The second step in calculating the visible space is to define the physical space by merging a terrain dataset (figure 3, step 2A) with a topographic dataset (figure 3, step 2B). For each observer point defined in step 1, a contour line layer was created (figure 3, step 1C). This contour line layer is the obstacle layer input for calculating the isovists (figure 3, step 4). The height value of the contour lines is the sum of the value of the height model at the location of the observer point and the eye level value.

9.4.3 Identify visual limitations

A person's field of view depends on their mode of perception and activity. For example, the field of view of car drivers is much smaller than the field of view of pedestrians. This limited field of view has been termed the 'useful visual field' and has been shown to be smaller than the peripheral visual field (Ball, Owsley et al., 1993; Caduff and Timpf, 2008). Visual limitations, like viewing angle and maximum line of sight, are inherent to human vision and have an effect on perceived landscape openness (Coeterier, 1994). For example, the maximum angle of view in the horizontal plane is about 210 degrees, with 120 degrees binocular overlap without movement of the head or eyes (Atchison and Smith, 2001). The useful visual field can have smaller values for the viewing angle, depending on the mode of perception. Another example is the maximum visual line of sight. Many studies relate threshold distances of the line of sight to the foreground, middle ground and background, but with varying Euclidean distances (Van der Ham and Iding, 1971; US Forest Service, 1974; Smardon, Palmer et al., 1986; Bishop and Hulse, 1994; Baldwin, Fisher et al. , 1996). The viewing angle and the maximum line of sight vary with activity, motion speed, and perhaps complexity of the landscape. These parameters are added to the model to increase the accuracy of the visibility measurements for describing landscape openness (figure 3, step 3).

9.4.4 Compute the Visible Space

The visible space is calculated with isovists, using ArcGIS and Isovist Analyst (Rana, 2002). The software calculates isovist polygons from two input datasets: a point layer which represents locations of observer points (figure 3, step 1) and an obstacles layer which represents the vertical landscape elements (figure 3, step 2). Visual limitations are simulated by parameter values that limit the size of the isovists (figure 3, step 3).

The isovist polygons for each observer point are constructed by first calculating a number of radials, which are straight lines from the observer point to the first obstacle and therefore represent lines of sight. The radials are calculated every *n* degrees. The most appropriate increment value for the radials (figure 3, step 4A) depends on the desired precision of the calculation and is also strongly correlated to computation time.

9.4.5 Select and Calculate Variables

The last step of the procedure is to derive variables from the isovist (figure 3, step 5). This is an important step. It adapts the output data better to the phenomenon of landscape openness and turns the output data into a format suitable for landscape policy making and planning.

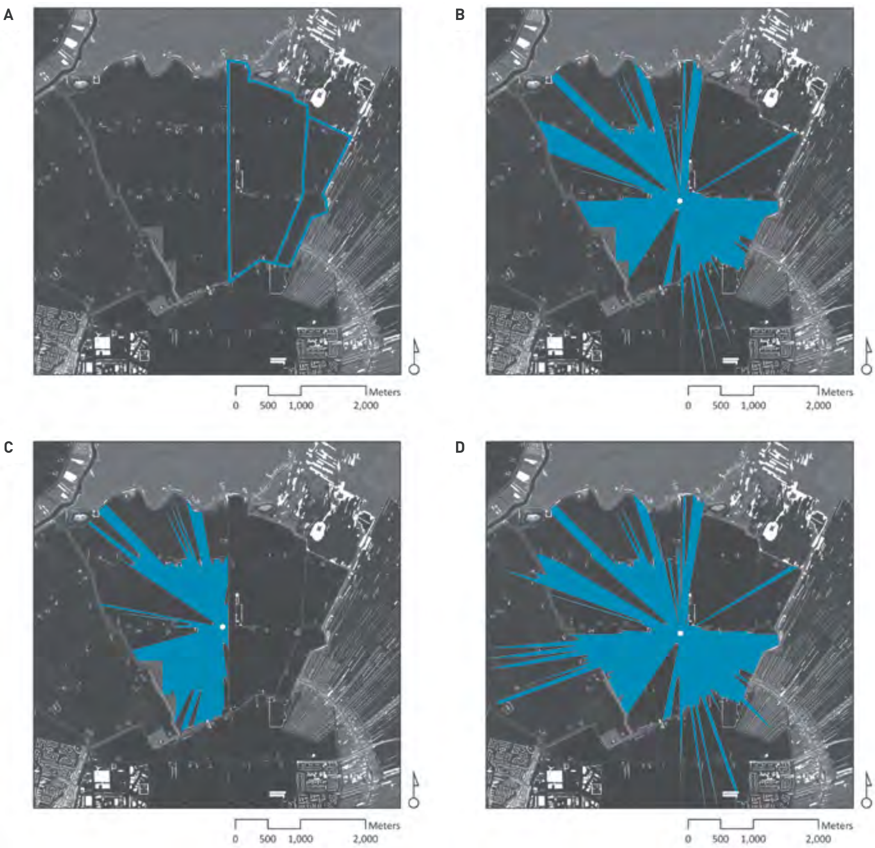
The variables can be derived from three unit types. The smallest unit is a point; the variables are derived from one isovist. The next unit is a line; the variables are derived from sequencing isovists. The last unit is a network; the variables are derived from multiple isovists. Three types of (statistical) analysis are proposed to derive the variables from the output data: average, variation and prominence. The average analysis produces one general description of landscape openness for a unit. The variation analysis produces a description that reflects the variation in openness within a unit. The prominence analysis selects a specific line of sight, isovist or sequence of isovists within a unit, which represents the character of landscape openness for that unit.

9.5 EVALUATION

The procedure is designed to assess landscape openness in a way that meets the requirements for a good description of landscape openness as well as a generic procedure for landscape policy making and planning. A workshop was organised in which scientists and Dutch policy makers were brought together to evaluate the usefulness of the procedure. Six actual landscape openness cases, which were provided by the policy makers themselves, were used to present and illustrate the procedure. Three of the cases are shown in figure 4: *Ronde Venen* in the province of Utrecht, figure 5: near Winschoten, Groningen, and figure 6: *Friese Meren*, Friesland. There are well-established criteria available for evaluating the usefulness of decision support models at the interface between science and policy making. Four criteria are selected: relevance to policy (Cash, Clark et al., 2003; Cash and Buizer, 2005; Jacobs, Garfin et al., 2005; Keller, 2009), scientific credibility (OECD, 1999; Cash and Buizer, 2005; Jacobs, Garfin et al., 2005; Doody, Kearney et al., 2009), usability for policy makers (OECD, 1999; Park, Stabler et

Figure 4

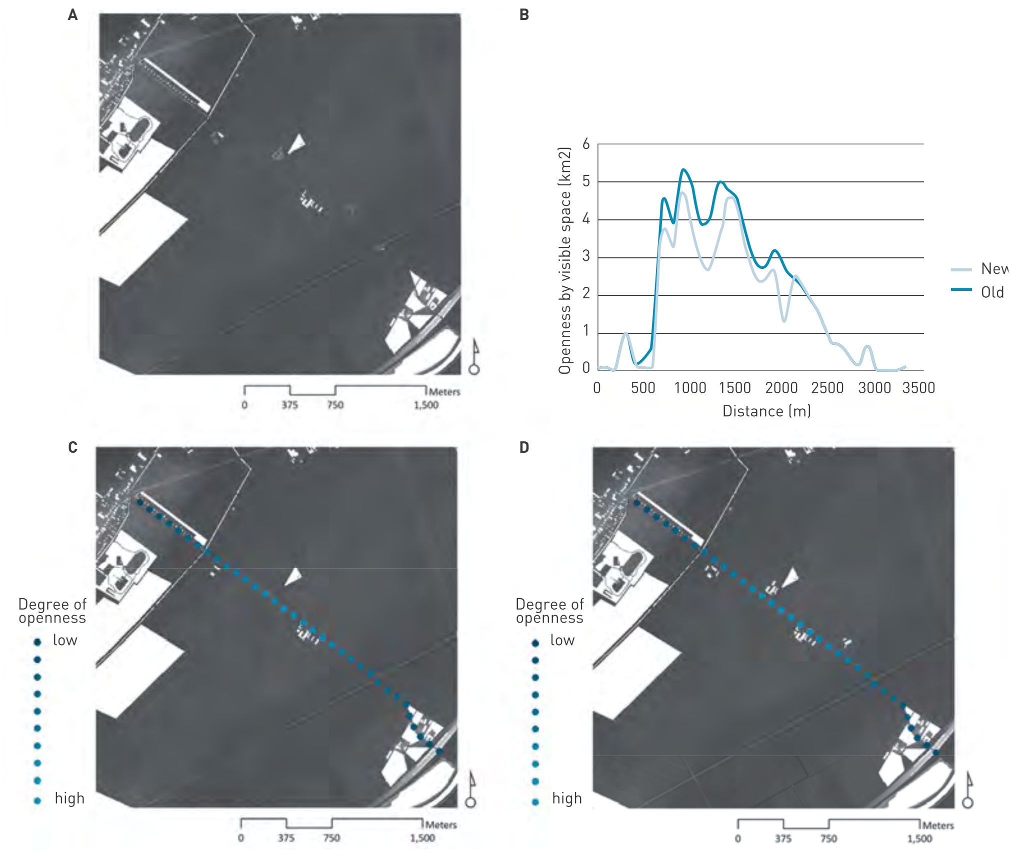
The case study area of Ronde Venen, Utrecht, is characterised by its polders, which have a high degree of openness. The development of natural habitats will require the construction of dikes to regulate the water table. Various scenarios for the location of dikes have been developed, one of which is shown in figure 4A. The background shows the height model of the landscape, the whiter areas representing higher height values and the darker areas representing lower height values. The policy question is how the dikes affect the openness of the landscape. The visible space from one viewpoint on the road, in the centre of the polder, is shown for the current situation in figure 4B. The viewing angle is 360 degrees and the maximum line of sight is 3000 metres at an eye level of 1.6 metres. In the possible new situation the same viewpoint is located on the planned dike and the visible space is therefore larger than in the current situation (figure 4D). However, the visible space decreases dramatically when located on a road next to the dike (figure 4C). This example illustrates that the exact location of the viewpoint is important when drawing conclusions about the effect on openness



al., 2004; Singh, Murty et al., 2009), and feasibility for implementation (OECD, 1999; Doody, Kearney et al., 2009). The policy makers who participated the workshop were asked to comment on these four criteria for the procedure.

Figure 5

The case study area of Winschoten, Groningen, is characterised by a contrast between large-scale open landscapes and enclosed landscapes. The open character is under threat, one of the reasons for this being the relocation of farm buildings from small settlements to the open agricultural areas. Figure 5.4A shows an example of recently built farmhouses. The provincial policy makers want to know the effect these buildings have on landscape openness. The calculation of the visible space is based on views from the road along which the buildings are located. To simulate the perception of openness during movement, viewpoints were fixed at 100 metre intervals along the road in the old situation (4C) and the new situation (4D), with the viewing angle set at 120 degrees in a southeasterly direction. The difference in visible space between the old and the current situation is shown in figure 5B. The difference is not big, partly because there were already some buildings and a patch of forest located along the road. The differences in openness at other locations on the road are even smaller because the road starts and ends in an enclosed area. The contrast between the enclosed areas and the open area along the road decreased slightly, but would still be perceived



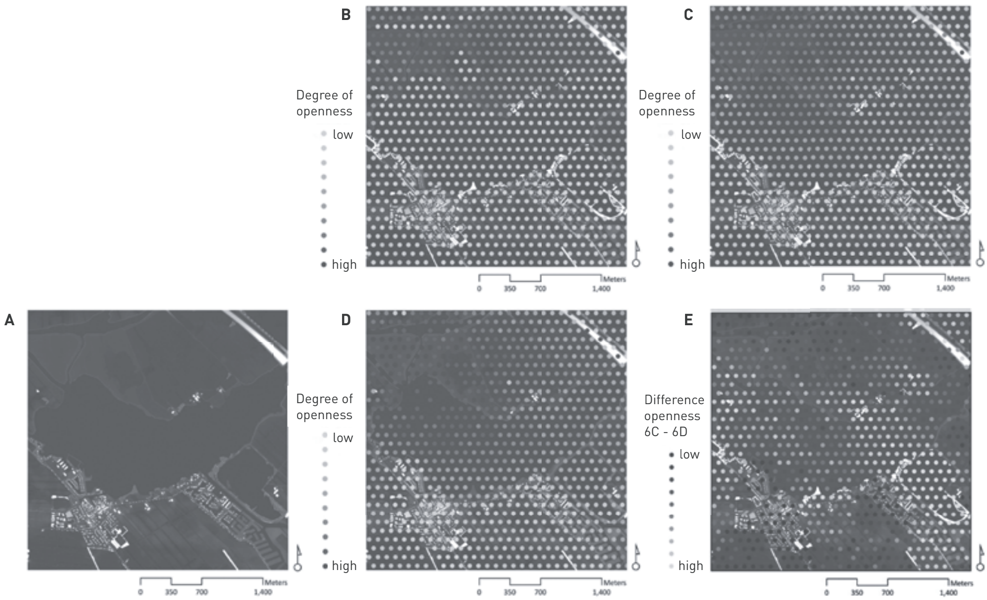


Figure 6
The case study area of the Friese Meren in the province of Friesland is characterised by its open landscapes. However, the spontaneous growth of vegetation around the lakes is reducing the openness of the landscape. The effect of the vegetation growth has to be assessed. The exact locations of the vegetation growth were not known, and the Top10vector may not show all this vegetation. We selected the vegetation within 50 metres of the shores of the lakes and designated it as spontaneous vegetation (figure 6A). We calculated the visible space for every location in the area based on a 100-metre grid. The viewing angle was set to 360 degrees and the eye level was set to 1.6 metres on the land and 1 metre on the water (figure 6B). A change in eye level can have a large effect on the openness. For example, the values for openness change dramatically when the eye level on the water is raised to 2 metres (figure 6C). The effect of the vegetation on openness can be seen by comparing figure 6C with 6D, in which the vegetation has been removed. The difference between the openness with vegetation (6C) and without vegetation (6D) is shown in figure 6E

9.5.1 Relevance

All the participants, including three who mentioned that they already used other methods, felt the need to assess openness. Openness is defined as one of the core qualities of Dutch national landscapes, and many other European countries also consider it relevant to measure openness. It was found relevant that people's perceptions are explicitly taken into account, and that landscape functions or activities could be linked to perception. The procedure makes it possible to identify perceived openness for activities such as driving a car and enjoying the view from a viewpoint, which is useful for policy making. The functions of modes of perception and visual limitations were generally appreciated by the participants because they make the procedure flexible enough to be applied to local situations. They also agreed that guidelines based on scientific research were indispensable for its proper use.

Furthermore the procedure was thought to be relevant because it can be used to develop valuation standards for openness. Although the procedure does not provide predefined standards for determining whether there is 'enough' or 'too little' openness, the participants agreed that the procedure would be helpful in developing these. There was a discussion on whether valuations should be included as a standard element in a procedure. This could increase the relevance of such a procedure, but may also decrease its credibility.

The procedure supports the communication of information about openness to stakeholders, such as other governmental organisations at different levels. The procedure was also considered to be useful for participatory planning because it is easy to generate visual impressions of openness and the effects of certain landscape changes on openness.

9.5.2 Credibility

The procedure was considered to be credible because it was clear and transparent. Participants considered the procedure much more credible than multi-criteria analysis, for example, which was compared with a 'black box'. The isovist technique that is used to calculate the visible space was considered to be an intuitively good representation of landscape openness. The input data, the AHN and Top10vector, were the best data currently available, but are not yet detailed enough to accurately represent some elements. Although some improvement is possible, the participants agreed that the procedure could never entirely replace other methods of collecting information, such as field visits, no matter how accurate and precise the input data. However, because policy makers are likely to differ in their landscape preferences and interpretations from the general public (e.g. Vouligny, Domon et al., 2009), the use of more representative tools, that can make policy makers aware of their biases, was considered to be very important. Some participants indicated that the credibility of the procedure could be improved by including parameters related to people's cultural background or living environments. These parameters would primarily affect their preference for a certain degree of openness. Among the participants of the workshop there was general agreement on the complexity of developing a procedure for assessing preferred openness.

9.5.3 Usability

The procedure is a usable instrument because of its transparency, which makes it possible to interpret the outcomes in an unambiguous way. The measured visible space is a usable basis for communicating landscape openness with other stakeholders because it is based on a simple and clear concept. The flexibility of the procedure, which allows for the selection of various modes of perception and other parameters for the visual limitations related to various activities, also contributed much to its usability. However, a guideline on how to make use of these options was considered to be necessary for proper use.

9.5.4 Feasibility

The procedure employs widely used software and data and fairly simple techniques within GIS to make the measurements; this was appreciated by the participants. However, the whole process was not yet automated and ready to be implemented in ArcGIS, the GIS software in use at the organisations where the participants were employed. The participants indicated that there is sufficient knowledge of GIS in their organisations to use the procedure if it could be implemented in ArcGIS. As their organisations do not have the necessary knowledge about landscape perception, and therefore about parameter values such as the viewing angle and the maximum line of sight, a guideline for the proper use of all the options related to different types of perception is required.

The data that was used for the procedure, the AHN and Top10vector databases, was available to the participants. If such a procedure were to be used at the European level, data availability would be a major issue, because at this level such high-resolution topographic datasets and elevation models are not available.

Having enough time and money is also a precondition for the feasibility of the procedure. The participants indicated that this would not be a problem, given that information about openness can be generated relatively quickly and at low cost. This is especially true in comparison with other procedures for including perception in policy making, such as surveys.

9.6 CONCLUDING REMARKS

A systematic GIS-based procedure for measuring landscape openness was developed which is explicitly modelled from the perspective of humans. The model provides exact estimates of possible visible space based on biological features of human vision, and physical features of the environment. In addition it estimates probable visible space by specifying modes of perception with corresponding visual limitations. From the perspective of human perception, an important limitation of the procedure is that it is restricted to calculating visible space, and does not include space as it is seen by people. What is seen not only depends on human vision and modes of perception, but also on other dimensions such as cultural values and personal learning experiences. The procedure was found useful by policy makers, in particular its transparency and flexibility were appreciated.

Openness manifests itself differently in different cultural landscapes, and the development of prototypical openness values for each landscape type could be used as a guide for plans and policies. At the European level landscapes are typically classified by experts using a top-down approach. A need has been expressed to link these European top-down approaches with more perception-based bottom-up approaches. Present research provides a first step in establishing this link by developing a perception-based approach that produces measurable data. This study provides the basis for research and identifies a number of areas where further research is required. The representation of openness may be improved by 3d isovists. However, validation is needed for indicating the benefits of 3d isovists. The three modes of perception also need validation to test how well the sampling strategies reflect how people perceive openness. Another area that needs further research is the implementation in planning and policy making. Guidelines need to be developed for the use of variable values. Finally, the development of prototypical descriptions of characteristic degrees of perceived openness for cultural landscape types, combined with bio-physical landscape types such as those of LANMAP (Mucher, Klijn et al., 2010), is another direction for further research.

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REFERENCES

Antrop, M. (2004) Landscape change and the urbanization process in Europe. *Landscape and Urban Planning* 67(1-4); 9-26

Antrop, M. (2005) Why landscapes of the past are important for the future. *Landscape and Urban Planning* 70(1-2); 21-34

Appleton, J. (1975) *The Experience of Landscape.* London, John Wiley.

Aspinall, R. J. (2005) GIS and landscape conservation. In: Longley, P. A. et al. (eds.) *Geographical information systems: principles, techniques, applications and management*. New York, Wiley, pp 358

Atchison, D. A., and Smith, G. (2001) *Optics of the Human Eye.* Oxford, Elsevier Health Sciences.

Baldwin, J., Fisher, P. et al. (1996) *Modelling Environmental Cognition of the View With GIS.* Third International Conference/Workshop on Integrating GIS and Environmental Modeling, Santa Fe, New Mexico.

Ball, K., Owsley, C. et al. (1993) Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science* 34(11); 3110-3123

Batty, M. (2001) Exploring isovist fields: space and shape in architectural and urban morphology. *Environment and Planning B: Planning and Design* 28; 123-150

Bell, S. (1999) *Landscape: Pattern, Perception and Process*. London, E & FN Spon.

Benedikt, M. L. (1979) To take hold of space: isovists and isovists fields. *Environment and Planning B: Planning and Design* 6; 47-65

Bishop, I. D., and Hulse, D. W. (1994) Prediction of scenic beauty using mapped data and geographic information systems. *Landscape and Urban Planning* 30; 59-70

Bourassa, S. (1990) A paradigm for landscape aesthetics. *Environment and Behavior* 22(6); 787-812

Brabyn, L. (2008) Using GIS to describe the landscape experience of hiking tracks. *New Zealand Geographical Society 24th Conference*. Victoria University of Wellington.

Buijs, A. E., Jacobs, M. H., et al. (1999) *Graadmeters beleving: theoretische uitwerking en validatie van het begrip 'afwisseling'*. Wageningen, Staring Centrum.

Caduff, D., and Timpf, S. (2008) On the assessment of landmark salience for human navigation. *Cognitive Processing 9*(4); 249-267

Cash, D. W., and Buizer, J. (2005) Knowledge-Action Systems for Seasonal to Interannual Climate Forecasting. Washington D. C.

Cash, D. W., Clark, W. C. et al. (2003) Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America* 100(14); 8086-8091

Coeterier, J. F. (1994) Cues for the perception of the size of space in landscape. *Journal of Enviromental Management* 42; 333-347

Coeterier, J. F. (1996) Dominant attributes in the perception and evaluation of the Dutch landscape. *Landscape and Urban Planning* 34(1); 27-44

Council of Europe (2000) *European Landscape Convention*. Florence.

Culagovski, R. (2007) *Three dimensional isovist analysis method*. SIGRADI, Mexico.

De Veer, A. A., and Burrough, P. A. (1978) Physiognomic landscape mapping in The Netherlands. *Landscape Planning* 5; 45-62

Doody, D. G., Kearney, P. et al. (2009) Evaluation of the Q-method as a method of public participation in the selection of sustainable development indicators. *Ecological Indicators* 9(6); 1129-1137

Dramstad, W. E., Tveit, M. S., et al. (2006) Relationships between visual landscape preferences and map-based indicators of landscape structure. *Landscape and Urban Planning* 78(4); 465-474

Fisher, P. F. (1991) First experiments in viewshed uncertainty: the accuracy of the viewshed area. *Photogrammetric Engineering & Remote Sensing* 57(10); 1321-1327

Fisher, P. F. (1996) Extending the applicability of viewsheds in landscape planning. *Programmetric Engeneering and Remote Sensing* 62(11); 1297-1302

Franz, G., and Wiener, J. M. (2005) *Exploring isovist-based correlates of spatial behavior and experience*. The 5th Space Syntax Symposium, Delft, The Netherlands.

Geertman, S. (2002) Participatory planning and GIS: A PSS to bridge the gap. *Environment and Planning B: Planning and Design* 29(1); 21-35

Gifford, R. (1987) *Environmental psychology: principles and practice*. Boston, Allyn and Bacon.

Hagerhall, C. M. (2001) Consensus in landscape preference judgements. *Journal of Environmental Psychology* 21(1); 83-92

Herzog, T. R. (1987) A cognitive analysis of preference for natural environments: mountains, canyons, and deserts. *Landscape Journal* 6(2); 140

Herzog, T. R., and Kropscott, L. S. (2004) Legibility, mystery, and visual access as predictors of preference and perceived danger in forest settings without pathways. *Environment and Behavior* 36(5); 659

Jacobs, K., Garfin, G. et al. (2005) More than Just Talk: Connecting Science and Decision Making. *Environment* 47(9); 17

Kaplan, R., Kaplan, S. et al. (1989) Environmental preference: a comparison of four domains of predictors. *Environment and Behavior* 21(5); 509-530

Keller, A. C. (2009) Credibility and Relevance in Environmental Policy: Measuring Strategies and Performance among Science Assessment Organizations. *Journal of Public Administration Research and Theory Advance Access*.

Koomen, A. J. M., Maas, G. J. et al. (2007) *Veranderingen in lijnvormige cultuurhistorische landschapselementen: resultaten van een steekproef over de periode 1900-2003*. Wageningen, Wettelijke Onderzoekstaken Natuur & Milieu.

Llobera, M. (2003) Extending GIS-based visual analysis: the concept of visualscapes. *International Journal of Geographical Information Science* 17(1); 25-48

McNie, E. C. (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science and Policy* 10(1); 17-38

Mucher, C. A., Klijn, J. A., et al. (2010) A new European Landscape Classification (LANMAP): A transparent, flexible and user-oriented methodology to distinguish landscapes. *Ecological Indicators* 10(1); 87-103

Nohl, W. (2001) Sustainable landscape use and aesthetic perception - preliminary reflections on future landscape aesthetics. *Landscape and Urban Planning* 54; 223-237

O'Looney, J. (2000) *Beyond maps: GIS and decision making in local government*. Redlands, ESRI Press.

O'Shea, C. (2006) Use of Geographic Information Systems (GIS) in Policy Making for Strategic Planning and Sustainable Development in Scotland.

OECD (1999) Environmental Indicators for Agriculture: Concepts and Framework. Paris, France, Organisation for Economic Co-operation and Development.

Palmer, J. F., and Hoffman, R. E. (2001) Rating reliability and representation validity in scenic landscape assessments. *Landscape and Urban Planning* 54(1-4); 149-161

Park, J. R., Stabler, M. J. et al. (2004) The use of a multiple criteria decision analysis to evaluate the effectiveness of landscape and habitat enhancement mechanisms: an example from the South Downs. *Journal of Environmental Planning and Management* 47(5); 773 - 793

Piorr, H.P. (2003) Environmental policy, agri-environmental indicators and landscape indicators. *Agriculture, Ecosystems & Environment* 98(1-3); 17-33

Rana, S. (2002). Isovist Analyst Extension. London, Centre for Advanced Spatial Analysis, University College London.

Roche, S., and Caron, C. (2009) *The organisational facets of GIS*. London, ISTE.

Rogge, E., Nevens, F. et al. (2007) Perception of rural landscapes in Flanders: Looking beyond aesthetics. *Landscape and Urban Planning* 82(4); 159-174

Scott, A. (2003) Assessing public perception of landscape: from practice to policy. *Journal of Environmental Policy and Planning* 5(2); 123

Singh, R. K., Murty, H. R. et al. (2009) An overview of sustainability assessment methodologies. *Ecological Indicators* 9(2); 189-212

Smardon, R. C., Palmer, J. F. et al. (1986) *Foundations for Visual Project Analysis*. New York, John Wiley & Sons.

Stamps, A. E. (2005) Isovists, enclosure, and permeability theory. *Environment and Planning B: Planning and Design* 32(5); 735 – 762

Steinitz, C. (1990) Toward a sustainable landscape with high visual preference and high ecological integrity: the Loop Road in Acadia National Park, USA. *Landscape & Urban Planning* 19(3); 213-250

Strumse, E. (1994) Perceptual dimensions in the visual preferences for agrarian landscapes in western Norway. *Journal of Environmental Psychology* 14(4); 281-292

Tandy, C. R. (1967) The isovist method of landscape survey. In: Murray, C.R. (ed.) *Methods of Landscape Analysis*. London, Landscape Research Group, pp 9-10

Tress, B., Tress, G. et al. (2001) Bridging human and natural sciences in landscape research. *Landscape and Urban Planning* 57(3-4); 137-141

Turner, A., Doxa, M. et al. (2001) From Isovists to visibility graphs: a methodology for the analysis of architectural space. *Environment and Planning B: Planning and Design* 28; 103-121

Tveit, M., Ode, et al. (2006) Key concepts in a framework for analysing visual landscape character. *Landscape Research* 31; 229-255

Tveit, M. S. (2009) Indicators of visual scale as predictors of landscape preference; a comparison between groups. *Journal of Environmental Management* 90(9); 2882-2888

US Forest Service (1974) *The visual management system. National Forest Landscape Management.* Washington, DC US Department of Agriculture.

Van der Ham, R. J. I. M., and Iding, J. A. M. E. (1971) *Landscape Typology System based on Visual Elements: Methodology and Application*. Wageningen.

Vouligny, É., Domon, G. et al. (2009) An assessment of ordinary landscapes by an expert and by its residents: Landscape values in areas of intensive agricultural use. *Land Use Policy* 26(4); 890-900

Wagner, M. (1985) The metric of visual space. *Perception & psychophysics* 38(6); 483-495

Wagner, M. (2006) *The geometries of visual space*. London, Lawrence Erlbaum Associates.

Wascher, D. M. (2000) The face of Europe. Policy perspectives for European landscapes: Policy perspectives for European landscapes. *ECNC Technical Report Series*. Tilburg, European Centre for Nature Conservation.

Weitkamp, G., Bregt, A. et al. (2007) *Three Sampling Methods for Visibility Measures of Landscape Perception*. COSIT 2007, Melbourne, Australia, Springer-Verlag.