
Predicting the scenic beauty value of mapped landscape changes in a mountainous region through the use of GIS

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Abstract. Planning frequently fails to include the valuation of public goods, such as scenic beauty. This can lead to negative economic impacts for a region over the longer term. Especially in mountainous regions such as the Alps in central Europe, which depend on tourist income, the change of landscape views through the development of facilities for recreation and tourism may negatively affect the tourism experience, and hence the economy. In this study we present a prototypical technique to predict preferences for views using geographic information system (GIS)-based variables. A three-dimensional GIS including the effects of slope, aspect, and distance, as well as the height of landscape features, is developed to calculate the proportion of land-cover areas that make up the view. A Web-based survey is used to gather data on scenic preferences for landscape changes in the region around Davos (Switzerland). Willingness-to-pay (WTP) responses are used to identify preferred landscapes. A forced-choice questionnaire asks participants to compare pairs of landscape photographs. Two original pictures were digitally altered to visually represent landscape change scenarios developed for the study area. The visual magnitudes of the different land-cover areas are found to be correlated with the WTP values expressed by the respondents. The relationship is used to predict changes in scenic values for another view in the region. The approach presented in this paper could be useful in regional planning to estimate the influence of view components on people's preferences.

Introduction

Most mountainous regions in the European Alps depend on tourism. Conflicting interests make landscape planning and management a challenge in these regions: there is considerable pressure to develop facilities for recreation and tourism, but such developments erode the visual quality and negatively affect the tourism economy. As landscape views possess public-good characteristics and thus have no market price, their value is seldom fully included in the economic accounting for the region (de Groot, 1992; Hufschmidt et al, 1983). This undervaluation leads to a smaller investment in the preservation and/or creation of public features that would be socially desirable (de Groot, 1992; Heal, 2000).

Economists have developed various techniques to value environmental goods or services such as visual quality (Freeman, 1992; Garrod and Willis, 1999). These approaches measure the demand for goods or services by examining individuals' stated or revealed preferences. The stated preferences are elicited via questionnaires directly addressed to individuals and often take the form of survey studies that relate human perception and judgment to environmental stimuli. The revealed preferences are obtained from approaches which examine individuals' purchases of market-priced goods, such as property value (Lange and Schaeffer, 2001; Luttk, 2000). Willingness to pay (WTP)

is a contingent valuation technique based on stated preferences. It is achieved by constructing a hypothetical market and asking individuals what they are willing to pay towards the preservation of a particular environmental good or service. A recent review of the strengths and limitations of the techniques has been given by Bateman and Willis (1999).

Many studies relate the economic value of scenic beauty to physical landscape features. Geographic information systems (GIS) have facilitated this procedure by providing accurate measurement of the physical variables (for example, Bishop and Hull, 1991; Brown, 1990; Hadrian et al, 1988; Iverson, 1985; Steinitz, 1990). Recently, several authors have shown how a GIS can be used to determine the landscape features which explain the variations in sale prices obtained by hedonic models. These studies have, however, generally taken a somewhat simplistic approach to the view analysis. For example, Lake et al (2000) included a distance effect and vertical elements; the latter, however, only as obstructers of the view. Paterson and Boyle (2002) did not take the effect of distance and heights of objects into account. Bishop et al (2004), investigating the influence of view components on high-rise apartment pricing in a flat area, did not include the three-dimensional (3D) effect of slope, aspect, and differences of heights between upright landscape features and the viewpoint. These factors are, however, essential for predicting scenic beauty in mountainous regions.

The objectives of the study is to show how mapped land-cover changes can be used for predictive scenic assessment (as estimated by WTP) in mountainous regions through the use of a GIS. Especially in these areas, which depend on tourism and in which suitable land for development is a scarce resource, planners need approaches to weight the economic impacts of different development strategies in regard to the degradation of the visual resource. Drawing upon two scenarios devised for the study area, we study the impact of three types of mapped land-cover changes on scenic assessment, including a raising of the tree line on the mountain (as a potential consequence of climate change), new ski runs, and urban expansion. In order to quantify the impact of the change in view content caused by the land-cover changes, we create a 3D GIS model which calculates the visual magnitude (VM) for each of the land-cover types that make up the view. The VM provides a measure of how the value of cells in a vision range impacts the viewer. Our focus here is on the development of the 3D GIS model, which calculates VM in mountainous regions, and thus includes factors such as slope, aspect, and height in the VM of the observed cell as well as the influence of height differences between upright landscape features and the viewpoint. We assess the view values by using photographs, with corresponding changes, in a Web-based survey. It is assumed in this paper that photographs are a valid way to measure visual quality. The issue of whether photographs are a valid representation of landscape for preference studies has been recently reviewed by Palmer and Hoffman (2001). Photographs have, however, the disadvantage of only showing what presently exists. Thus, as suggested by several authors (Bishop and Hull, 1991; Hunziker and Kienast, 1999; Orland, 1993, Zube et al, 1987), we manipulate images from two views in the Swiss Alps to correspond to the land-cover changes planned on the map. We use WTP as the landscape-assessment metric. This has the advantage that it provides (1) people with a firm basis from which to assess their degree of preference for a preferred landscape and (2) the prospect of immediate comparison with other measures of change available in monetary form. This second advantage depends upon the assessed WTP being supported by more detailed studies of this aspect. Also, we show that the GIS-based VM measures can be linked to the WTP responses and that the derived prediction equation can be applied to another view in the same region. If this final result can be generalized then it becomes unnecessary to undertake additional photograph-based

surveys in this region when assessing the effect of land-cover change on the value of the scenic resource.

Method

The procedure to illustrate, how a 3D GIS model can be used to predict scenic values from mapped variables in mountainous regions, consists of three major components: scenario building, VM calculations, and scenic assessment using WTP as a metric. The scenario-building component consists of the modification of the land-use maps, according to scenarios developed for the case-study region. In this step planners are required to adjust the land-use maps to reflect new development strategies or the effects of natural processes (for example, climate change). The modified land-use maps serve as the input to the VM calculations and as the basis for modification of the photographs for the scenic assessment. The VM model estimates the portion of the field of view occupied by the different land-cover changes through the use of a 3D GIS model. In the scenic assessment component, a WTP survey asks people about their preferences for the land-cover changes, which are represented on photographs. Last, the GIS-based VM measured are used as predictors for people's preferences for different land-cover changes.

Study area and scenarios

The study area is the 'Landschaft Davos', a commune in the eastern part of the Swiss Alps, which spans an area of 254 km² (figure 1). The area consists of a NE–SW-oriented main valley (Landwassertal) and four SE–NW-oriented valleys. The altitude of the valley bottom is 1400–1600 m above sea level, and the highest peaks are over 3000 m above sea level. The local population is about 13 000 people with 25 000 guest

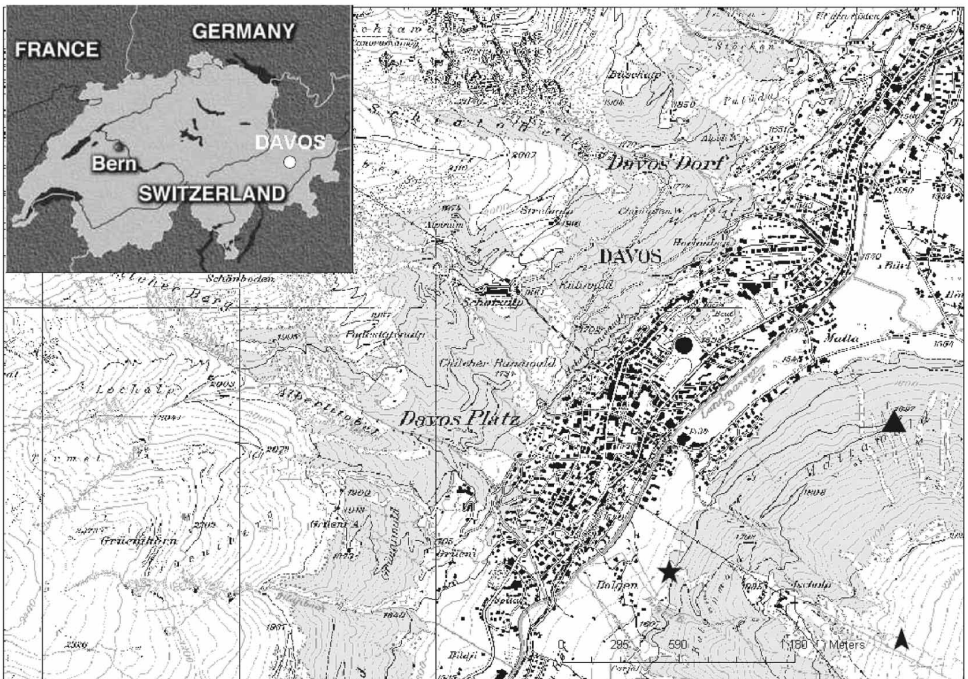


Figure 1. The municipality of Davos, covering totally 254 km², is located in the eastern part of Switzerland. The triangle shows the location of the point of view for image A, the star shows the location of the point of view for image B. Available in colour at <http://www.enplan.com/misc/b32051/>.

beds; the main economic source is tourism. Several medical clinics and four scientific institutes with approximately 400 employees also contribute to the economy of the region. Forestry (22% of the total area of 254 km² is forested) and agriculture, including about 90 farms, provide further employment in the area and have a significant impact on the character of the landscape.

Scenarios are devised for the study area in the frame of the Swiss National Research Project 48 (Bebi et al, 2003). Conditions of future developments until 2050 are formulated during workshops with the main stakeholders of the municipality of Davos. This information provides the base for scenario stories. Three main types of land-use change associated with those scenarios are determined, including the raising of the tree line on the mountain, new ski runs, and urban expansion. Walz et al (2004) provide details about the calculations of the size of the land-cover changes.

Scenario 1 is a climate-change and landscape-change scenario characterized by an increase in average temperature of +2.4 °C (OcCC, 2003) associated with the abandonment of alpine pastures caused by a decrease in governmental subsidies (Anwander et al, 1990; Broggi, 1995; Bugmann et al, 2005). The land-use change associated with this scenario is a densification and expansion of the forest cover at altitude. Scenario 2 is a tourist-development scenario taking place under a large sporting event, such as the winter olympic games. Land-use changes associated with this scenario are an increase in urban area of 40 ha and the addition of a new ski slope of 11 ha above Davos to accommodate the predicted 2.4% increase in people visiting Davos.

Image preparation

The initial visual stimulus is two photographs of existing views from above Davos (figure 2). Views from these locations have been available as postcards for several decades in many shops in Davos. We felt that they were representative of the views of the landscape in the case-study area. The most recent images were taken with a 50 mm lens and pixel dimensions of 1280 × 1024. Natural and man-made features are distinguishable in both images. Criteria to select the images included: (1) enclosure of major land-cover types (both resort related and natural) which define the region, (2) field of view of all the important land-cover changes expected by the locals in the next fifty years, (3) provision of two different viewpoints covering the same land area, (4) provision of views representative of those from vacation rentals, and (5) viewpoints with different distances to the urban area. The locations of the two points of view are shown in figure 1. Figure 2(b) includes a gondola, which is characteristic of the views



(a)



(b)

Figure 2. Original photographs (left = A, right = B) of the two views from above Davos (courtesy of Foto Furter, Davos). The photographs were taken using a manual camera with a 50 mm lens. Available in colour at <http://www.envplan.com/misc/b32051/>.

in the ‘Landschaft Davos’. Both images were taken in the same season to reduce uncertainty in the interpretation of results.

In order to determine the location on the photographs of the land-cover changes made on the maps, we georeferenced the images through the use of an algorithm written by Corripio (2002). The process of projecting the base photographs onto the digital elevation model (DEM) consisted of georeferencing the oblique photographs to the DEM, and defining a mapping function between the information contained on a given pixel of the photograph and the corresponding cell of the DEM. A perspective projection of the DEM was performed after a viewing transformation into the camera coordinate system (figure 3). As each dot represents a grid cell, we were able to determine the locations on the photographs corresponding to the changes in the mapped land-cover data. The process was validated using ground control points: at the location of known standing objects, such as churches or important buildings, we created imaginary ground control points at the same $x - y$ location but varying in height (1 m interval). We georeferenced these ground control points and obtained vertical lines which we then aligned with the church towers or the sports buildings. As we did not have exact information on the size of each tree or building, an average height value of 20 m was assumed for forest land cover and 15 m for urban land cover.

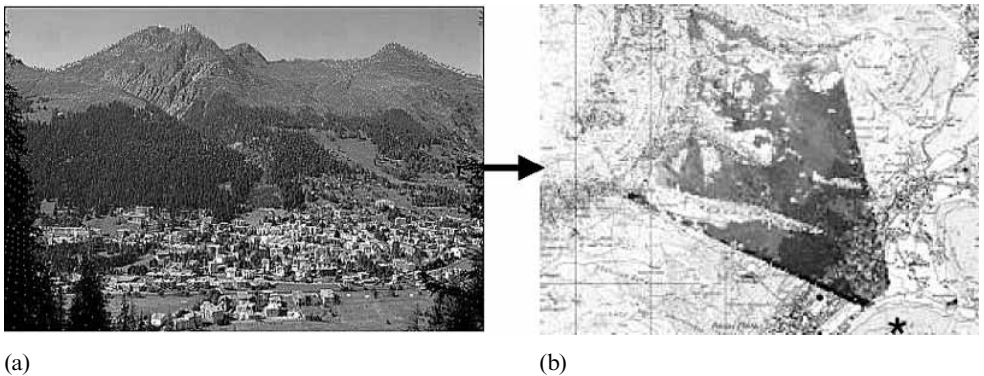


Figure 3. Perspective projection of a digital elevation model of the original photograph from above Davos (a). Every dot in (a) represents a grid cell after a viewing transformation and perspective projection. The georeferenced photograph (b) matches the map of the area fairly well. The star in (b) represents the position of the observer. Available in colour at <http://www.envplan.com/misc/b32051/>.

Knowing the location of the mapped land-cover changes on the photographs, we visualized the scenarios in eight different views by adding photograph fragments from the original photographs with Corel PhotoDraw[®]. In order to study the effect of distance of the land-cover types on their VM, we added the land-cover types in the foreground and the background. Figure 4 gives an example of the photomanipulations for each of the three land-cover changes corresponding to the climate-change scenario and the tourism scenario.

3D GIS model to estimate visual magnitude

Because the areas and sizes of landscape objects presented to a viewer have a definite influence on the viewer's responsiveness to changes (Bishop et al, 2004; Oh and Lee, 2002; Paterson and Boyle, 2002), a 3D GIS model of the landscape was developed to calculate how much of a land-cover area with its features occupies the field of view of the observer. Iverson (1985) defined the portion of the field of view occupied by an object as ‘visual magnitude’. As a measure of VM, he used square minutes to illustrate

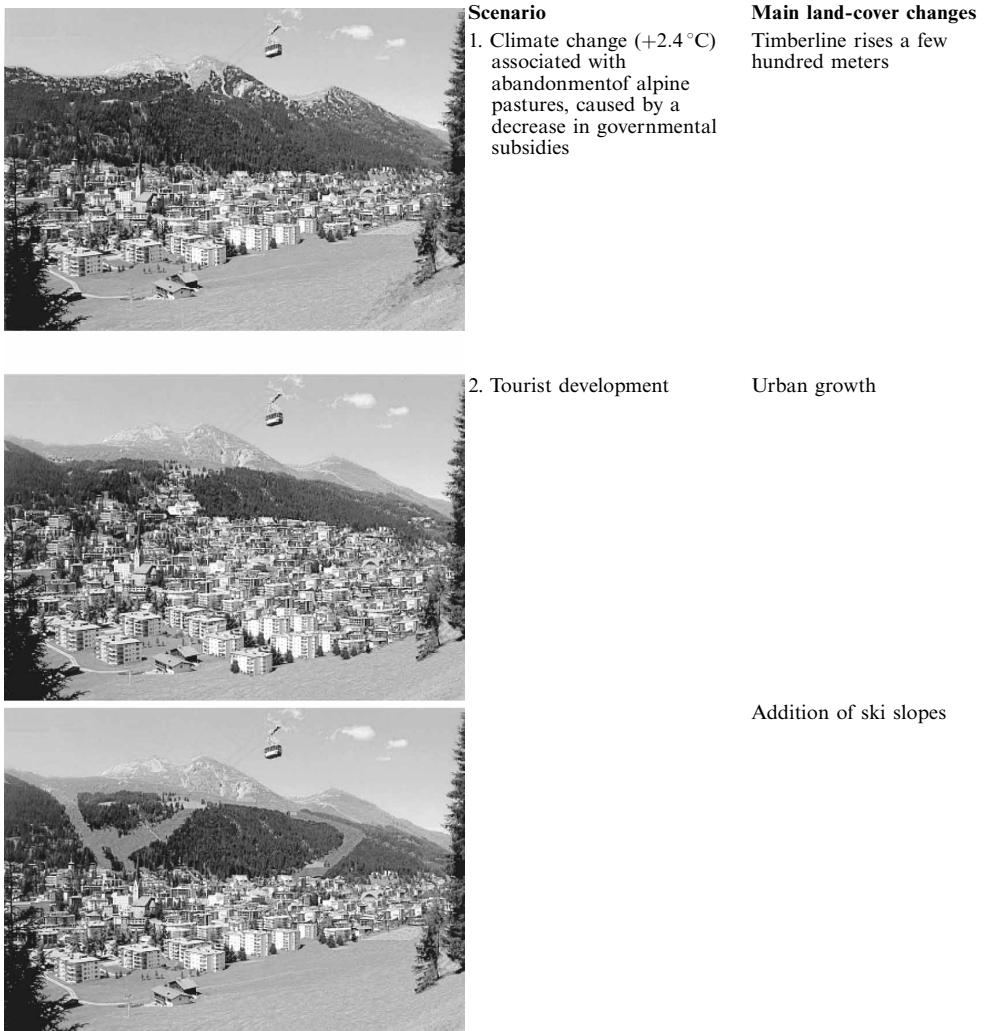


Figure 4. Principal land-cover changes associated with scenarios and examples of simulated views. Available in colour at <http://www.envplan.com/misc/b32051/>.

the fact that the ability of the retina of the human eye with 20/20 vision to perceive separation of an image from its background is normally limited to a visual angle of one minute. By adding the number of square minutes that a unit of landscape occupies in the field of vision, one can estimate the degree of impact of a landscape alteration on the viewer. In his VM calculations, Iverson (1985) showed that VM depends on the slope, aspect, and distance of the object from the observer: apparent visual magnitude of a grid decreases as distance increases and/or as the aspect relative to the observer decreases.

In order to study the visual impact of the land-cover changes devised in the scenarios, we estimated the VMs of the grid cells whose land-cover types were modified. The sum of the VMs of each land-cover type gave a measure of the visual importance of the land-cover changes. As factors such as the difference of height between upright landscape features and the viewpoint are relevant in mountainous regions, we added the measure of the height of vertical objects to the VM calculations.

A DEM of the Landschaft Davos, with $25\text{ m} \times 25\text{ m}$ grid cells, was used as the base for the visibility analysis, and the mapped land-cover changes provided information about the land-cover type of each grid cell. The procedure was coded in a single programming language (<http://www.visualbasic.net>) to create a standalone routine and was linked to ArcGIS 8.3 (ESRI Inc., Redlands, CA) for display.

To minimize computing time, we first performed a viewshed analysis on the DEM. “The viewshed is that area of land all of which is visible by unimpeded line of sight, from a single point” (Brantingham et al, 2005, page 7). The visibility of each point was determined by comparing the altitude angle to the point with the altitude angle to the local horizon. The local horizon was computed by considering the intervening terrain between the point of observation and the current point. If the point lay above the local horizon it was considered to be visible. A detailed review of the mathematical procedure is given in De Florian and Magillo (2003). This analysis restrained the VM calculation to just those cells visible from the original viewpoint of the photograph. The VM calculations for these visible cells were then based on a vector field generated for each grid cell and defined by two variables:

- (1) an orthonormal vector (\mathbf{n}) (perpendicular to the terrain, with a magnitude of one); and
- (2) the viewing vector (\mathbf{o}), with its origin on the cell and direction towards the viewer.

Figure 5 illustrates the calculations of the angle of VM (AVM) for four different situations. The calculation of the AVM is explained using the simplified case of figure 5(a), in which a viewer sees a flat cell: The AVM (θ_{VM}) is the complement of the angle (α) obtained by projecting the surface orthonormal (\mathbf{n}) onto the viewing vector (\mathbf{o}). Thus angle (α) is

$$\alpha = \arccos \left(\frac{\mathbf{n} \cdot \mathbf{o}}{\|\mathbf{n}\| \cdot \|\mathbf{o}\|} \right), \quad (1)$$

and the complement of angle (α), θ_{VM} , using standard trigonometric functions

$$\theta_{\text{VM}} = \arcsin \left(\frac{\mathbf{n} \cdot \mathbf{o}}{\|\mathbf{n}\| \cdot \|\mathbf{o}\|} \right). \quad (2)$$

Equations (1) and (2) can be applied to all possible situations as illustrated in figures 5(b), (c), and (d). In general, negative values of AVM occur when the cell is not facing the viewer. A value of 0 means that the cell surface is parallel to the viewing vector, and a value of 1 means that the cell surface is perpendicular to \mathbf{o} . DEM cells with a value close to 1 are directly facing the viewer and have the largest visual effect.

We also included the effect of distance in the VM estimations, and the VM was calculated as:

$$V = \theta_{\text{VM}} \frac{1}{D^2} A = \frac{\theta_{\text{VM}} A}{D^2}, \quad (3)$$

where A is the area of the cell and D is the distance between the viewer and the cell. The θ_{VM} term accounts for the AVM, the D^2 term accounts for the distance effect. The closer a cell, the more its presence occupies our field of view and the bigger the VM. In order to estimate the total VM of a land-cover area, we summed the VM of all the cells included in this area.

In order to test how well the estimates of VMs matched with the areas in the photographs, we calculated the ski, urban, and forest areas in all the photographs by pixel counting. A simple least-squares regression analysis compared the areas calculated from the photographs with the GIS-derived VMs of these areas. The effect of height on the VM estimates was also investigated by estimating the VMs without

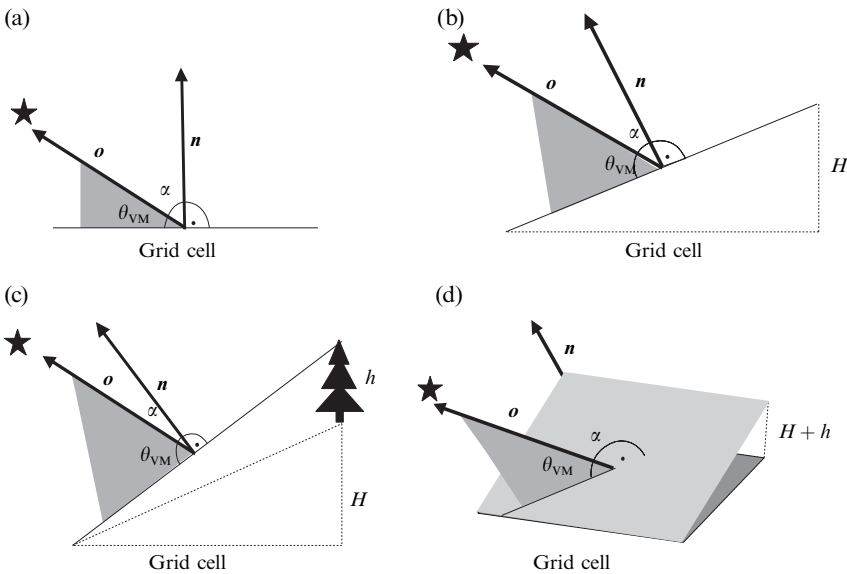


Figure 5. Schema of the calculation of the angle of visual magnitude (AVM) for one grid cell, for four different cases. Figure 5(a) presents the simplified case, in which a viewer, represented by a star, sees a flat cell: The AVM (θ_{VM}) is the complement of the angle (α) obtained by projecting the surface orthonormal (n) onto the viewing vector (o). The steeper the slope, the smaller the angle (α) between n and o , the more 'seen area' will be revealed, and the bigger the AVM [figure 5(b)]. In figure 5(c), we added a vertical object, such as a tree, on top of the grid cell. In order to include this supplemental height into the VM calculations, we added the height value (H), corresponding to the height of the vertical element, to the slope. The surface orthonormal (n) will thus be more inclined so that the angle (α) is diminished and the AVM amplified. In figure 5(d), we modify the aspect of the grid cell relative to the viewer as well as the position of the viewer. In this situation, the direction and length of the viewing vector o will be modified because of the position change of the viewer, and the direction of the surface orthonormal (n) will be modified because of the aspect change. The more directly the cell is turned toward a viewer, the smaller the angle (α) and the bigger the AVM.

including the height factor and comparing the results with the VM calculations which did include the height factor.

Willingness-to-pay survey

A WTP approach is used to assess scenic-beauty preferences. The importance of the survey is to provide data which could be used in the GIS analysis to establish the appropriate mechanism for differentiating view values on the basis of the land-cover distribution. A choice-modeling questionnaire was designed, which consisted of four parts. The first part included the purpose of the study, instructions to answer questions, and information about the authors of the study. Respondents had the choice to take the survey in German, French, or English.

In the second part, respondents were asked to compare pairs of pictures from landscape views and to select the preferred view. No written text explaining the scenarios was provided to the survey participants. Only the pictures, presented side-by-side, were presented in the survey. Table 1 gives the sequence of photographs presented to the respondents. With this relatively small number of pairs, we tried to optimize both the number of respondents and data validity, as too many picture comparisons might lead to fatigue of the respondents and unreliability of their responses.

Table 1. Description of photographs used in survey.

Pair	Left photograph	Original photograph	Right photograph	Original photograph
1	Added ski slopes	A	Original photograph	A
2	Original photograph	B	Added maximum forest	B
3	Added maximum buildings	B	Added maximum buildings	A
4	Added ski slopes	B	Original photograph	B
5	Added maximum forest	A	Original photograph	A
6	Original photograph	B	Added maximum buildings	B
7	Original photograph	A	Original photograph	B
8	Added medium forest	B	Original photograph	B
9	Added medium buildings	A	Original photograph	A

The third part tackled the respondents' WTP for their preferred views. An open-ended payment-card approach was adopted to provide respondents with direct prompts, to clarify their WTP, and to allow them to express their preferred amount if they were not satisfied with the given choices. This approach was selected because it provides respondents with explicit and straightforward information, which helps them to construct hypothetical transactions, and it encourages them to reveal WTP amounts. The bid structure was constructed on the basis of experts' suggestions and a pilot survey. Respondents were asked to indicate how much extra per week they would be willing to pay for the weekly rent of their apartment, which costs 800 Swiss francs (\$570) per week, in order to have the preferred view. They were given the choice between 0 SFR (0\$), 10 SFR (7\$), 20 SFR (15\$), 50 SFR (37\$), 100 SFR (74\$), and more than 100 SFR. In the analysis, we replaced 'more than 100 SFR' with '100 SFR'. It is obvious that taking the expressed bid and not the mean between two bids, as well as taking 100 SFR for the response 'more than 100 SFR', provides a quite conservative measure of the WTP responses. This is, however, in conformity with the following findings of the contingent valuation method panel of the NOAA (1993, page 32): "conservative design increases the reliability of the estimate by eliminating extreme responses that can enlarge estimated values wildly and implausibly." Furthermore, responses of people who had a preference, but were not willing to pay, were kept in the analysis. We chose vacation rentals because of our tourist survey group and their probable greater familiarity with rental prices. An average rental apartment in Davos costs from around 800 SFR per week upwards. After having made their monetary choice, respondents were asked to select a budget category, from which their money would come. This was added to the survey to remind the respondents of the need to make compensating adjustments in other types of expenditure to accommodate the additional financial transaction implied by the survey and thus to increase the accuracy of the WTP answers (Arrow et al, 1993). At this point they could also go back in the survey to revise their bid amount. The last part of the questionnaire gleaned socioeconomic information: gender, age group, educational level, place of residence, and monthly income, but we did not use it in the analysis as it was not the focus of the research. A study in progress (Gehring et al, 2003) is investigating the impact of socioeconomic variables on public preferences for similar future landscape developments in a region close to the case-study area through the use of similar photomanipulations. We used the Internet as a medium for gathering the data. The survey used a collection of documents written in hypertext markup language (HTML) and programs written in practical export and reporting language (PERL), using the common gateway interface (cgi) protocol. A pilot survey was conducted with 129 employees from the University Corporation of Atmospheric Research in Boulder, CO.

The test aimed to verify whether the questionnaire was logical and unambiguously worded, and whether respondents could correctly understand it. It provided hints for several refinements to make the questionnaire more user friendly.

The final questionnaire was posted on the website of the office of tourism of Davos for three weeks. As the experiment was focused on assessing the use of GIS variables to measure the visual impact of land-cover changes on scenic beauty preferences, we used the Internet to quickly obtain responses from a sample of people renting apartments in Davos. The Davos tourism website is the main portal for booking vacation rentals in the region. As Wherret (1999) concluded, such surveys are representative of an *Internet general public* (of tourists to Davos) rather than the general public as a whole.

Using the GIS-based variables to predict scenic assessment

We identified the predictors of WTP responses by performing least-square regressions of the VMs of the land-cover areas against the WTP responses. The WTP responses were taken as the dependent variables, and the percentage changes in total VM of the land-cover areas between the modified and the original photographs were taken as the independent variables. We tested different functions, including linear, half-logarithmic, root-transformed, and squared function forms in the dependent variable in order to find the best form to predict WTP responses. In the logarithmic form, WTP responses of 0 SFR were replaced by 1 SFR.

In order to assess aggregate benefits, mean WTP responses were used. As Harrison and Kriström (1996, page 2) argue, “there is virtually no rationale behind the exclusive use of the median when the goal is to assess aggregate damages to a population. Since these data are invariably right-skewed, with the mean being larger than the median, this suggests that damage assessments using the median may have understated damages” Mean WTP responses were calculated for each image pair by taking the WTP responses for the modified photograph as positive values and the WTP responses for the original photograph as negative values. We used a Wilcoxon signed-rank test to test the influence of the different land-cover area changes on WTP responses. This nonparametric test was chosen because the data were not normally distributed.

The applicability of the prediction model to address other views in the Landschaft Davos was tested by asking people about preferences between the original photographs A and B (figure 2). Respondents were invited to compare the two original photographs A and B (pair 7—see table 1) with the two original photographs with added buildings (pair 3). The resulting WTP responses for the two pairs of images were then compared with the prediction results based on the regression model between VMs and WTP responses.

Results and discussion

Survey results

The main survey was filled out by 266 people. The 2394 responses given by the respondents are shown in figure 6. The majority of the responses indicated a preference for a certain photograph (78.8%), but only 33.7% of them included WTP; 44.1% were not willing to pay and 21.2% of the responses showed no preferences. This result, with many people having a preference but being unwilling to spend even 10 SFR to support their preference, suggests that the survey was treated seriously by the participants and that the instructions were generally well followed. But, it also might suggest that tourists might move to other regions providing the same attractions if visual quality degrades.

Clear (negative) preferences were expressed for changes related to the development of ski areas (pairs 1 and 4) and to the development of large urban areas (pairs 3 and 6),

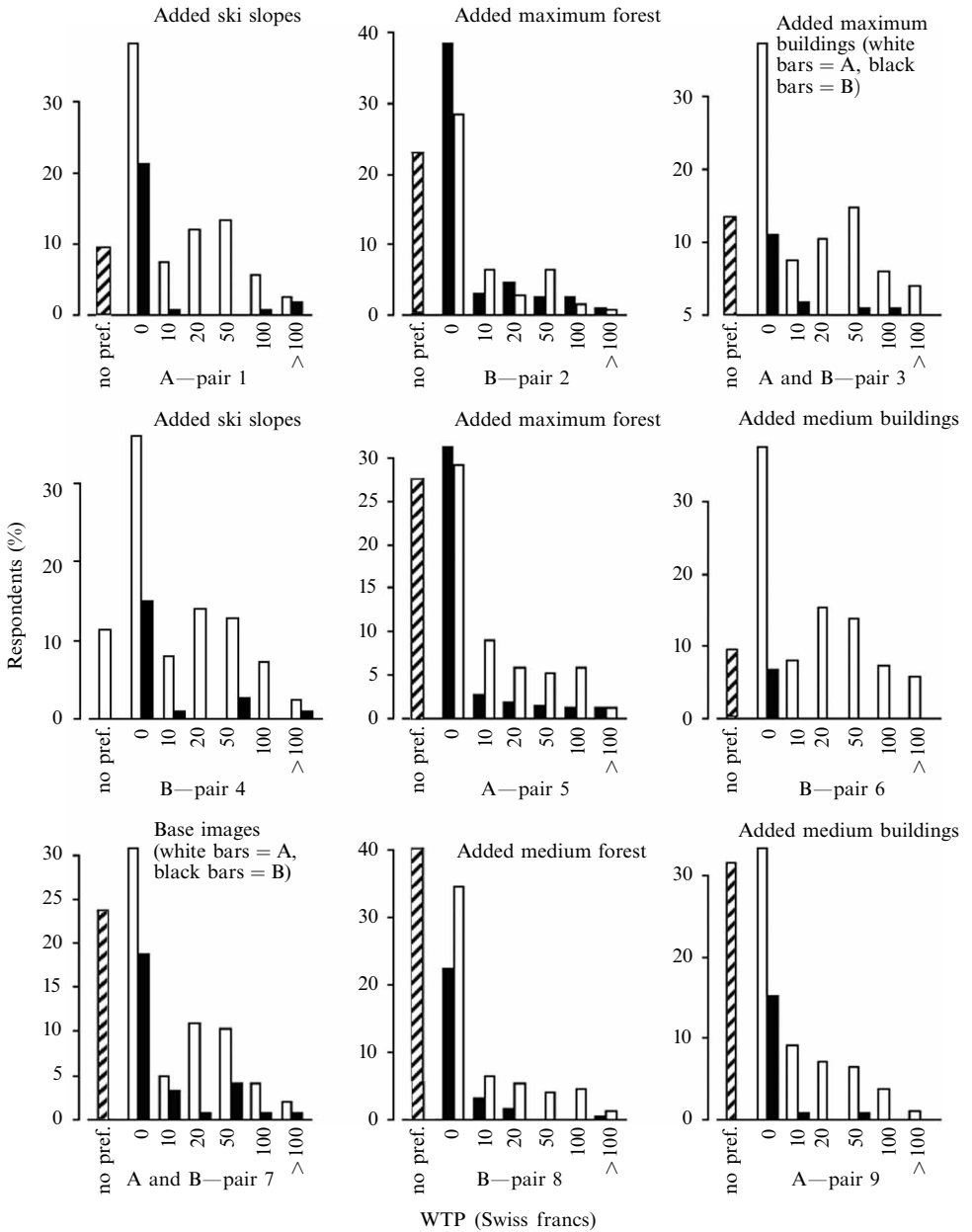


Figure 6. Distributions of willingness-to-pay (WTP) responses. The white bars represent the WTP responses for the base images (except for pairs 3 and 7), the black bars represent the WTP responses for the modified images (except for pairs 3 and 7), and the striped bars represent the number of respondents who had no preference for either image.

but there was a large difference in WTP for these changes. In contrast, respondents did not have strong preferences for changes in forest cover and small changes in urban development. The distributions show that the range of available WTP values are appropriate, but a finer scale between 0 SFR and 50 SFR would probably lead to a more complete picture of the WTP. This behaviour was not observed in the pilot survey, which could have helped adjust the bid level before the main survey was conducted.

In addition, the data are skewed towards low WTP values owing to the uneven interval levels of WTP choices given to the respondents (figure 6).

The mean WTP responses for each photograph and the results of the paired two-tailed Wilcoxon signed-rank test are presented in table 2. The means between the pictures in a pair were significantly different at the 0.1% level for the addition of ski and urban areas. The largest WTP was recorded *against* developments of ski areas (22 SFR) and against developments of large urban areas (26 SFR). These results can be compared to the findings from other studies, in which tourists prefer conservation of landscape to urban and tourism development (Hunziker, 2000; Sell and Zube, 1986). However, Zube et al (1989) found that locals had preferences for infrastructure development. They explained this difference by the fact that people's preferences for development depend on individual interests for projects. This explanation seems valid in this investigation, as the majority of respondents were tourists with a probable low personal interest in local development projects.

In contrast, the respondents did not express a clear preference for an increase in forested area (table 2). Other studies have shown that people like some forest expansion, but that large forested areas have a negative influence on their preferences (Hunziker, 2000; Tahvanainen et al, 1996). A similar trend can be observed in the distribution plots (figure 6), but the results are not significant. This might come from the small size of forest modifications made to the original pictures or the already large forest areas present in the original photographs. Tahvanainen et al (1996) also observed that when the differences between alternatives were slight, inconsistencies in evaluation were easily generated. However, even under an extreme climate change, a higher timberline in these regions in the next fifty years is not expected owing to other growth-limiting factors at these altitudes (Guisan et al, 1998; Körner, 1998). A different manipulation of the photographs—corresponding to other causes of an increase in forest density, such as naturally occurring forest disturbances—might have larger effects on the WTP responses. The scenarios used in this study were only selected to illustrate potential major landscape changes in the region.

Table 2. Average willingness-to-pay (WTP) responses for each photograph and paired two-tailed Wilcoxon signed-rank test.

Photograph modification	Pair	Original photograph	Two-tailed Wilcoxon signed-rank test					
			Z^a	p -value	Mean WTP for original photograph ^b	N	Mean WTP for modified photograph ^b	N
Added ski slopes	1	A	9.5	0.000***	20.0	210	1.3	30
Added maximum forest	2	B	1.9	0.060*	8.2	139	4.5	65
Added ski slopes	4	B	9.7	0.000***	21.9	213	1.1	23
Added maximum forest	5	A	-2.7	0.007**	5.1	88	9.5	10
Added maximum buildings	6	B	11.1	0.000***	26.2	233	0.0	8
Added medium forest	8	B	-2.9	0.004**	1.6	73	9.2	86
Added medium buildings	9	A	8.1	0.000***	15.3	163	0.3	19

* $\alpha = 0.1$ level; ** $\alpha = 0.01$ level; *** $\alpha = 0.001$ level.

^a Standard normal value for the paired Wilcoxon's two-tailed signed-rank test.

^b Values in Swiss francs (SFR).

Visual magnitude analysis

In order to test how well the VM estimates represented the proportions of the different land-cover areas that made up the view, we ran a linear least-square regression between the areas in the photographs and their corresponding VMs, estimated from the areas in the georeferenced photographs (figure 7). The good fit between the total VM and the corresponding areas in the photographs (multiple R^2 of 0.81 for the VM estimations using the height of the standing objects) confirms that the VMs calculated using the GIS data reflect closely the visible land-cover areas within the view.

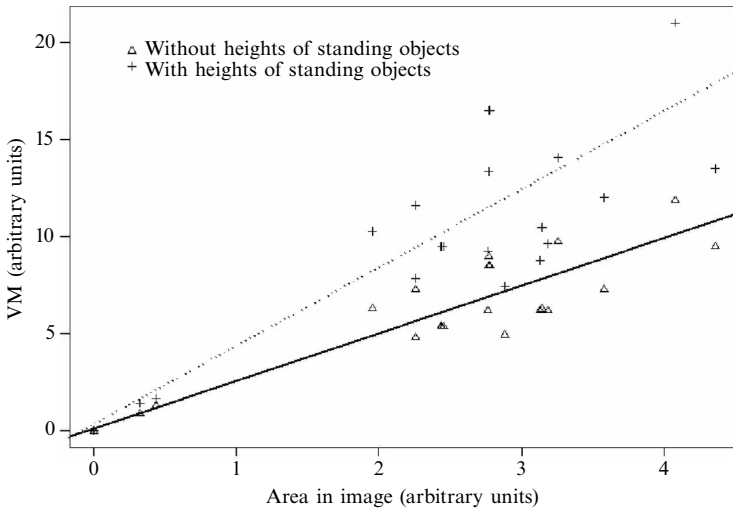


Figure 7. Relationship between visual magnitudes (VM) and areas in photograph.

In figure 7 we show the effect of the height on VMs: the larger the areas in the photographs, the larger the effect of height on the VMs. As the distance has the largest effect on VM [see equation (3)], the increase in height effect, linked to an increase in VM, is caused by the distance: the closer an object to the viewer, the bigger its VM, and the more significant the effect of height. However, as we used a 25 m raster and attributed a unique height of the standing object to each cell, we did not account for irregularities in feature tops, such as different sizes of trees or shapes of roof tops. It could be interesting, however, to repeat this experiment with a smaller raster dataset to study the effect of the inclusion of the varying height of different standing objects close to each other on VM estimates.

Relationship between GIS-based variables and scenic assessment

If visual values can be predicted using the GIS-derived data and the computational capabilities of a GIS, the highly objective and replicable VM measurements could be used directly to compare the impacts of different development strategies in the same region. In order to test if the GIS-based variables could be used to predict WTP responses, we ran two least-square regression analyses between VM and WTP responses. The input values for the regression are shown in table 3. In table 4 we show the results of the regressions with only the two significant variables, ski and urban areas. The percentage changes in VM of forested areas did not contribute significantly to changes in WTP responses. The best regression form between all the WTP responses and ski and urban areas was a half-logarithmic function in the dependent variable against the predictor variables. The coefficients are presented in table 4(a). Percentage changes in VM of the urban and ski areas explain 15% of the variation in the WTP responses.

Table 3. Average willingness to pay (WTP) for each pair of photographs and percentage change in the visual magnitude (VM) of the land-cover areas between the original photographs and the modified photographs (% modified – % original).

Pair	Mean WTP ^a	STD ^b WTP ^a	N	Change (%) in total VM of forest areas	Change (%) in total VM of ski areas	Change (%) in total VM of urban areas
1	18.3	34.4	240	8.6	–5.7	0.0
2	–3.7	29.4	204	7.9	0.0	0.1
4	20.3	34.7	236	4.0	–5.3	–0.3
5	4.9	33.3	193	14.6	0.0	–0.6
6	25.6	35.5	241	12.1	0.0	–13.9
8	6.9	28.0	159	7.2	0.0	0.0
9	15.4	29.0	182	3.9	0.0	–3.4

^a Values in Swiss francs (SFR).

^b Standard deviation.

Table 4. Coefficients of (a) the logarithmic regression, and (b) the linear regression, willingness-to-pay responses against changes in visual magnitude of the different land-cover areas considered in the study.

	Value	Standard error	Pr(> t)
(a) Intercept	0.73	0.025	0.00
Ski area	–0.14	0.007	0.00
Urban area	–0.05	0.007	0.00
Multiple $R^2 = 0.15$			
$F_{2,1452} = 34; p = 0.00$			
(b) Intercept	3.88	2.73	0.22
Ski area	–2.75	0.81	0.03
Urban area	–1.67	0.42	0.02
Multiple $R^2 = 0.83$			
$F_{2,4} = 10; p = 0.03$			

Ordinary least-square methods of contingent valuation data often have a low explanation content (OECD, 1989) and similar magnitudes have been found in other contingent valuation studies (Jung, 1996; Nielsen, 1992; Roschewitz, 1999). Mitchell and Carson (1981, pages 5–29) point out that ‘the reliability of a contingent valuation study which fails to show an R -squared of at least 0.15, using only a few key variables, is open to question. Thus, an adjusted R^2 of 0.15, shows that the expressed WTP responses are not random, but are in a systematic relationship with the predictor variable. However, it points at the noise in the WTP responses, which suggests a large heterogeneity among the respondents (Palmer and Hoffman, 2001).

In order to test if the height factor had an impact on scenic assessment, the same regression analysis was run between the VMs of urban and ski areas and the logarithm of all the WTP responses, but this time without considering the height factor in the VM calculations. The analysis provided an R^2 of 0.14 ($F_{2,1452} = 34, p = 0$). The height of the standing objects thus has a small impact on the visibility analysis. This may be because the standing objects were not close to the camera in most of the images and their effect on the VMs was therefore small.

The second regression was based on average WTP responses and the predictor variables urban and ski areas. Percentage changes in VMs of the urban and ski areas

Table 5. Average willingness to pay (WTP) for the photograph pairs 3 and 7 and percentage difference in the visual magnitude (VM) of the land-cover areas between photographs A and B (% in B – % in A).

Pair	Mean WTP ^a (<i>N</i> = 265)	STD ^b WTP ^a	<i>N</i>	Difference (%) in total VM of forest areas	Difference (%) in total VM of ski areas	Difference (%) in total VM of urban areas
3	–22.3	35.5	230	–11.2	0.00	19.5
7	–15.0	34.3	203	–1.5	0.00	14.7

^a Values in Swiss francs (SFR).

^b Standard deviation.

explain 83% of the variation in the average WTP responses. This result compares well with the study of Bishop et al (2004), who found a multiple R^2 of 0.86. The intercept of 3.9 SFR can be explained by the fact that the respondents were only given the choice of 0, 10, 20, 50, 100, and more than 100 SFR to express their WTP for a given photograph. The smallest amount they could pay was therefore 10 SFR, which probably leads to an overestimation of WTP for very small changes in land-cover areas.

The applicability of the prediction equation to another view in the same region was tested on the basis of pair 3 and pair 7 (table 5). Pair 7 compared the two original photographs A and B; pair 3 compared the two original photographs with the addition of the same amount of buildings on the map. Mean expressed WTP responses for these two pairs and associated land-cover changes between the photographs are presented in table 5. People preferred the original photograph A over the original photograph B by 15 SFR, and preferred photograph A with added buildings over photograph B with added buildings by 22 SFR. Thus the addition of buildings increased the mean WTP response (for view A) by 7 SFR. By implementing the percentage area changes in ski slopes and urban areas between photographs A and B into the regression equation, through the use of the coefficients presented in table 4(b), we obtained a mean WTP response of 20 SFR for pair 3 and of 28 SFR for pair 7. The difference between the estimated WTP responses was 8 SFR, which is close to the 7 SFR difference in WTP responses expressed by the respondents between the two pairs of photographs. This suggests that the approach might be used to estimate preferences for land-cover changes for other views in the area, with the differences between the original photographs known. However, as the regression line is only based on a single view and on the results of a Web-based survey, a further round of image taking and public assessment are required to strengthen this result. Furthermore, the difference in the predicted view values and the values expressed by the respondents between the base photographs A and B show that other, unmeasured, visual differences between the pictures might have an effect on WTP responses.

Conclusions

In this study we show that a 3D GIS model can support prediction of scenic-beauty preferences. Furthermore, the inclusion of the height of standing objects in the calculations of visibility measures is important, as omitting height may lead to incorrect conclusions regarding the relationship between scenic preferences and the land-cover variables. However, before drawing any final conclusions, the advantages and disadvantages of the approach and its limitations will be summarized.

(1) The method was solely based on the VM of three types of land-use changes: a raising of the treeline on the mountain, new ski runs, and urban expansion. Results suggest that urban growth and the addition of ski slopes negatively impact

scenic-beauty preferences. The validity of the presented instrument is, however, restricted to similar cases, and more work needs to be done to test the validity of the method on other land-use types, with the use of more explanatory variables.

(2) In the study we apply the regression between average WTP responses and land-cover changes to predict WTP responses for another similar view in the Landschaft Davos on the basis of VMs of the land-cover changes. The predicted results correspond closely to the responses given during the Web-survey. However, the method has been tested on only one other view in the region. More research has to be conducted to determine if the same method can be applied to other views in the regions and to other alpine regions as well.

(3) The model is based on a 25 m × 25 m raster dataset. This makes it difficult to deal with isolated structures, such as a few trees or a small building on a cell. However, the study shows that the inclusion of height in the VM calculations provides a better estimation of the proportion of the different land-cover areas and their features that make up the view. Thus, the smaller the raster dataset, the better the estimation of the contribution of the different land-cover areas and their associated features to the view values.

Considering the limitations described above, we can draw some conclusions: the initial success of the significant relationship between VMs and WTP responses suggests that a GIS-based approach to predict scenic-beauty preferences is viable. As plans are nowadays often made on digitized maps, this approach might be most appropriate for assessing preferences for certain landscape changes in a specific region. It might facilitate land-use management and planning by enabling planners and designers to assess the consequences of potential actions on visual resources. Furthermore, the study shows that the height of standing objects, such as trees and buildings, should be included in the GIS model as they contribute significantly to the view values. However, the prototypical approach presented here needs to be further tested if it is to be applied in the practice of landscape planning.

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