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Use of computer graphics for predicting the amenity of forest trails

Ismo Nousiainen & Timo Pukkala

TIIVISTELMÄ: TIETOKONEGRAFIIKAN KÄYTTÖKELPOISUUS METSÄPOLKUJEN ULKOILU- JA MAISEMAOMINAISUUKSIEN ENNUSTAMISESSA

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Ten trails, one kilometre each, were evaluated by 15 persons for scenic beauty, recreational value and variety. All trails passed through commercially managed forests dominated by conifers. The trails were first evaluated by viewing computer simulations based on a series of graphical illustrations of forest landscapes, then from a slide show, and finally in the field. In the computer simulation and slide show, landscape pictures along the trail at an interval of 35–40 m were presented for 3–4 seconds. The ranks between slide show and field were slightly more similar than those between simulation and field. The mean correlation of 12 persons between the field ranking and assessment of either computer simulations or slide shows varied from 0.506 to 0.680. Variety was easier to evaluate from slides or graphics than scenic beauty or recreational value. Spearman's rank correlations computed from median scores of a group of 12 peers were clearly better than the average of individual persons varying from 0.6 to 0.9.

Koehenkilöt arvioivat kymmenen yhden kilometrin pituisen ulkoilureitin maisemallista kauneutta, ulkoiluarvoa ja vaihtelevuutta. Ulkoilureitit sijaitsivat havupuuvaltaisissa talousmetsissä. Reitit arvioitiin ensin tietokonegrafiikalla tuotettujen piirrosten avulla, sitten diakuvista ja lopuksi maastossa. Tietokone- ja diaesityksissä koehenkilöille näytettiin näkymiä polulta 35–40 m:n välein, kutakin näkymää 3–4 s. Dioista arvioitu polkujen paremmuusjärjestys oli hiukan lähempänä maastoarvioiden järjestystä kuin tietokonegrafiikasta arvioitu paremmuusjärjestys. Kahdentoista henkilön keskimääräinen dioista tai tietokonegrafiikasta tehdyn arvion järjestyskorrelaatio maastoarvion kanssa vaihteli välillä 0,506–0,680. Vaihtelevuus kyettiin arvioimaan grafiikasta paremmin kuin maisemallinen kauneus ja ulkoiluarvo. Koehenkilöiden poluille antamien pisteiden mediaanista lasketut järjestyskorrelaatiot olivat selvästi parempia (0,6–0,9) kuin yksittäisten henkilöiden korrelaatiot.

Keywords: amenity value of forests, landscape, simulation, management, planning.
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Correspondence: *Timo Pukkala*, University of Joensuu, Faculty of Forestry, P.O. Box 111, 80101 Joensuu, Finland.

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1 Introduction

The main product of Finnish forests has traditionally been timber and other woody products. Because of this, forests have been managed for wood production only. Management planning systems are designed to produce plans that maximize the timber yield in a sustainable manner (Siitonen 1983).

This traditional picture is now changing rapidly: for many forest owners, wood production is not the most important objective of forest management. The most important objective may be recreation and other related uses (Järveläinen 1988). Recreation in the forest is very common and highly valued by both forest owners and non-owners. It seems that most forests near urban areas produce more benefits to the nation through recreation than through timber production (Pouta 1991).

In this situation it is necessary to integrate amenity values in management planning tools. To accomplish this, a crucial step is to develop methods to value non-monetary products. Because non-monetary products, like scenic beauty and recreational value, are difficult to predict and express numerically, several new methods use computer graphics to show to the decision maker the present and future states of the forest (e.g. Pukkala 1993). These graphical illustrations, with numerical information, are used to evaluate different management alternatives.

There are already several studies about the use of computer graphics for the evaluation of far-view amenity (Myklestad and Wagar 1976, Angelo 1979, Pukkala and Kellomäki 1987, Pukkala 1988, Kellomäki and Pukkala 1989), and some examples of using computer graphics to assess within-stand amenity (Pukkala et al. 1988). Some of the studies indicate that computer graphics can help to evaluate the impacts of forest treatment on far-view landscape and within-stand amenity.

The most important amenity parameter of Finnish forests is not far-view scenic beauty, and not the amenity of individual stands either. Rather, the whole experiential sequence of a person travelling through a forest consisting of many stands should be predicted. People usually walk along footpaths in the forest. Therefore, assessment of the amenity of a trail, track or footpath provides a fairly good estimate for the amenity of the whole surrounding forest as well.

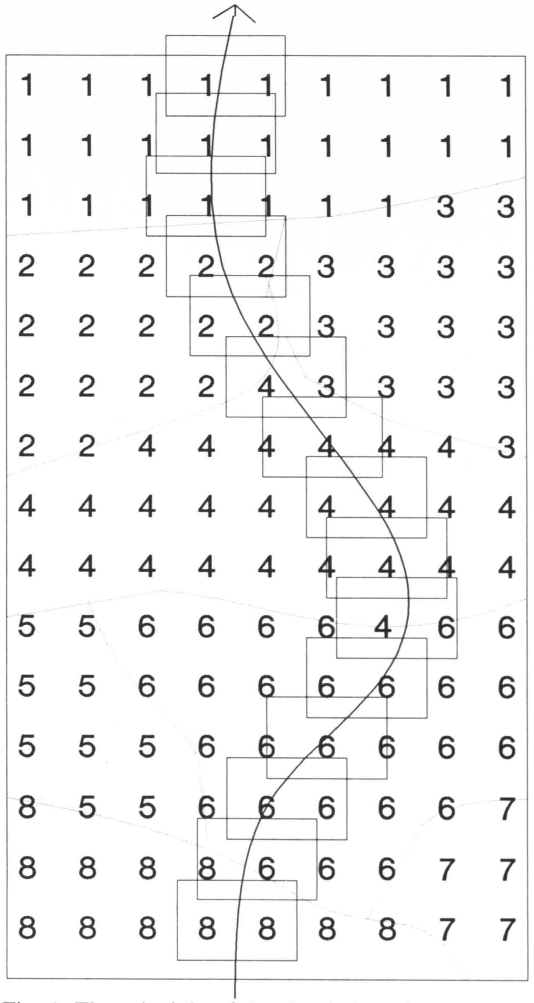

Fig. 1. The principle of the simulation of movement along a trail. Dotted lines are compartment boundaries. Numbers 1 to 8 represent points of the Digital Elevation Model (DEM) indicating the compartment number of the point. The square is a moving subarea that is drawn on the computer screen for 3 to 4 seconds. Different tree symbols are drawn around each point of the DEM corresponding to the species composition, tree size and stand density of the compartment.

There are at least three ways to evaluate the amenity of a trail. The first possibility is to walk along the trail in the forest. Another method is to take photographs along the trail at regular intervals, and assess the amenity through them. This technique, in a form of a slide show, has been used for individual stands e.g. by Daniel and Boster (1976), Benson (1979), and Schroeder and Daniel (1980, 1981). The third possibility is to use computer graphics and simulate the movement through forest on the computer screen (Fig. 1).

Field visits and slide shows can be used to evaluate a particular existing trail, or compare different locations of a prospective recreation route. The benefit of a slide show compared to the field visit is that only one person needs to visit all the places (Craik and Feimer 1979). However, both methods are insufficient for forest management planning because for planning we are interested in the future states of the forest. Since computer simulation and computer graphics can present future and imaginary situations, they may greatly help forest manager to evaluate the long-term impacts of different management alternatives on the recreational properties of a forest. Presently, this evaluation must be done on the basis of forest maps and numerical information describing timber production.

Before using computer graphics techniques, it is necessary to know how well such computer-based evaluations can predict the recreational properties of a forest area. This study tested the usability of computer graphics by comparing it to slide and field evaluations. The usability of a presentation media was evaluated based on the rank correlation with field assessments. Because rank correlation depends on the variation among trails it is not alone sufficient for judging an evaluation method. Because slides are a familiar tool for amenity evaluation, comparison of graphics with slides gives a general idea about the usability of computer graphics for amenity evaluation.

2 Material and methods

Trails

Ten trails, one kilometre each, passing through normally managed forests in North Karelia, Finland (64°N, 31°E), were selected for the study. The trails made an almost continuous route. The dominant tree species in the study area was Scots pine (*Pinus sylvestris*). There were a few pure Norway spruce (*Picea abies*) and birch (*Betula* spp.) stands, and mixtures of these species, the most common mixture being pine with spruce.

The area included stands of different age classes: from recently planted areas to mature stands. A trail usually crossed three to ten compartments with more or less distinct boundaries and clearly different stand characteristics. One trail passed through a newly clearcut area where the soil was cultivated for plantation. The terrain varied from quite even to slightly undulating land. The area contained many small lakes, but they were not easily visible from the trails. Thus, the main factors affecting the amenity of the trails were the terrain and the properties of forest compartments.

Differences among the study trails reflect the normal variation among adjoining areas in Finnish forest; the amenity variation among trails was quite small (Table 1).

Slides

Slides were taken in July along each trail at 40-m intervals using a 35 mm wide angle lens, and a film with the sensitivity of 50 ASA. No effort was made to avoid obscuring vegetation before the camera. All slides were taken towards the walking direction. The camera was mounted on a tripod that helped to take the shots horizontally at the height of observer's eye with the trail in the centre of the photograph. The number of slides per trail was about 25. When taking slides, the weather varied from clear to an almost overcast sky. In poorly illuminated spots, several slides were taken, and the best one was used in the evaluation.

Computer graphics

For creating computer graphics the stands along the trails were divided into reasonably homoge-

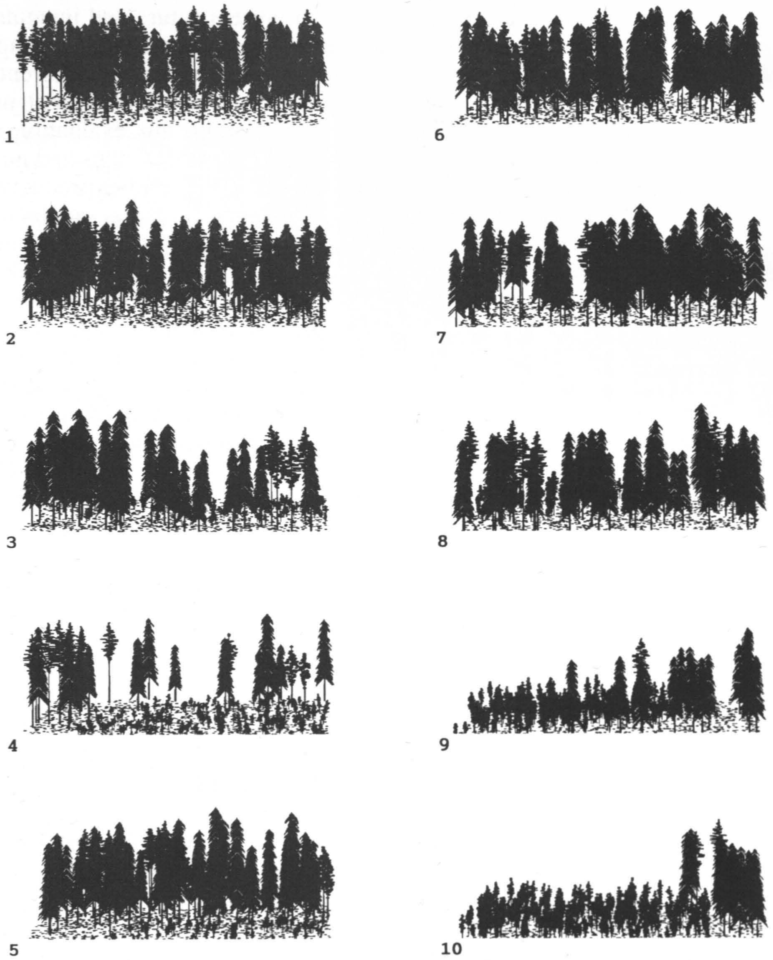

Fig. 2. Printouts of successive views in one of the study routes. In the evaluations, the graphics were presented on a 19" colour monitor.

nous stand compartments, the boundaries of which were drawn on a map. All stands that were near the trail were demarcated. The stand characteristics of each compartment were surveyed by ocular standwise inventory, using a relascope to measure stand basal area, hypsometer to measure tree height, and calipers to measure tree diameter. In each compartment, the following parameters were recorded separately for each tree species and canopy layer: stand basal area, or in young stands, number of trees/ha; mean age of trees; mean height of trees; minimum, mean and maximum of the diameter distribution.

The field data were used to create for each compartment, a theoretical tree population consisting of five trees per species in each canopy layer. As a first step, the diameter distribution of a species was predicted from the field measurements, using the beta function as a theoretical distribution (e.g. Päivinen 1981). In the second step, the distribution was divided into five diameter classes of equal width, and the number of trees per hectare in each class was computed. The heights of the trees were predicted with a height model that was calibrated using the mean diameter and height as measured in the field. Every theoretical tree was described by species, diameter, height, and number of trees per hectare.

Compartment boundaries were digitized using a map program (Pekkonen 1991). The contour lines were also digitized to create a Digital Elevation Model. The map data and the map program were utilized to create a data file that contained the x, y and z coordinate, and the compartment number of each point of a systematic lattice. The interval between the lattice points was 8 m in x and y directions.

The graphical illustrations of stands were created by drawing three symbols around each lattice point (Fig. 2). The probability to draw a particular symbol was proportional to the frequency of the diameter class and tree species. If the stand was dense enough (in this study: 3000 trees/ha), all lattice points were occupied. With lower stand densities some of the points remained empty. Short horizontal lines showing the ground location were drawn around all points. Different tree species were drawn with different colours or shades of a colour. The colour of foliage was different from the bark colour. The bark colour of pine and birch depended on tree size.

The principle of simulating movement through forest was to draw on the screen a small subarea at a time, and rapidly change this area (Figs. 1 and 2). In this study, the depth of the subarea was 10 lattice points (80 m) and the width 6 lattice points (48 m). Points along the trail were stored in a data file, the distance between two successive points being 35–40 m. Therefore, successive subareas overlapped by 25 to 30 m giving an impression of continuity and movement.

3 Evaluations

The ten trails were assessed by 15 persons for scenic beauty, recreational value and variety. All these variables correlate with the amenity of the forest and with each other (e.g. Gustke and Hodgson 1980, Pukkala et al. 1988). In Finnish language they have a clearer meaning than amenity. Variety also measures amenity because discontinuities in a trail increase pleasure (Gustke and Hodgson 1980). When evaluating recreational value, the people were advised to think of the suitability of this forest and trail for their way of recreating.

Seven of the test persons were foresters while the others (8 persons), having a variable background, were all interested in outdoor recreation. About 50 % of the persons were familiar with the area represented by the trails.

The trails were first evaluated from computer graphics, then from slides, and finally in the field. The order was from the method with the least visual information to the one with the most. This order prevented the persons from recognizing the trails, as seen in the field, from graphics or from slides, also from recognizing a particular slide show from computer graphics. Slides and computer graphics were evaluated in one day, and the field assessments were done 1 or 2 days later.

The test individuals were instructed to imagine the forest in nature, and evaluate that forest rather than the quality of slides or graphics. A few graphical illustrations outside the study area, with slides of the corresponding spots, were shown to the people being tested before the presentation of graphics. The purpose was to make these people more familiar with graphical illustrations, because when computer graphics are used in practical planning the users will certainly have previous experience with it.

The order of trails was different with different methods, and random in the computer simulation and slide show. The test persons could seldom connect a given slide show to a particular computer simulation, or a given field evaluation to a particular computer simulation or slide show. Therefore, the three assessments were almost independent of each other.

When a trail was completed, its scenic beauty, recreational value and variety were evaluated using a scale from 0 (very poor) to 10 (very good). This scale has been used earlier e.g. by Daniel and Boster (1976), Benson (1979), Schroeder and Daniel (1980), Benson and Ullrich (1981), and Pukkala et al. (1988). For computer simulations and slide shows the persons were divided into three groups, and for the field evaluations into two groups. In the computer simulation and slide show, each subarea was shown for 3–4 seconds. This time was found sufficient by testing the presentation methods before the study. There was a break of one to two minutes between each trail. In the field, there was a short break after each trail, and a longer rest of 40 minutes after the sixth trail.

The similarity of computer or slide assessments with the field evaluations were studied using the Spearman's rank correlation. The trail scores by each person were ordered into ascending order, and a correlation coefficient was computed for the similarity of ranks based on computer simulations and field assessments, and another coefficient for the ranks based on slide shows and field visit.

Another analysis was carried out by assuming that a group of peers evaluates the trails. In this analysis, a median score of 12 persons was first computed for each trail, and the rank correlation was computed from the medians.

4 Results

The scores indicated that the ten trails were quite similar with respect of scenic beauty, recreational value and variety (Table 1). This was to be expected, because no attempt was made to have much variation among trails. The scores of field and graphics evaluations were very near each other. In terms of differences in the mean and median scores, graphics gave clearly better results than the slide assessments.

The rank correlations of individual persons were mostly between 0.5 and 0.7. Most correlations were significant at 5-% risk level and a few at 1-% risk level. There were three persons for which all the correlations were very poor. It might be that these persons had no clear opinions what is a beautiful, good or variable forest. Another possibility is that they could not well enough imagine the forest from slides and computer graphics. It is also possible that for these persons the trails really were almost equally good, and this explains the low correlation, although the evaluations may be nearly correct. Because of these reasons, these three persons were excluded from the analysis. If the reason for poor correlation is an insufficient ability to interpret graphics or slides, it is not likely that these persons will be utilized in real situations.

The mean correlation coefficients were slightly better for slides than for computer simulations, but the differences were small (Table 2). The median coefficient for scenic beauty ranks is better for computer than slide evaluations. In all other instances slide ranks correlated better than computer ranks with the field ranks.

Table 1. Median, 20-% quartile deviation, and range of variation of the mean scores of 12 persons for 10 trails. The scale in evaluation was from 0 (very poor) to 10 (very good).

Method of evaluation	Median	Quartile deviation	Minimum	Maximum
		Scenic beauty		
Graphics	6.0	0.7	3.8	7.6
Slide show	5.5	1.4	2.5	7.8
Field visit	6.1	0.8	2.6	6.7
		Recreational value		
Graphics	6.7	0.6	3.7	7.4
Slide show	5.8	0.8	3.8	8.1
Field visit	6.6	0.6	3.3	7.1
		Variety		
Graphics	5.4	0.7	3.5	6.9
Slide show	4.7	1.3	3.1	7.3
Field visit	5.1	1.1	3.0	7.1

Table 2. Statistics of rank correlations for 12 persons. The correlation describes the similarity of field ranks with evaluations based on slide shows or computer graphics. The critical value of the correlation coefficient is 0.564 at 5-% risk level, and 0.746 at 1-% risk level.

Method of evaluation	Mean	Median	Minimum	Maximum
		Scenic beauty		
Graphics	0.616	0.702	0.010	0.835
Slide show	0.634	0.649	0.327	0.888
		Recreational value		
Graphics	0.506	0.615	0.012	0.781
Slide show	0.659	0.713	0.387	0.788
		Variety		
Graphics	0.654	0.665	0.364	0.875
Slide show	0.680	0.693	0.409	0.917

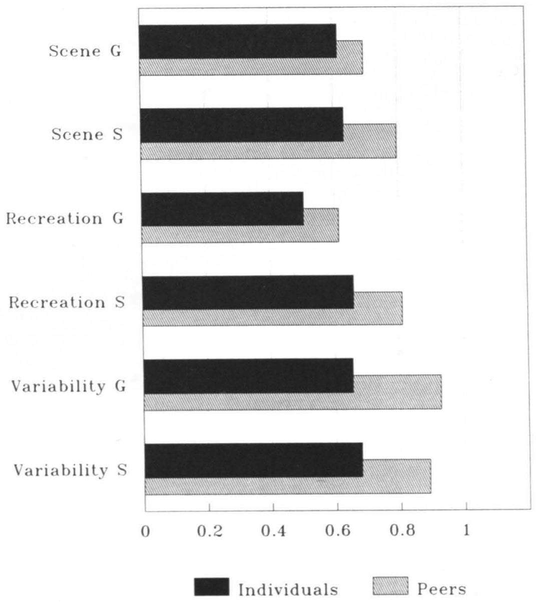

Fig. 3. Rank correlations computed for a group of peers (12 members) compared to the mean correlations of individual members. G = graphics, S = slides.

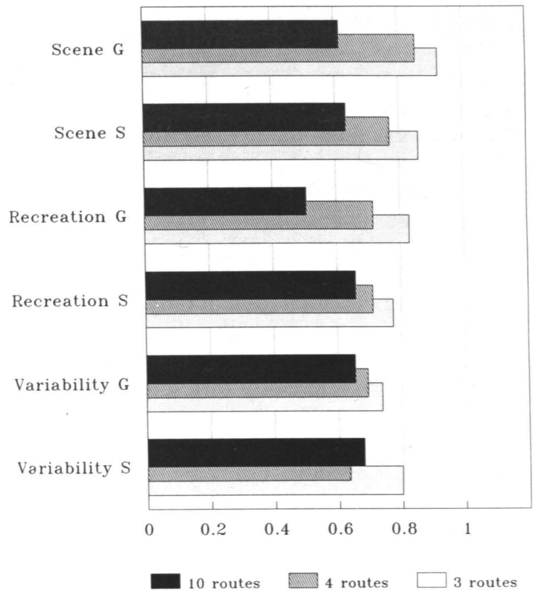

Fig. 4. Mean rank correlations of 12 persons computed for four or three clearly different routes compared to the mean correlations of all 10 routes. G = graphics, S = slides.

With both methods, correlations were the best for variety and with the slide method poorest for scenic beauty. With the computer graphics the correlations were poorest for recreational value. It seems that recreational value is difficult to evaluate from computer graphics, presumably because low bushes, dwarf shrubs and obstacles on the ground were omitted from the illustrations although they greatly affect the recreational value (Hultman 1983).

Rank correlations computed from the median scores of several persons were clearly better than the mean correlations of individual persons (Fig. 3). A group of people could assess different trails from slides and computer simulations more reliably than individuals. For variety, the correlation coefficient was about 0.9 which means that ranks based on graphics or slides were nearly the same as in the field. The results that slides are slightly better than graphics also applied to a group of peers.

The correlation coefficients are valid in this study material only, and they should improve with more variation among the routes. This assumption was tested by computing the rank correlations for four and three trails that were more clearly different with respect of scenic beauty, recreational value and variety. The analysis of three trails included the best and the poorest trail, and one trail of medium quality. In the analysis of four trails, two medium trails were included.

With only one exception, rank correlations of four trails were better than those of ten trails (Fig. 4). Correlations of three clearly different trails were always better than those of the group of ten or the group of four trails. This result indicates that both slides and graphics can depict clear differences of amenity properties of forest trails.

5 Discussion

The two ways other than field visit, to rank forest trails according to some amenity properties were almost equally good, slides being only slightly better than computer graphics. The correlation of slide or graphics ranks with field ranks was typically about 0.65. This corresponds to a degree of determination of only 42 %. There are two reasons for the rather low correlation. The first is that slides and graphics are insufficient in depicting amenity differences of trails. The second reason is errors and inconsistencies in the evaluations. It is very difficult to rank ten alternatives, especially if they are nearly equally good and the ranking is based on several criteria. For example, Kangas (1992) found that with two repeated evaluations of ten forest regeneration alternatives with the same presentation method, the mean rank correlation of individual forest owners was 0.66 only.

In this study, too, the low correlations may be partly explained by errors in the evaluations. In several instances a trail contained beautiful stands with less-attractive monotonous tree plantations in-between. This makes the evaluation difficult and inconsistent. Because the evaluations were not important to the test persons, their concentration may not have always been sufficient.

If the same persons should rank the trails again in the field, it is not likely that the order will be the same as in the present study. Rank correlations between two independent field evaluations would most probably be clearly below one, and possibly not very much better than correlations of the field ranks with slide or graphics evaluations. Unfortunately it was not possible to test this hypothesis, because the test persons would have remembered their first field scores during the second visit.

The result that correlations were better for a group of peers than for individuals indicates that the ranks by individuals with different background resemble each other. The same result has been found earlier e.g. by Pukkala et al. (1988) and Kangas et al. (1993). The method is more robust for a group of peers because the use of median and mean scores greatly decreases the effect of inconsistencies and errors in the evaluations. The method of independent peers also decreases the effect of exceptional opinions.

Three persons were omitted when comparing the mean rank correlations. If these persons had been included the mean rank correlations had decreased from 0.65 to about 0.55, but the main result that slides are slightly better than computer graphics had remained unchanged.

The shortcoming of slides is that branches, stems and other objects near the camera can cover too much of the view. In the field a person looks to many directions, which gives her or him a much better conception about the forest than a single slide. With the computer simulation it is also possible to look at different directions, and it is possible to deviate from the trail and move freely in the forest. The distance of the viewpoint can also be adjusted, and several illustrations with the viewpoint at different distances may be drawn at the same time. This gives a spatial framework to the evaluation.

Taking into account the flexibility of computer graphics, it is perhaps a more promising method of amenity evaluation than the slides. As mentioned before, sides and field visits are not sufficient for forest management planning, which typically compares future states of the forest.

Despite flexibility, computer graphics can never depict all the elements of a real environment. For example, the system used in this study presented only trees, lakes, fields and the terrain. However, in a practical planning situation the planner and the decision maker are familiar with the area and have plenty of field experience. The role of computer simulation is only to visualize the effects of forestry operations and stand development.

Symbols for other objects than trees can be easily added to the computer graphics, and tree symbols can be improved, to make the graphics look more like a real forest. The landscape may be presented in summer, autumn and winter colours. Sounds, smells, temperatures, physical exertion and animals that also affect the experience of a recreationalist are of course more problematic and some of them are almost impossible to simulate by the computer. One drawback of computer simulation is that it does not show exceptional trees and features, although they may greatly affect the experience of a recreationalist.

Because of these limitations, computer simulation should not replace field evaluation if field planning is possible. This is the case e.g. when comparing alternative plans to set up a recreation trail in the present forest. Also here computer simulation may be useful if there is a need to look into the future.

The methodology to test the usability of computer graphics had some shortcomings that should be avoided in the coming investigations. First, it is advisable to repeat the field assessment twice to separate errors due to the evaluation method from those that arise from the inability of people to give consistent evaluations. Second, trails shorter than one kilometre with less within-trail variation should be used. Increasing the variation among trails improves results, but it is likely that in the practical use of a presentation method trails to be compared are quite similar.

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Review of manuscripts in 1992
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Kirjapaino Oma Ky, Jyväskylä