Forest Landscape Assessment for Cross Country Skiing in Declining Snow Conditions: the Case of Haanja Upland, Estonia

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Abstract

Snow cover is an important climatic characteristic as well as a significant recreational attraction of Estonian winter landscapes. In Estonia, over the last decade, the intensity of various forms of winter recreation has significantly increased. However, due to climate change the variability of snow cover is increasing year by year. Variations in snow cover are more significant in lowland areas while uplands retain more stable conditions. In order to identify suitable areas for developing cross-country ski-tracks likely to retain stable snow cover in what are also psychologically restorative natural environments, an integrated approach for landscape assessment has been developed. Micro- and meso-scale (1:10 000) studies of snow cover and climate in a highly diverse landscape were combined with an evaluation of the restorativeness of natural environments. Integrating snow cover investigations with questionnaire-based restorativeness analysis showed that forest edges have a higher value for both restorativeness and favourable snow conditions. Edge zones of forests provide inward and outward views, which were often considered more restorative by respondents. Thus, the routing of ski tracks towards the forest edge zone would tend to increase the restorativeness as well as giving a longer period of optimal skiing performance. Taking the micro-climatic conditions into account when planning the layout of cross-country ski-routes is likely to ensure the most efficient use of natural snow cover and higher quality ski tracks with lower maintenance costs. This also provides more opportunities for small-scale and family-run tourism enterprises, thus indirectly supporting the management of cultural landscapes for sustainable development.

Key words: GIS-based modelling, landscape assessment, forest landscape management, SRRS, psychological restoration, snow cover, winter recreation, cross-country skiing

Introduction

The last decade has witnessed tourism and recreation, including winter recreation and ski-tourism, becoming one of the fastest growing industries worldwide (Report… 2001). Likewise, the economic and social transitions with sustained economic growth have favoured the emergence of various forms of winter recreation in Estonia (Statistics Estonia 2004, 2007) of which cross country skiing is the major form. Snow cover is an important climatic characteristic as well as one of the significant recreational attractions of Estonian winter landscapes. For example, the Estonian Ski Association has been organising the FIS World Cup series in cross-country skiing at Otepää since 2001. However, due to climate change the variability of snow cover from year to year has been increasing, with some years having much higher than average and other years lower than average snowfall (Tooming and Kadaja 2006). Therefore, the extensive use of artificial snow has been needed to guarantee the quality of ski tracks during years of lower snow cover. According to Laternser and Schneebeli (2003) the mean snow depth, the duration of continuous snow cover and the number of snowfall days all showed a statistically significant decrease from the early 1980s towards the end of the 20th century throughout the temperate and sub-polar Northern Hemisphere. In Estonia the changes are more significant in lowland areas while the uplands have tended to retain more stable snow cover (Jaagus 1997).

There are several regions in Estonia, such as Otepää, Aegviidu, Alutaguse and Haanja, where ski-centres have traditionally been located. Cross-country ski tracks in these centres were originally laid out without extensive knowledge of or the need for maximising snow conditions. Neither has knowledge about recreational or tourist skiers' preferences for particular landscape elements as a recreational setting been fully considered in planning. Opportunistic planning of ski-centres based solely on land ownership and topographical features may not yield the highest effectiveness for the physical and psychological enjoyment of skiing as a recreational activity (Geneletti 2008). For managers it is an important goal to maximize benefits from the scarce available resources, ensuring durable ski tracks with low maintenance costs and high restorative qualities for the wider general public (Yu et al. 2009, Pouta et al. 2009). By meeting those goals it would be possible to attract even more people to use outdoor settings to relieve the stress of daily life.

This context sets new and particular challenges of landscape assessment for recreation. So far, little extensive research on this subject has been conducted. Kliskey (2000) has demonstrated an approach where needs for a specific type of recreation, including landscape aspects, have been combined to produce a suitability map for snowmobiling in the North Columbia Mountains of British Columbia. In his study, however, Kliskey was not able fully to take into account the aspects that determine the snow cover, using surrogate variables of exposure and elevation instead of a true snow cover model. Additionally, user preferences for visual aspects were based solely on the variable of openness. Nevertheless, a similar approach could be used to determine possible areas for cross-country skiing.

A number of studies have demonstrated possibilities to incorporate microclimatic conditions caused by land cover into recreation planning in situations of warm climates (e.g. Schiller and Karschon 1974, Schiller 2001). It can be inferred that the influence of land cover on microclimatic conditions and landscape perception should also be considered in landscape assessment for winter recreation (Mansfeld et al. 2007).

Much research has explored the use of scenic beauty estimation as a contributor to land use decision making (Daniel 2001, Silvennoinen et al. 2001, Franco et al. 2003, Arriaza et al. 2004). It can be hypothesized that different vegetation types or groups of visually similar vegetation types have an influence on landscape character and thus on the preferences of people for recreational environments (Cheng et al. 2005, Gül et al. 2006), potentially becoming an important factor for designing the routes for cross-country ski-tracks. Although visual preference plays an important part in the formation of landscape perception (i.e. restorative experience) (Parsons and Daniel 2002), it is not necessarily the only factor in such experience (Tahvanainen et al. 2001). Therefore study methods should use a more comprehensive model specifically designed to measure restorative effects rather than using a simplistic rating of views based on visual preference when trying to determine factors that influence outdoor recreation.

The concept of "restoration" and "restorative environments" has received a lot of attention in the literature (Han 2003, Hartig 1997, Ulrich 1983, Kaplan 1989 etc) and can be linked to the traditional benefits of recreation in natural areas such as "getting away from it all". Numerous studies have focused on the effects of environment (i.e. natural settings) on restorative experience by measuring reaction to views of different settings (Bjerke et al. 2006, Hartig and Staats 2006, Herzog, Maguire and Nebel 2003, Chang et al. 2008). The degree to which restoration is achieved through both carrying out a physical activity (which itself may in part provide an antidote to stress) and doing so in a natural environment has been explored to lesser extent. Nevertheless, Korpela et al. (2008) discuss that physical activity could be a possible determinant of restorative experiences. Some studies have been able to isolate the benefits of exercise in natural surroundings as opposed to indoor locations and shown higher restorative quality of natural environments (Hug et al. 2009).

The assessment of restoration potential methodology is reasonably well-developed. Different scales have been developed to rate landscapes (from photographs) in terms of their perceived restorativeness (Hartig et al. 1997, Han 2003) which provide possibilities to make sophisticated assessment of a landscape for recreation potential. One of the more recent approaches is to use a so-called "self reported restoration scale" (or SRRS) which has a broad perspective integrating both the Kaplan (1989) and Ulrich (1983) theories of restorative environments. While similar to Hartig's revised perceived restorativeness scale RPRS (Hartig et al. 1997), it also measures the restoration potential of a given environment but focuses on recovery from stress from a broader perspective: not only on the recovery from mental fatigue (Han 2003). It has a small number of items (two questions per each of the dimensions of restoration – emotional, physiological, cognitive and behavioural reactions) which makes its utilisation attractive from the practical point of view.

The preference for different landscape types has been studied by Ulrich (1986) and Parsons and Daniel (2002) who show that park-like or savannah-like structures produce the highest preference scores. Another notion of Ulrich (1986) is that people tend to prefer land cover types with a smooth surface, which favours movement across them. This would also suggest that bushes and scrub would be viewed unfavourably as it hinders walking or skiing through it. The presence of water features directly or indirectly has also traditionally resulted in high preferences (Ulrich 1986, Parsons and Daniel 2002), although in winter frozen snow-covered lakes are not necessarily readily identifiable as water.

When planning new ski tracks it should also be considered that the location of the person within a particular landscape influences the character of the view. Fry and Sarlöv-Herlin (1997) suggest designing paths near the edge of woodland areas which, besides having many ecological values, also contribute to aesthetically pleasing qualities and increase the recreation potential of woodlands. It may be hypothesized that in comparison to a homogeneous view within a forest, those stands can be more inviting when viewed inwards from visually open landscapes or produce attractive views when looking outwards from such stand-types into the visually open landscape. Additionally the prospect–refuge theory of Appleton (1975) suggests that views out to an open landscape from within vegetation where the viewer can feel hidden while being able to view surroundings, appear to produce a positive response. Thus ski tracks which pass through zones of denser vegetation while offering views towards open areas may suggest even greater attractiveness and offer additional physical comfort through sheltering against wind.

Recommendations on the design of recreational areas and routes suggest that variety in the experience is desirable (Kaplan et al. 1998, Bell 2008). Since skiers proceed at some speed through the landscape the rate of change of the scene – passing from within a forest stand into an open area, having views out followed by views back into the forest – is important. Studies of how moving views are experienced, suggest that a viewing duration of 3-5 seconds is needed for a person to take in a view before the scene changes again (Bell 2008). This means that the ski route should also be located to experience different vegetation types over time, passing through open areas with views of sufficient scale to enable the view to be enjoyed. This hypothesis is capable of being tested using the methods proposed here.

This study aims to provide an integrated approach for winter landscape assessment by combining micro- and meso-scale snow cover studies of hilly forest landscape with evaluation of its restorative quality in the context of cross-country skiing in Estonia. The research questions are linked: is it possible to construct a model for assessing and predicting likely snow conditions in order to optimise ski route layout? and is it possible to combine snow predictability with forested skiing landscapes which also provide the most psychological restoration potential? The study takes each of these aspects in turn and then combines them.

Material and methods

Study area

Trends of long-term snow cover time series and regional climate change scenarios show a significant decrease in snow cover duration (Jaagus 1997, Tooming and Kadaja 2006). There are four main regions in Estonia where, due to meso-climatic conditions, snow cover is more stable than elsewhere: Haanja, Alutaguse, Otepää and Aegviidu. In this study our investigations focus on the Haanja Upland which has the country's deepest and most long-lasting snow cover. The region extends to 816 km^2 in area (Arold 2005) and is the highest region in Estonia (the highest point, Suur Munamägi, at 317.6m above sea level, is also the highest point in the Baltic countries). The Haanja Upland is located in the south-east corner of the country (Figure 1).

The Haanja Upland region is a hilly/hummocky landscape with a variety of different sized moraine hills, glacio-lacustrine and glacio-fluvial kames, eskers and sandy plains (around the fringes of the upland). The upland area is intersected with deep (up to 200 m) primeval or sub-glacial valleys, mostly filled with glacio-fluvial gravels and sands. This geological structure makes the topography extremely complex: relative heights achieve 50–60 m difference and steepness of slopes can be 30–35°.

Climatically, the Haanja Upland produces an orographic effect on precipitation (up to 800 mm per year), which is about 10–20% higher than at the surrounding plains, deeper and longer snow cover (up to 4 weeks longer than on the plains) and significant microclimatic differences between the summits and slopes of hills and valleys/depressions.

This very diverse relief also determines the high degree of patchiness of soil distribution and vegetation cover. The vegetation cover of the present-day patchy cultural landscape consists of an intricate mosaic of forests, fields and settlement whose distribution reflects that of the dominant colluvial podzolic and pseudo-podzolic soils. Forests cover 62 % of the total area (Arold 2005). Since the study area is located at the southern limit of the boreo-nemoral forest zone, two deciduous tree genera (*Alnus* spp. and *Betula* spp.) and two coniferous species (*Picea abies* and *Pinus sylvestris*) are the major constituents in these woodlands. Arable fields cover 7% and grasslands 29% of the area. In the valleys and depressions there are over 1000 small peatlands (various mire, fen, transition bog and raised bog site types) and 170 small lakes, covering about 1% of the area. Only 1% of the entire Haanja Upland area can be classified as settlement (Arold 2005). However, typically for Estonian rural settlements, the farmsteads (about 500) are dispersed on the area. As a result, a highly natural appearance, landscape diversity and local cultural heritage make the Haanja region equally attractive for tourism in summer and winter.

Construction of the snow prediction model

Orography and land use data

Estonian Basic Map data at a scale of 1:20 000 was used to derive a digital elevation model, to calculate slopes and slope aspects and to identify snow accumulation areas in micro-scale depressions. The main height contours are defined at 5m intervals, supplementary contours being at 2.5 m intervals. In addition, the local maximum and minimum heights of landforms are provided as spot heights. Land use, especially the location of settlement, arable land, grasslands and abandoned lands were derived from CORINE land cover (1995) which was updated using the Estonian Basic Map. The composition of the forested areas was obtained from forest management maps (1:10 000 scale, updated in 2000) which divide the forest into stands with distinct age classes, species composition and growth conditions.

Snow cover and meteorological data

The aim of the snow cover analysis was to study the spatial and temporal meso- and microclimatic variability of snow depth and duration in the study area. Snow depth is highly variable within the boundary of the study area. This variability is caused by the upland itself: the shape, the height of the land above sea-level, its relative height from the foot of the hills, the degree of variability of relief and land cover. The following parameters: slope aspect and gradient, steepness, surface type and forest density result in different distribution of climatic characteristics e.g. wind exposure, solar radiation and air humidity which have an effect at the surface (Palo 2004, Tooming and Kadaja 2006). This is the main reason behind the high microclimatic variability of snow cover across the uplands.

Snow depth measurements were carried out along 10 transects and at 74 points in 15 sample plots during the winters of 2001/2002 and 2002/2003 (for location of transects see Figure 1). The sampling scheme was developed specifically to study micro scale spatial variability of snow cover at the Haanja Upland. All sampling points and transects were created bearing in mind the aim to cover a wide variety of landscape types (both homogeneous and heterogeneous), transitional vegetation types (edge effect), slope angles and aspect (orientation). To assess edge effect on snow most of transects were long enough to extend at least to two vegetation types (e.g. grassland/forest; grassland/shrub/forest). Within the forest and dense shrub the number of sampling points was lower as these types are physically unsuitable for cross-country skiing and additional data from forest observation post of EMHI were extracted (Tooming and Kadaja 2006). More sam-

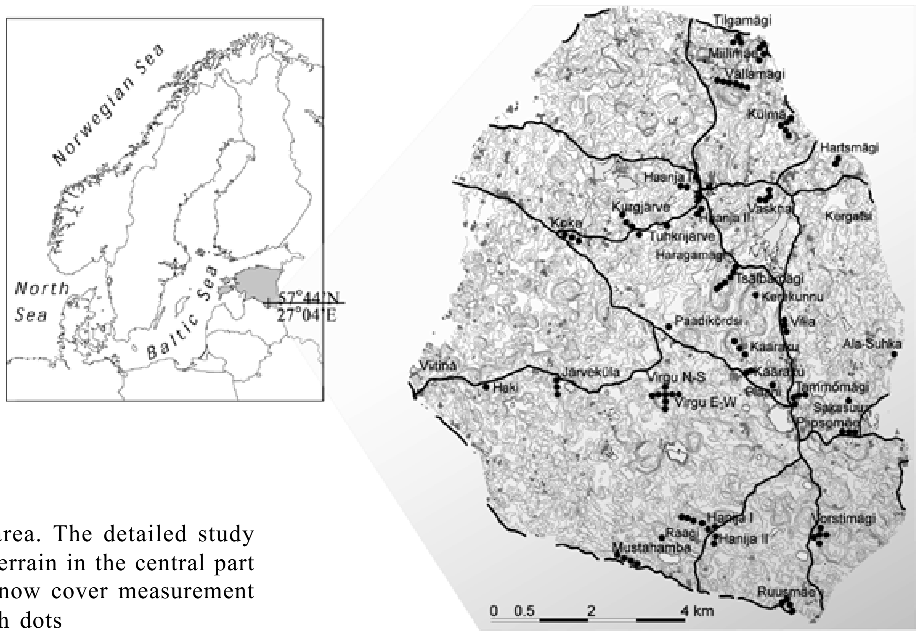

Figure 1. Location of the study area. The detailed study area covers orographically varied terrain in the central part of the Haanja Upland. The main snow cover measurement plots and transects are marked with dots

pling points in the forest were located along the natural forest paths (2-4 m wide) where skiing is possible. All the main vegetation classes at Haanja Upland were covered. The snow sampling procedure followed the regulations of the WMO (World Meteorological Organisation) applied at meteorological posts.

In addition to snow measurements a topographic and vegetation survey was also carried out at the measurement sites. The actual meteorological parameters in the central part of the Haanja Upland were measured using one specially installed automatic weather station in the central part of the Haanja Upland (at Haanja village). The following meteorological parameters have been recorded since 2000: minimum, maximum and average air temperature (°C); soil temperature (°C at 10 cm depth); intensity of solar radiation (W/m^2); solar energy (Ly); air pressure (mb); wind speed (m/s); maximum wind speed (m/s); wind direction (°); wind chill (°C); precipitation (mm); precipitation intensity (cm/hour); relative humidity (%) and dew point (°C).

Long term climatic and snow cover data were provided by the Estonian Meteorological and Hydrological Institute (EMHI). For the meso-scale analysis data from 13 EMHI measurement sites (Haanja, Mauri, Ruusmäe, Plaani, Konnuvere, Varstu, Rõuge, Vana-Kasaritsa, Krabi, Misso, Vastseliina, Meremäe and Otsa) at the Haanja Upland and around it were used. The time series began in 1968.

Development of the model

Based on statistical (regression analysis) and geostatistical analysis of snow cover data and topographic information, empirical equations (Eq. 1 and 2) were worked out to develop a simple empirical GIS model. This GIS model was used to estimate snow cover depth and continual snow cover duration in the central part of the Haanja Upland. Snow cover depth was modelled as the product of the meso-scale and micro-scale factors that affect climatic conditions in the upland region (Equation 1).

$$SC_{local} = (SC_{regional\_170m} + E^* c_1) * f(LC) * f(SG) * f(SA) \quad (1)$$

where

SC_{local} = Snow cover depth at local level, 10*10 m resolution (in centimetres);

$SC_{regional\_170m}$ = Snow cover depth at regional level reduced to level of 170 m above sea level (a.s.l.) (in centimetres);

E = Relative elevation from foothill (170 m a.s.l.) in metres;

c_1 = coefficient, snow cover depth increment per increase of absolute elevation (0.08 cm/m);

f(LC) = function of land cover, f(LC) = 1 for cultivated grassland;

f(SG) = function of slope gradient and snow sink, f(SG) = 1 for slope gradient 0º;

f(SA) = function of slope aspect for small local depressions, f(SA)= 1 (except local depressions).

On the meso-scale approach the general pattern of snow cover was modelled across the entire Haanja Upland area as affected by the shape of the hills, the absolute height and consequent average temperature gradient in winter. Based on long-term snow cover observations at EMHI measurement sites the mean annual regional (meso-scale) snow cover depth and duration were calculated and reduced to a unilevel surface of 170 m above sea level (the base of the upland). Micro-scale variation of spatial distribution of snow cover was modelled as the effect of the relative height of the landforms, slope gradient, slope aspect and land cover type. Coefficients used in model were based on geostatistical analysis of measured snow cover data and topographic information from the Haanja Upland and derived from the literature (Arp and Oja 1997, Palo 2004, Tooming and Kadaja 2006). All the GIS calculations were performed at a spatial resolution 10*10 metres. Local snow depth is partly dependent on snow drift but in the calculations it was assumed that snow drift has a random character both within the season and in year-to-year comparisons (Kull 1996, Oja and Kull 2000). Therefore, wind distribution and slope aspect were discarded in the snow depth calculations except for small local depressions which are always filled by snow if snow drift occurs, regardless of wind direction. However, slope aspect and gradient were considered when snow cover duration was calculated as this is strongly dependent on insolation, which in turn is affected by these variables (Equation 2).

$$SD_{local} = (SD_{regional\_170m} + E^* c_1) * f(LC) * f(SG, SA, LF) \quad (2)$$

where

SD_{local} = Snow cover duration at local level, 10*10 m resolution (in days);

$SD_{regional\_170m}$ = Snow cover duration at regional level, reduced to level of 170 m a.s.l. and corresponding to open cultivated grassland (in centimetres);

E = Relative elevation from foothill (170 m a.s.l.) in metres;

c_1 = coefficient, snow cover duration increment per increase of absolute elevation (0.23 day/m);

f(LC) = function of land cover, f(LC) = 1 for cultivated grassland;

f(SG, SA, LF) = function of slope gradient SG, slope aspect SA and landform LF (depressions, hilltops, convex slopes etc.).

The spatial distribution of the modelled snow parameters was validated using high resolution snow data from the winters of 2001-2003. To ensure an independent data set for validation the snow cover sampling data from 2001-2003 were randomly divided into 2 parts – one to create empirical formulas for the model, another set to validate model results. Long term corrections of snow depth and duration were carried out based on the time series from the EMHI meteorological posts (Mauri, Rõuge, Misso, and Haanja) located in the central part of the Haanja Upland. To assess model quality we correlated the measured independent random data set (with known coordinates, i.e. location) with modelled values at the same location (average of 10*10 square as the modelling scale). Better accordance was found for open areas (arable land, grasslands) where R^2=0.78 while in forest R^2=0.62 occurred due to high natural variability (stand density, patchiness, mixed age and species composition). Weaker correlation between modelled and measured data was characteristic of younger stands and old (patchier) woodland types.

Restorative potential of the land cover

Methodology used

The self-rating method developed by Han (2003) – the "short-version revised restoration scale" (SRRS) was used as a basis for evaluating the restorativeness of natural environments in terms of the different vegetation types found in the study area. The test subjects were shown winter landscape photographs and asked to rate specific aspects of their reaction towards those images using a number of differently worded questions on a nine-point Likert scale.

The polling of subjects and statistical analysis of data in the study were conducted as described in the methodology of SRRS. The selection of visual stimuli for use in the test was based on the principles described by Han (2003) but followed additional guidelines specific to the aims of the study (see below).

Selection of vegetation classes and their visual representations

The photographs used for the restorativeness test were chosen according to a simplified selection of vegetation classes characteristic of the Haanja Upland (pine forests, spruce forests, deciduous forests; younger spruce plantations; bushes; open arable land; wetlands). It has been noted (Palmer and Hoffman 2001) that using only one photograph as the representation of a particular situation may compromise representational validity. Accordingly, for each vegetation class, a selection of different photographs of similar vegetation site types was chosen. Vegetation site types were first selected following the national habitat classification system (Paal 1997); the selection was later clarified through on-site observations in the conditions of snow cover and finally consolidated into 16 distinct groups of visually similar vegetation types. Man made types – fields and grasslands – were also included in the selection as these determine the visually open scenes and are usually perceived as natural in character (Ulrich 1986).

It was assumed that existence of the edge of the vegetation type within the view would influence the restorativeness of that vegetation type, especially when visually enclosing vegetation (i.e. various forest stand types) is situated next to visually open vegetation such as grassland or arable fields. In addition to the uniform view within the vegetation type (Figure 2A), two more views were taken when possible – the view from the visually open landscape towards the vegetation (Figure 2B) and the view from within the vegetation type outwards to the visually open area (Figure 2C). It was impossible to obtain all three view-types with each vegetation type because: 1) some visually enclosed types were seldom located next to a visually open landscape, 2) some types, composed of dense vegetation at eye level were visually impervious. The above-mentioned views were grouped into the following classes: views towards the vegetation, views within and views outwards from the vegetation. A total of 34 slides were used in the study (see figures 2A to 2F for samples).

In order to determine the relationship between the restorativeness and the vegetation types it was necessary to eliminate any bias caused by varying photographic quality and other factors that may influence the landscape content. All pictures were taken at eye level in the same weather conditions (sparse cloud cover, sunshine producing shadows, no precipitation, weak wind) with the same camera lens setting and orientation towards the horizon. Flat topography in the scene was preferred because an undulating sightline may increase the degree of aesthetic preference by conveying a sense of mystery (Kaplan 1982, Ulrich 1986). However, in the case of some scenes it was impossible to eliminate topographic variations completely due to the particular topography of the test area.

The presence of obvious man-made structures in the photos was avoided as the presence of these in otherwise natural-appearing scenes is known from other studies to reduce the attractiveness of a scene, often dramatically (Ulrich 1986), leading people to rate the signs of human influence in the landscape rather than the vegetation itself. In terms of the composition, the views were chosen where there were uniform depictions of the vegetation type without dominant ob-

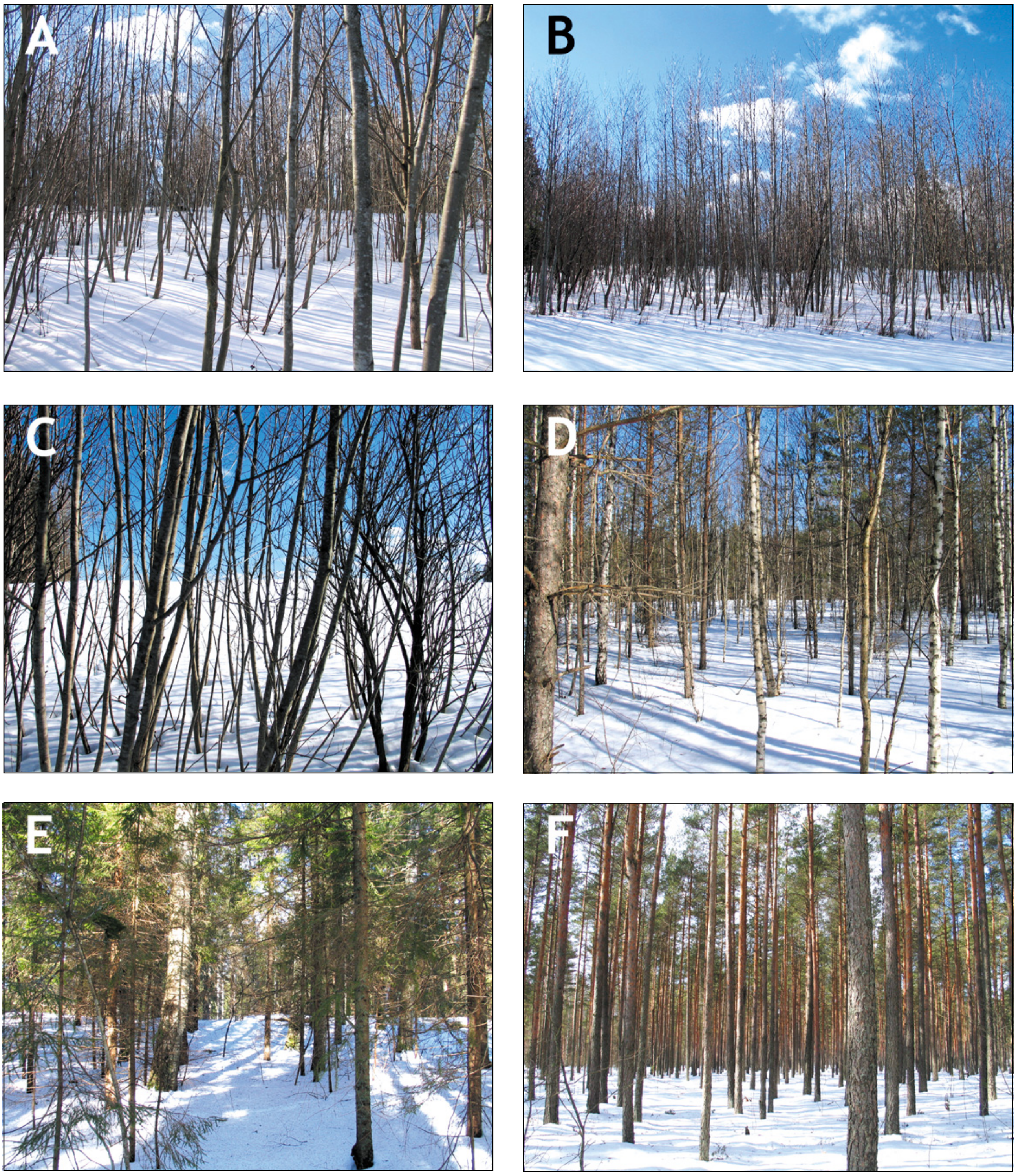

Figure 2. Sample of photos used in restorativeness test including an example of different view types of the same vegetation type. A – view within alder bushes; B – view towards alder bushes; C – view outwards from alder bushes; D – view within younger thinned deciduous forest; E – view within spruce forest without understorey; F – view within pure pine forest

jects or prominent groups of objects created by Gestalt principles (Bell 1999, 2004). Objects occurring in groups tend to be seen as single landscape elements and this helps interpretation of the view and is one of the key factors determining the preference of views (Kaplan 1982, Bell 2004). Thus, making "dull and uniform" pictures enabled the measurement of reactions towards a vegetation type rather than the overall composition of the scene.

Questionnaire and statistical analysis

The SRRS questionnaire used for each slide (Table 1) consists of eight questions, two for each dimension of restoration (emotional, physiological, cognitive and behavioural reaction). The questions are devised so as to be bipolar, enabling the use of a Likert scale from 1 (strong disagreement or negative response) to 9 (high agreement or positive response) to record the response. The resulting two numerical values are averaged across each dimension and combined to produce composite scores of all four dimensions. The questions on physiological response in the SRRS are set up to measure physiological arousal, the opposite of restoration, so resulting value scores must be reversed before further calculations are carried out (see Han 2003 for details). The resulting four composite scores are averaged to form the index score of restorativeness of the landscape scene.

Table 1. An overview of the SRRS – Short Revised Restoration Scale (Han 2003) with Likert scale from 1 to 9

Imagine you were in the projected scene. How would you describe your emotional response?	
	Grouchy (very much) = 1; Good natured (very much) = 9
	Anxious (very much) = 1; Relaxed (very much) = 9
Imagine you were in the projected scene. How would you describe your physiological response?	
My breathing is becoming faster	not at all = 1; very much so = 9
My hands are sweating	not at all = 1; very much so = 9
Imagine you were in the projected scene. How would you describe your cognitive response?	
I am interested in the presented scene	not at all = 1; very much so = 9
I feel attentive to the presented scene	not at all = 1; very much so = 9
Imagine you were in the projected scene. How would you describe your behavioural response?	
I would like to visit here more often	not at all = 1; very much so = 9
I would like to stay here longer	not at all = 1; very much so = 9

Our study used 86 respondents (25 male, 61 female; the balance was coincidence within a group of volunteers) to assess the restorativeness of vegetation types and particular view-types within the vegetation. The average age of respondents was 21.4 years. The test was conducted in April 2005. Respondents were undergraduates of landscape architecture and environmental protection from the Estonian University of Life Sciences, and geography students of the University of Tartu. Considering the high popularity of cross-country skiing in Estonia and the fact that skiing has been a compulsory part of physical exercise education from primary school age, all the respondents can generally be regarded to have sufficient skiing experience comparable to recreational-skiers. Thus there was little chance that the respondents would not be able to place themselves in a situation where they were skiing, invalidating the results. Students were also familiar with the general landscape character of the Haanja upland. The sample size was sufficient to achieve statistical significance in the resulting analysis as it was larger than minimum required by power analysis for one-way repeated measures ANOVA.

The respondents were asked to imagine that they were in the depicted environment and to answer eight questions associated with each slide. They were given an overview of the questionnaire prior to the test itself. The slides were projected on a large wall screen while the subjects were filling out the SRRS questionnaire. The duration of each slide shown was determined by the test subjects who would give note to the operator that they had filled out the sheet and were ready for the next slide. Respondents viewed slides in groups of 7 to 20 people, in two distinctive arrangements of slides (A and B, respectively). In total, 48 persons viewed the slides in order A and 38 in order B. The sequence of slides was obtained using a random sequence generator and followed two rules – not more than two similar vegetation types should be next to each other in the sequence and not more than two similar view-types should be next to each other in the sequence (Herzog et al. 1997).

Two different reliability tests were carried out on the data to verify the reliability of the SRRS scale being used and the reliability of the responses given by the subjects. Firstly, Cronbach's alpha test was carried out. This calculates the lower bound for the true reliability of the survey (a function of the number of test items and the average inter-correlation among the items, SPSS Inc. 2004). It was used to examine the relationship of the score of each of the eight questions to the overall restorativeness score and then the scores of each of the two questions per dimension to the score for the dimension as a whole. The second test examined the intra-class correlation (calculated from specific mean square components of an analysis of variance of the data, SPSS Inc. 2004), among respondents' personal restorativeness scores to determine whether the rating pattern of the respondents was consistent (Palmer and Hoffman 2001, SPSS Inc. 2004). It was used to calculate the reliability of the whole group and the individual reliability.

In order to test whether vegetation classes actually do elicit different levels of restorativeness a Mann

Whitney U test (a non-parametric analogue to ANOVA) was carried out. Personal restorativeness scores given to the internal views within the individual vegetation types were pooled to the appropriate seven vegetation classes' data, then a pairwise test of all possible combinations between seven vegetation classes was performed. The Mann Whitney U test assumes that the variable's distribution is similar in both groups, so the two-sample Kolmogorov-Smirnov test was used prior to validate the assumption of similar distributions.

Similarly, the Mann Whitney U test and accompanying two-sample Kolmogorov-Smirnov test was used to make pairwise comparisons to determine whether the hypothesised difference between view types existed. These comparisons were done on two levels – within sixteen individual vegetation types and within pooled data of seven vegetation classes.

Coupling of snow cover with restorativeness of land cover

In order to identify the combination of areas with a long duration and sufficient depth of snow cover as well as a high restorativeness value, we used GIS analysis based on map algebra. All parameters (snow cover duration and depth, landscape restorativeness) were divided into three categories based on Natural Breaks classification method.

As the first step, the analysis of the GIS layers of snow cover depth and snow cover duration were combined using a multiplicative scale. Three classes of snow cover were then determined based on suitability for cross-country skiing: unfavourable, moderate and favourable. Favourable areas were those where snow cover duration was longest (>134 days) and snow cover deepest (>45 cm), unfavourable areas were those with snow cover shorter than 97 days or having snow cover depth less than 34 cm. All other areas were considered as having moderately favourable snow conditions. Limits of favourability/unsuitability of snow depth or duration were based on empirical knowledge of local cross-country ski track managers and do coincide with snow quality assessment data from other ski resorts (Elsasser and Bürki 2002, Scott et al. 2003). The primary criterion for favourability of snow conditions was based on minimal snow depth (<34 cm) which determines the possibility of creating a ski-track across managed grassland, while favourable snow depth class (> 45 cm) is in most cases sufficient for creation of easily manageable ski tracks even in case of roughest surface covered by natural grassland with bushes or in forest areas. The secondary parameter was snow cover duration which was divided into three periods (less than 97 days, 98-134 days, over 134 days).

In the second step of GIS analysis the snow cover suitability map was overlaid with the map of landscape restorativeness where all vegetation types were divided into three groups: unfavourable (<5), moderate (5–5.9) and favourable (>5.9). This produced a combined map with 9 possible dimensions of suitability and restorativeness.

Results

Snow cover

The model of snow cover depth (Figure 3A) and duration (Figure 3B) showed that snow cover in the Haanja Uplands normally starts forming around the beginning of November, and a permanent snow cover is established on average some 15 days earlier than on the surrounding lower plains. Snow melt usually starts in late March to early April, this melting being less intensive and lasting about 20 days longer in the central part of the upland than elsewhere. The distribution of snow cover and the extent of variability depend upon weather patterns. The snow period can be divided into three different periods: the accumulation period following the first snow falls, when the snow builds up in depth and becomes permanent, the period of continual snow cover, and the snow melt period when the snow gradually thaws and disappears. Snow cover is deepest (45–52 cm) and most stable (122–150 days) in the central area of the upland (Table 2) and along the main crest of the area which runs in a north–south direction (see Figure 3A and 3B). Temporal–spatial variability of snow depth is higher on exposed areas than in sheltered areas (like forests), which create a more stable environment for snow accumulation because they are more sheltered and also produce shade which reduces the rate of snowmelt.

Table 2. Snow cover characteristics in the Haanja Upland

Class	Snow depth		Snow duration	
	cm	ha	days	ha
1	<25	209	<72	210
2	25–33	1540	72–96	422
3	34–42	4465	97–121	3211
4	43–52	2774	122–148	4938
5	> 52	863	> 148	1070

The spatial pattern of snow depth across the landscape was found to be strongly influenced by the relief parameters of slope orientation (aspect), slope gradient and shape of the slope, as well as the presence of depressions, hill–tops, gullies and slope roughness. Their effect on snow cover is mainly expressed in terms of the redistribution of snow and subjected to fairly significant year–to–year variation rather than being

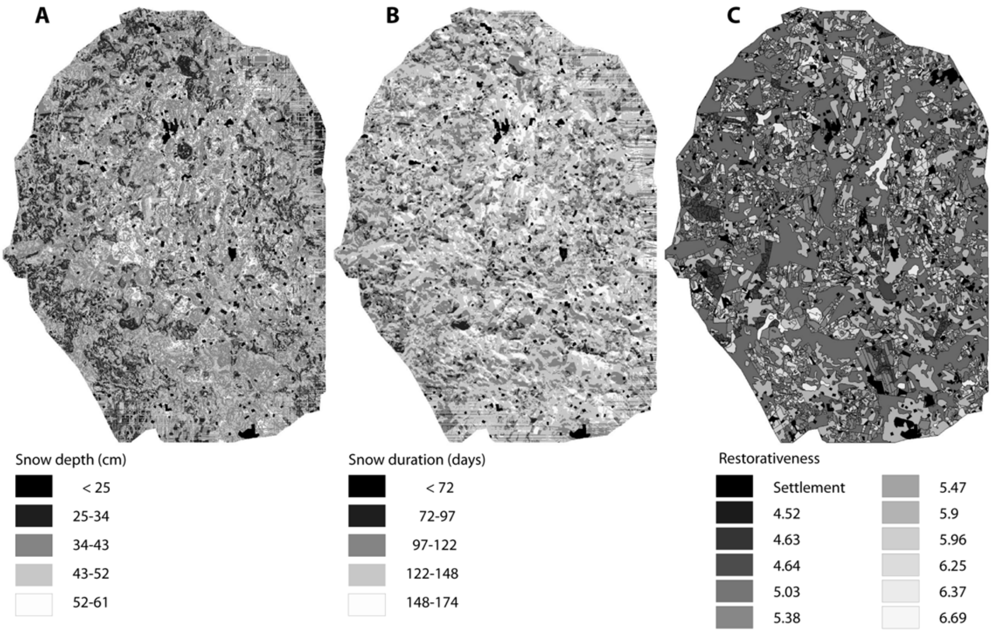

Figure 3. Spatial distribution of snow depth – A (cm); duration of continuous snow cover – B (days); and restorativeness value of representative vegetation types – C (scale 1 to 9) in Haanja Upland

characteristic of the site (except hilltops and small local depressions). Snow drift was found to be most pronounced on hilltops and the higher parts of windward slopes (i.e. slopes with a south to west aspect). The most windswept slopes tend to be convex to windward (associated with slope crests and shoulders, where airflows converge and enhance the potential snow erosion) or gently undulating. The main accumulation sites are topographically sheltered locations and leeward slopes. The degree of accumulation on leeward slopes was found to depend greatly on the shape and gradient of windward slopes.

The most important forest stand characteristics found to affect snow cover accumulation and variability were woodland type (conifer or broadleaved, tree height, stand density, forest edge structure, orientation and distance). The greatest snow depth and longest duration of snow cover were observed in deciduous forest stands (especially in shrubs and bushes) due to heavier snow accumulation during snowfalls (less canopy interception than in conifers), greater snow accumulation by wind drift (less shelter than in conifers) and much longer snow melting period due to sheltered solar radiation. In the case of deciduous trees water from melting snow or rain tends to flow down the stem and be locally concentrated around the base of the tree, while in coniferous trees (especially spruce) melting snow and rain drips from the whole canopy, which causes a diffused pattern of water falling from the canopy to the surface increasing the area affected by water and thus the thawing of the snowpack. In addition there is usually a lot of debris on the floor of coniferous stands which, combined with snowmelt water, changes snowpack properties, making the snow dirty and porous with patchy cover, reduces surface albedo and thus increases the energy available for snowmelt, while an increase in snowpack density and unfrozen water content leads to increased thermal conductivity.

A deeper snow cover is characteristic of north and north-east facing forest edges (Figure 3A). Greater snow depth in these areas is not only caused by increased accumulation by snow drift but also by a slower rate of snow melt (Figure 3B) as forests provide both shade and lower diurnal temperature variation.

Assessment of restorativeness of land cover

The restorativeness values for each vegetation class and its component vegetation types with views towards, outwards from and within them were obtained from the questionnaire data (Table 3). The analysis of the restorativeness data (see Tables 3 and 4) shows that vegetation classes often do provide different degrees of restorativeness in winter landscapes, as it was hypothesized (see Figure 3C). However, it is not always possible to demonstrate statistically significant difference between restorativeness of some vegetation classes with neighbouring restorativeness values. For example, on the scale from 1 to 9 the restorativeness of bushes showed the lowest restorativeness at 4.34 (Table 3) and the value was significantly different from all other vegetation classes (Table 4). Similarly, the restorativeness of pine forests (see Fig. 2F for a sample view) reached 6.47 for views within the stand and

Table 3. Restorativeness (scale 1 to 9) of vegetation classes and their subcomponent vegetation types in different view

Vegetation class and its component vegetation types	Restorativeness in different view (scale 1 to 9 provided with standard error and N; * – data based on single sample) and statistically significant view type difference (difference confirmed: + ; difference not confirmed: -): Towards the type / class	Difference	Within the type / class	Difference	Outwards from the type / class
Pine forests	**6.54 ± 0.125 (n=86)***	**-**	**6.47 ± 0.093 (n=171)**	**+**	**6.79 ± 0.134 (n=86)***
Pine forest on wet boggy sites (*Pinus sylvestris*)	N.A.		6.69 ± 0.123 (86)		N.A.
Pure pine forest	6.52 ± 0.126 (86)	-	6.25 ± 0.137 (85)	+	6,76 ± 0,137 (86)
Wetlands	**6.17 ± 0.139 (n=85)***	**-**	**6.33 ± 0.104 (n=171)**		**N.A.**
Lake shores with reed-beds	6.17 ± 0.139 (85)	-	6.37 ± 0.167 (86)		N.A.
Raised bog with scattered small pines	N.A.		6.30 ± 0.123 (85)		N.A.
Young Spruce plantations	**6.02 ± 0.090 (n=172)**	**-**	**5.69 ± 0.138 (n=86)***		**N.A.**
Young spruce plantation (*Picea abies*)	6.23 ± 0.122 (86)		N.A.		N.A.
Spruce plantation thicket	5.79 ± 0.131 (86)	-	5.68 ± 0.138 (86)		N.A.
Open areas	**N.A.**		**5.47 ± 0.101 (n=172)**		**N.A.**
Open field without the dead grass protruding through the snow	N.A.		5.90 ± 0.144 (86)		N.A.
Open field with dead grass protruding through the snow	N.A.		5.03 ± 0.127 (86)		N.A.
Spruce forests	**5.59 ± 0.085 (n=256)**	**-**	**5.37 ± 0.086 (n=257)**	**+**	**5.81 ± 0.092 (n=172)**
Spruce forest without understorey	6.29 ± 0.136 (86)	-	5.96 ± 0.154 (85)	-	5.97 ± 0.119 (86)
Spruce forest with understorey	5.57 ± 0.135 (85)	-	5.47 ± 0.130 (86)	-	5.65 ± 0.140 (86)
Pine forest with spruce understorey	4.89 ± 0.128 (86)	-	4.64 ± 0.127 (86)		N.A.
Deciduous forests	**5.63 ± 0.087 (n=172)**	**+**	**5.27 ± 0.090 (n=172)**	**+**	**5.60 ± 0.149 (n=86)***
Deciduous forest	5.63 ± 0.120 (86)	-	5.38 ± 0.127 (86)	-	5.60 ± 0.149 (86)
Younger thinned deciduous forest	5.61 ± 0.129 (86)	+	5.15 ± 0.128 (86)		N.A.
Bushes	**4.83 ± 0.092 (n=257)**	**+**	**4.34 ± 0.087 (n=258)**	**+**	**4.90 ± 0.087 (n=258)**
Alder (*Alnus incana*) bushes	5.07 ± 0.147 (86)	+	4.63 ± 0.152 (86)	+	5.25 ± 0.159 (86)
Birch (*Betula pendula*) bushes	5.16 ± 0.158 (85)	+	4.52 ± 0.129 (86)	-	4.73 ± 0.131 (86)
Willow (*Salix sp*) bushes	4.27 ± 0.155 (86)	+	3.88 ± 0.156 (86)	+	4.72 ± 0.153 (86)

Table 4. Comparison of vegetation classes based on restorativeness values of views within those classes

Vegetation classes compared (restorativeness difference confirmed: + ; restorativeness difference not confirmed: -)	Bushes	Deciduous forests	Spruce forests	Open areas	Young spruce plantations	Wetlands	Pine forests
Bushes	x	+	+	+	+	+	+
Deciduous forests	+	x	-	-	+	+	+
Spruce forests	+	-	x	-	-	+	+
Open areas	+	-	-	x	-	+	+
Young Spruce plantations	+	+	-	-	x	+	+
Wetlands	+	+	+	+	+	x	-
Pine forests	+	+	+	+	+	-	x

this value was significantly different from all other vegetation classes except for wetlands with the restorativeness of 6.33 which also differed from all other vegetation classes except for pine forests.

Young spruce plantations (5.69) were not distinguishable from more mature spruce forests (5.37) and open areas (5.47), but differed from the rest of vegetation classes. On the other hand, restorativeness values given for deciduous forests (5.27; see Fig. 2D for a sample view), spruce forests (5.37; see Fig. 2E for a sample view) and open areas (5.47) were so closely placed that it was not possible to determine a significant difference between data streams.

The hypothesis that views towards, outwards from and within the same vegetation type can elicit different degrees of restorativeness was partially supported by the data. On the level of 16 individual vegetation types it was possible to observe higher restorativeness values for views towards and outwards from the vegetation than the views inside the vegetation type (with just one exception of lake shores with reed), but the differences were too subtle to be detected as significant by Mann Whitney U test in several cases (see Table 3 for specifics). Looking at the consolidated data with 7 vegetation classes, however, Mann Whitney U test showed statistically significant differences between many cases. All views outwards from the visually enclosing vegetation class had significantly higher restorativeness than views inside those vegetation classes. Additionally, views towards bushes and deciduous forests had significantly higher restorativeness than views inside those vegetation classes.

The statistical analysis supported the reliability of the data. The reliability measure (Cronbach's alpha) across all eight variables (two questions per factor) was 0.945; the reliability across four factors of emotion, physiology, cognition and behaviour were 0.965; 0.946; 0.991 and 0.997 respectively. This permitted the conclusion that the variation of the data originated from the individuality of respondents and the nature of the slides shown rather than any lack of clarity in the wording of the questionnaire (SPSS Inc. 2004). The intra-class correlation coefficient was 0.239 for single measures and 0.919 for average measures which showed that despite their individuality the group of respondents was generally rating according to a similar pattern (SPSS Inc. 2004, Palmer and Hoffman 2001).

Snow cover and restorative quality of biotopes

Combining snow data with the restorativeness of land cover allows us to establish the best potential locations for winter recreation areas (Figure 4). While the snow cover is deepest and longest in duration in alder and birch scrub and deciduous forest, the restorativeness of such vegetation types is less favourable. At the opposite extreme, young spruce plantation (but also its mature successor spruce forest) has relatively high restorativeness, but the thick canopy preventing snow from reaching the ground renders it an unfavourable location for ski-track planning. Pine forest

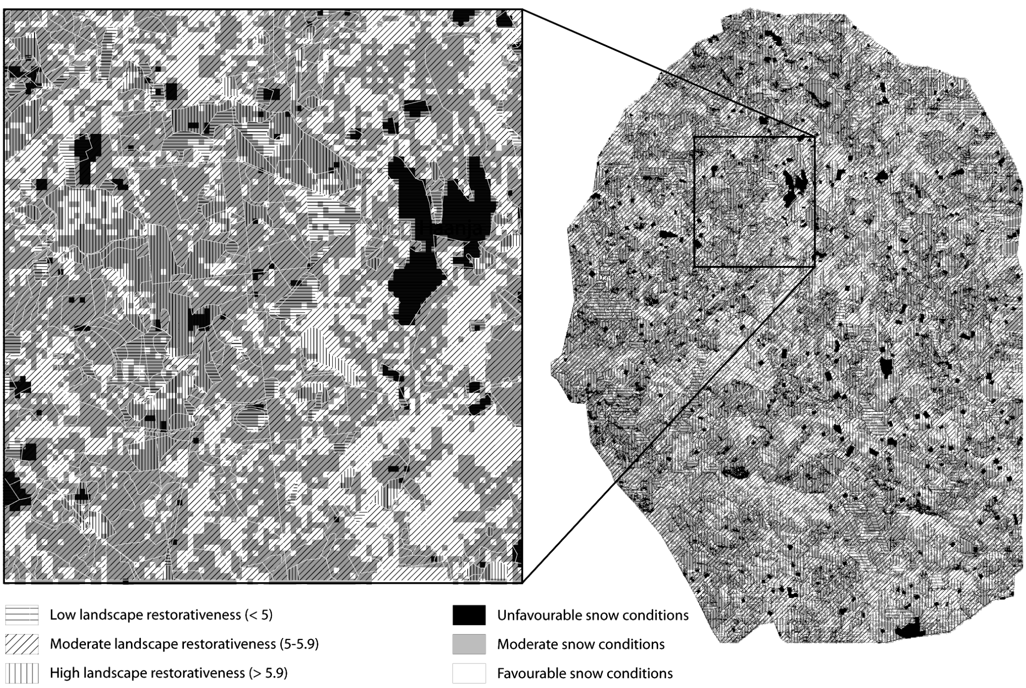

Figure 4. Snow cover quality (indicated with different colours) and restorativeness of vegetation classes (indicated with different hatching) in the Haanja Upland

is the best suitable vegetation class for obtaining both high restorativeness and good snow conditions.

Forest edge zones have high value both as performing higher restorative potential and as having favourable snow conditions on eastern, north-eastern, northern, north-western and western facing margins.

Discussion and conclusions

The snow model showed that certain areas are more likely to receive and retain snow than others. The deciduous stands and location along shady north and east facing edges were most likely to retain snow due to combination of factors such as lack of canopy interception, accumulation of drifting snow and shading effects. This knowledge provides valuable guidance to anyone wishing to lay out snow tracks where the skiing season will last the longest. Since the snow persistence is different for different stand types it could be expected that as a forest develops – for example a deciduous birch or alder stand may succeed to spruce – the snow pattern over time may change and the track designed for the best snow may need to be rerouted.

Analysis of the results of the restorativeness test showed that vegetation classes in winter landscapes, despite appearing bare and lifeless compared with summer ones often do create meaningful differences in restorativeness; however it was not always possible to demonstrate statistically significant differences between restorativeness of some vegetation classes with neighbouring restorativeness values. Restorativeness values given for deciduous forests, spruce forests and open areas were so closely placed that it was not possible to determine significant difference between data streams. Obviously forests and open areas are very different in essence and physical effect (e.g. wind shelter), but from the restorativeness point of view they seem to form a uniform average group.

The high score of restorativeness given to pine forests is congruent with Ulrich (1986) and Parsons and Daniel (2002) where visually open structures with smooth ground surface tend to produce the highest preference scores. Whether the perceived ability to ski across or through vegetation can besides aesthetic preference be directly associated with restorativeness is another matter. However, this fits with the highest scores of pine forest vegetation class and its component vegetation types - scattered pine forest on wet boggy sites (6.69), pure pine forest (6.25; Figure 2F). The same holds true for the lowest restorativeness of bushes vegetation class and its component vegetation types - alder (4.63; Figure 2A), birch (4.52) and willow (3.88) bushes (Table 3). The high scores of young spruce plantations' vegetation class (6.23 towards and 5.69 within the class) contradict the idea that perceived ease to walk across or through the vegetation influences its preference, but may be explained as a result of semiotic association where young spruces resemble Christmas trees and scenes from winter postcards.

In the case of this study the score of wetlands' vegetation class (6.33) and its component vegetation types – frozen lakeshore with reed-bed (6.37) and raised bog with scattered small pines (6.30) was consistent with the observation of water being a positively attractive feature, although whether the respondents were able to recognize the snow-covered surface as being a part of a wetland cannot be ascertained.

A distinct pattern could be noted that views outward from generally produced higher restorativeness than views within the vegetation class itself, which may correspond to Appleton's prospect –refuge theory (1975). Additionally, views towards bushes and deciduous forests had significantly higher restorativeness than views inside those vegetation classes. This result may seem to be in stark contrast to prospect-refuge theory. It may be that the lack of foliage in deciduous vegetation classes in winter increases visual permeability thus giving observer a better overview of the environment and effectively cancelling the frightening uncertainty and substituting it with higher visual variation and mystery. The scope of this study allowed us to focus only on the existence of the edge within the view, but not the metrics of the edges. Further studies should address this issue concentrating on viewer's distance and orientation in relation to the edge of vegetation in different seasons.

A possible concern detected in this study that justifies some caution regarding the SRRS questionnaire is the extremely high reliability (Cronbach's alpha over 0.9) which may suggest redundancy in the restorativeness scale. However, it was not in the scope of this study to alter the original SRRS scale. In his paper, Han (2003) demonstrated similar levels of alpha being over or close to 0.9. As SRRS is a multifactor model, Han (2003) specifically points out the need to use two questions per dimension of restorativeness (a prerequisite that might be causing the redundancy) to make the model function properly.

Combining the analysis of snow distribution and the restorativeness of different land cover enabled the best potential locations for winter ski routes in the Haanja study area to be determined. The best suitable vegetation class for providing a combination of high restorativeness and good snow conditions in the study area was pine forest, while snow conditions and restorativeness of other vegetation classes showed some disparity. The forest edges, which allow both inward and outward views, possessed a higher restorativeness and had more favourable snow conditions. Thus, ski tracks located at or within the north- and east-facing edge zones would give a longer period of performance through the winter as well as increased restoration. The most favoured forest landscapes such as pine stands are not, however the best for snow potential, so that there is clearly no simple positive association between the best places to find snow and the most restorative landscapes.

From the ecological point of view, when planning the management of woodland edges it is important to consider the fact that south- and west-facing edges usually develop higher structural diversity than north- and east-facing edges (Fry and Sarlöv-Herlin 1997). This difference in suitability of forest edges for winter recreation and ecological conservation could provide planners with an application enabling them to minimise conflicts between those two interest groups. In the Haanja conditions, however, this relationship is not unambiguous, due to the high degree of patchiness of landscape.

A considerable proportion of the study area (see extensive areas of low restorativeness Figure 3C) is occupied by abandoned fields which have started to grow into birch and alder scrub. As the restorative potential of such vegetation types now and later on in the course of ecological succession is lower, this poses a challenge for landscape maintenance and landscape design.

It remains an open question as to how much of the cross-country skiing experience is undertaken with psychological restoration in mind. An aspect out of the scope of this study is that some skiers may want to obtain physical exercise, develop fitness and experience speed. However, one of the main motivations for taking part in outdoor recreation in natural landscapes is to relieve stress, to “recharge the batteries” and to be close to nature (Bell 2008). The population of recreational skiers is not homogeneous. The study subjects were all young adults, largely female and had an interest in the landscape and nature. They were able to distinguish between vegetation types because they have been educated to be able to do so. This may have biased the results compared with a more demographically representative sample. The results are therefore not definitive. It would be valuable to carry out further exploration of the preferences and perceptions of different user-groups such as sportsmen, children and older skiers, and other user needs such as solitude or physical challenge.

The study did not attempt to evaluate the experience of moving through a landscape, which is the essence of cross-country skiing. Thus the static photographs do not replicate the sense of moving through a landscape and experiencing a different sequence of landscape types providing diversity of landscape at a higher level of spatial scale than the individual biotopes used here. With the advent of technology such as the “virtual landscape theatre” this is theoretically possible, under controlled conditions. More research in this area may yield different results.

Conclusions

In declining snow conditions it is very important to consider micro-climatic conditions of the landscape when planning cross-country ski-routes. This ensures the most efficient use of natural snow cover and higher-quality ski tracks with lower maintenance cost. Well-planned ski routes without significant input of artificial snow allow the development of winter recreation in economically marginal least-favoured areas, thus supporting the management of cultural landscapes for sustainable development. By ensuring that the tracks are also laid out where the people who use them will obtain the highest psychological benefit also maintains their functionality.

This study has shown that it is possible successfully to combine a predictive, GIS-based snow model with a preliminary attempt at measuring restorative potential of forest landscape using photographs and that there is some degree of commonality in the places most likely to see snow persisting and which are likely to be most attractive to skiers but that there are also places most popular for restoration yet not ideal for snow. However, with the two sets of findings the designer and manager of a ski centre should be able to find the best of both worlds.

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ОЦЕНКА ПРИГОДНОСТИ ЛЕСНЫХ ЛАНДШАФТОВ ДЛЯ КАТАНИЯ НА ЛЫЖАХ В УСЛОВИЯХ НЕУСТОЙЧИВОГО СНЕЖНОГО ПОКРОВА: ПРИМЕР ХОЛМИСТОГО РАЙОНА ХААНЯ В ЭСТОНИИ

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Резюме

Снежный покров является важным показателем состояния климата и значительным фактором привлекательности зимних ландшафтов Эстонии. Разнообразие зимних видов спорта и рекреации за последнюю декаду возросло. В связи с изменениями климата, увеличилась также изменчивость снежного покрова. Эти изменения более значительны на равнинах, в холмистых районах ситуация остается более стабильной. Для выбора мест лыжных трасс, которые бы учитывали различные факторы как, с одной стороны, устойчивость снежного покрова, и, с другой стороны, привлекательность природных ландшафтов, были разработаны комплексные методы оценки состояния зимних ландшафтов. Для этого подходы к оценке состояния снежного покрова и климата для территорий на микро - и мезо уровне (1:10 000) были совмещены с оценками восстановимости природной среды (см. Хан 2003). Применение описанного комплексного подхода оценки состояния зимних ландшафтов выявило важную роль окраин лесов, где существуют благоприятные условия для сохранения и восстановления снежного покрова. Опрос пользователей также подтвердил высокую привлекательность данного типа ландшафта. Таким образом, планирование лыжных трас в местностях, которое принимает во внимание микроклиматические условия, позволяет эффективно использовать природный снежный покров, увеличивая продолжительность использования лыжных трас при уменьшении затрат на их поддержку и восстановление. Это особенно важно для малых туристических предприятий, а также в долгосрочной перспективе - для организации экологически устойчивого управления культурными ландшафтами.

Ключевые слова: Моделирование ГИС, оценка ландшафта, управление лесным ландшафтом, МОПР (метод оценки восстановимости природной среды Хана 2003), психологическая восстановимость природного ландшафта, снежный покров, зимняя рекреация, катание на лыжах