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Hegetschweiler, K.T., Fischer, C., Moretti, M., Hunziker, M. (2020)

Integrating data from National Forest Inventories into socio-cultural forest monitoring – a new approach

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Abstract

Information about social aspects of forest is frequently collected with questionnaire surveys. Several countries conduct nation-wide surveys in order to monitor outdoor recreation and the relationship of the people to the forest. While this gives a representative picture of the respondents' preferences and activities, it is not possible to link their answers to the real characteristics of the forest they are describing. On the other hand, forest characteristics are commonly recorded in National Forest Inventories (NFIs). Concerning forest recreation, both the physical characteristics of the forest as well as the social aspects play an important role. To establish a link between socio-cultural forest monitoring and the Swiss NFI, we used photos taken in all four cardinal directions from the centre of the NFI sample plots. The photos were integrated in an online survey dealing with visual attractiveness of forest. Forest characteristics were derived from the photos according to NFI-criteria. An evaluation of this method revealed that most parameters studied could be deducted reliably from the photos. Results show that visual attractiveness could be explained by a combination of several NFI-parameters and social factors. We conclude that this approach is a possibility to integrate forest characteristics into socio-cultural forest monitoring.

Keywords: Visual attractiveness of forest, linkage of physical and social data, photo interpretation, visitor preferences, forest characteristics

Introduction

Urban and peri-urban forests are often the main areas with natural qualities that are accessible to the public for outdoor recreation (Bell, Simpson, Tyrväinen, Sievänen, & Pröbstl, 2009). The increasing importance of forests for recreational purposes also poses questions on how to integrate forest visitor needs and preferences into forest management. Outdoor recreation and other social dimensions are often assessed by conducting nationwide household surveys on a regular basis (Sievänen et al., 2008). They provide valuable information about the relationship of the general public to the forest, usage patterns and motivations for forest recreation. In these surveys, respondents are often asked to describe their last visit to a natural area or to describe the forest they visit most often (Hunziker, von Lindern, Bauer, & Frick, 2012). While this gives a representative picture of the respondents' preferences and behaviour, it is not possible to link their answers to the real characteristics of the forest they are describing, as we do not know which specific forest they are referring to. On the other hand, characteristics such as tree species, stand structure, ground vegetation cover etc. are commonly recorded in National Forest Inventories NFIs (Tomppo, Gschwantner, Lawrence, & McRoberts, 2010). They monitor a wide range of natural scientific aspects of forests and trees and document changes over time, using statistical sampling designs, mostly with plots on systematic grids covering whole countries (Lawrence, McRoberts, Tomppo, Gschwantner, & Gabler, 2010). Regarding forest recreation, both the physical characteristics of the forest in which recreation takes place as well as the social aspects such as visitor preferences and behaviour play an important role (Ciesielski & Sterenczak, 2018). What is still missing is a planning and inventory tool bridging both aspects of forestry: the wood production and biodiversity related physical side, as well as the social dimensions (Hegetschweiler, Plum, et al., 2017).

One possible model describing this bridge between physical and social factors is proposed as the so-called "confluence model" in Hegetschweiler, de Vries, et al. (2017). According to the confluence model, social factors characterizing the population determine the demand for cultural ecosystem services as defined by the Millenium Ecosystem Assessment (MEA, 2005). Physical factors such as characteristics and facilities of forests and other green spaces form the basis for the supply of cultural ecosystem services. The benefit obtained by the services provided by forests is a result of a match between the social and physical factors (Hegetschweiler, de Vries, et al., 2017).

In order to provide a basis for managing multifunctional forests for recreation, numerous studies have addressed the question which forests are attractive to the public (Gundersen & Frivold, 2008; Pröbstl, Wirth, Elands, & Bell, 2010). One big cluster of studies uses the Scenic Beauty Estimation Method (SBE) developed by Daniel and Boster (1976). In these studies, participants evaluate the scenic beauty of a series of forest stands depicted on photographs. Forest characteristics are measured on-site using standard inventory techniques and relationships between forest characteristics and scenic beauty are established by statistical methods (Edwards et al., 2012). Examples of the Scenic Beauty Estimation Method include a study of the relationship between stand age, average BDH, stocking density and scenic beauty (Buhyoff, Hull IV, Lien, & Cordell, 1986), an estimation of scenic beauty inside mature forests and timber harvests (Ribe, 2009), and a comparison of timber harvest designs across continents (Ribe, Ford, & Williams, 2013). Further studies with similar methodology, though not explicitly using SBE and partly complemented by verbal cues, evaluate stem densities after thinning (Jensen & Skovsgaard, 2009; Petucco, Skovsgaard, & Jensen, 2013), preferences regarding forest cover and stand structure (Carvalho-Ribeiro & Lovett, 2011) or the effect of different seasons (Tyrväinen, Silvennoinen, & Hallikainen, 2017). Another predominant method is the usage of digitally edited images on which characteristics of interest are manipulated. For example Tyrväinen, Silvennoinen, and Kolehmainen (2003) used digitally edited photographs to depict conflicts in urban forest management such as thinning, understorey management, leaving of dead snags and logging residues and decaying wood. Wang, Zhao, and Meitner (2017) manipulated understorey height, flowers and footpaths to assess aesthetic and recreational preferences. Hegetschweiler, Rusterholz, and Baur (2007) used digitally edited images to investigate visitor preferences concerning recreational infrastructure, ground vegetation and forest surroundings at picnic sites.

Although these studies have revealed important insights into visitor's opinions on the visual attractiveness of forests managed for recreation, the question remains whether photographs really replicate the physical and visual qualities of the real setting (Palmer & Hoffman, 2001). One possible solution to this is not to use photos, but to rely on the resource-intensive method of face-to-face interviews, asking forest visitors to rate the forest on-site (Hauru, Koskinen, Kotze, & Lehvävirta, 2014; Hegetschweiler, Plum, et al., 2017; Shelby, Thompson, Brunson, & Johnson, 2003). A variation of this method is visitor-employed photography, in which forest characteristics are inventoried along a pre-defined trail and study participants are asked to take pictures of attractive scenes (Heyman, 2012; Nielsen, Heyman, & Richnau, 2012; Rathmann, Sacher, Volkmann, & Mayer, 2020).

While the above-mentioned studies provide valuable information on visitors' opinions concerning the impact of logging on scenic beauty and on various forest management practices, especially in coniferous forests in North America and Scandinavia, none of them are conducted as part of a standard long-term forest monitoring. In the following, we present a study with the aim of developing an instrument to measure visual attractiveness of forests that integrates social and physical aspects and is closely related to both social forest monitoring and National Forest Inventories (NFIs). Visual attractiveness serves as one possible measure for recreational value. In the above-mentioned confluence model, visual attractiveness is the dependent use and benefit variable based on social factors assessed using socio-cultural forest monitoring and forest characteristics assessed using the NFI.

The Swiss socio-cultural forest monitoring WaMos (Waldmonitoring soziokulturell) has been conducted twice up to now – in 1997 (BUWAL, 1999) and in 2010 (Frick, Bauer, von Lindern, & Hunziker, 2018; Hunziker et al., 2012). It is a representative survey of the Swiss population conducted by telephone with the option to switch to an online questionnaire. Among other things, it explores the population's attitudes to the forest, what they know about it and their behaviour when visiting forests. In the interview, respondents are asked to describe the forest that they visit most often. We therefore have a clear picture of people's perceptions of different forests. We do not, however, know where exactly these forests are and which characteristics the forests have in reality.

Forest characteristics are provided to us by the Swiss National Forest Inventory, which has been running since 1982 with the aim of recording the current state and development of the Swiss forest in a representative and reproducible manner (Brassel & Lischke, 2001). Terrestrial sample plots on a grid covering the whole country are surveyed to record a number of variables. They form the basis for measures which quantify forest functions or the ecological importance of the forest (Brassel & Lischke, 2001). Concerning recreation, infrastructure and damage by recreational use are investigated and the potential recreational demand is predicted using models based on the distance to settlements and surveys with the local forest service (Brändli & Ulmer, 2001; Ulmer, Bischof, Brändli, & Cioldi, 2010). Direct measures of people's attitudes, such as forest preferences or recreational satisfaction, and behaviour, such as time spent in the forest, aesthetic perceptions or recreational activities, are not investigated.

In short, we have a National Forest Inventory providing us with detailed information about the physical forest, but lacking details on recreation and other social aspects of forest. On the other hand, we have a socio-cultural forest monitoring providing us with exactly these details on social aspects, but without a link to the physical forest. Both aspects, social and physical, need to be considered in multifunctional forest management and planning. If we succeed in developing a tool to bridge the gap and integrate these two monitoring instruments, it should be possible to model and derive and/or and explain parameters relevant to forest recreation, e.g., visual attractiveness and other measures of recreational value, from social and physical data (Hegetschweiler, Plum, et al., 2017). To achieve this, we are aware of two possible approaches. One approach is to take (parts of) the questionnaire from a household survey, e.g., the Swiss socio-cultural forest monitoring, use them in an on-site forest-visitor survey at NFI sample plots and relate recreational use and forest perceptions to respective on-site forest data. This approach was successfully tested in a pilot study (Hegetschweiler, Plum, et al., 2017). The second approach which is the one we employed in the present study, is to take visualizations, e.g., in the form of photographs, of NFI sample plots with underlying forest data and use them in a survey. If successful, the approach could be used to integrate the relevance of forest characteristics stemming from any NFI with photo documentation into household and online surveys.

As the use of visualizations can be problematic due to the difficulty of capturing the real forest characteristics measured in the field on photographs (Palmer & Hoffman, 2001), we chose to derive the data directly from the photographs rather than to use field data from the locations the photos were taken from. The big difference is that this approach relies entirely on estimates from two dimensional pictures – direct measurements of the three dimensions are not possible. To our knowledge, this has never been tested and evaluated in a systematic way. Thus, the aim of the study was to test the method of using photos in an online survey and deriving forest characteristics from these photos according to NFI-criteria as a way of integrating data from National Forest Inventories into socio-cultural forest monitoring. Furthermore, we aimed to determine which NFI-variables and social parameters predict the visual attractiveness of forests and compare our results to findings in the literature as an indication of the plausibility of our model. Our research questions therefore were:

1) Is it possible to use photos in an online survey as a way of combining the data from the two monitoring instruments, NFI and the Swiss socio-cultural forest monitoring in the same statistical model?
2) Is it possible to derive forest data (physical forest characteristics) from photographs according to NFI-criteria and how consistent are the estimates?
3) Which physical and social parameters predict perceived visual attractiveness of forest as seen on photographs and are these findings in line with current literature?

Material and methods

Collection of physical forest data ("NFI-data")

Since NFI 4 (2009/17), each NFI-sample plot is documented with five photos taken in each cardinal direction from the centre of the sample plot and one facing the plot centre. Most photos can be found on the NFI-website (LFI, 2019). Starting point for the selection of photos for the survey was the pool of photos taken at sample plots with a high or very high recreational demand according to the local recreation potential model (Brändli & Ulmer, 2001). This model calculates the potential demand for recreation from the number of permanently and temporarily occupied households within a 2-km radius around each plot (Brändli & Ulmer, 2001). A sample size of 50 plots is recommended by Baltes-Götz (2013) for multilevel modelling. The selection of the photos then followed a process of elimination. Pictures that had been taken with non-foliated trees, blurred photographs and photos that had a large tree trunk or an impenetrable curtain of leaves directly in front of the camera lens were excluded as unsuitable for use in a survey. The selected photos covered various forest types and regions in Switzerland (Lowlands and Alps). Based on the NFI field survey manual (Keller, 2011, 2013) a set of parameters was defined to characterize the forest on the photos (see also Table 1). Eight parameters followed the definitions of the NFI (ground vegetation cover, shrub layer cover, cover of berry bushes, stand structure, stage of stand development, degree of mixture, crown closure, geomorphological objects). Five parameters were elements that are assessed in the NFI, but were adapted for the present, recreation-focused study: Stumps and lying dead trees normally form one variable in the NFI, as the aim is to estimate timber stock. For this study, we split stumps and lying dead trees into separate variables, as they are perceived as different elements by forest visitors. Snags (standing dead trees) were recorded irrespective of their estimated volume, whereas in the NFI, they are only considered at a volume > 1 m^3. Dead wood was recorded at an estimated diameter > 3 cm instead of > 7 cm, as small pieces of dead wood can be relevant for recreation, e.g. to build campfires. Root plates were not defined closer according to height and age as in the NFI, but simply recorded as present or not present. Eight, possibly recreation-relevant parameters were additionally defined: The presence of moss, ivy and ferns could be important for visual attractiveness and was therefore assessed as % of the picture covered and later recoded into present or not present. A high variability of DBH, i.e. a mixture of large and thin tree trunks, traces of logging and tree trunks from logging left at the edge of the road were recorded as present or not present. Finally, the average DBH of the trees and the average visibility range were estimated.

Each photo was independently evaluated by two experienced NFI-field team members, gathering NFI-data as if they were in the field. On photos depicting more than one forest stand (8 photos), both stands were assessed separately, although only data from the main stand were used for analysis. The evaluations were then harmonized by two scientists from the NFI for data analysis by majority decision. To evaluate the reproducibility of extracting forest data from photos, we compared both interpretation results. For categorical variables, we assessed the class distance (Table 1). For continuous variables, mean values and standard deviations were calculated.

Online survey

We conducted a nation-wide online survey in 2016 using the Swiss internet panel of the market research institute Bilendi. Using a pretest, the questionnaire was improved where necessary. Further, pretest data were checked for consistency. The link to the final questionnaire was then sent to members of the panel in German, French and Italian until given quotas regarding language, age, gender and level of education were filled. Quotas were based on census data of the Swiss population from the Swiss Federal Office of Statistics. The questionnaire was completed by 1090 respondents aged 14-65 years, among them 199 teenagers aged 14-18 years. Small incentives were given for participation. All respondents who had taken less than 8 min. to complete the entire questionnaire (89 respondents) were removed, resulting in 1001 respondents. There were 633 respondents from the German-speaking part, 317 from the French-speaking part and 51 respondents from the Italian-speaking part. A comparison between the quotas and Swiss census data can be found in the supplementary materials (Tables S1-S4).

Contents of the questionnaire

The questionnaire was developed based on expert interviews, and on the WaMos-questionnaire (Hunziker et al., 2012). At the start of the questionnaire, each respondent was shown 6 randomly selected photos out of the pool of 50 and asked to rate the perceived visual attractiveness on a scale from 1–10. Respondents were asked about their own inherent forest preferences in forests close to their home, e.g. whether they generally preferred deciduous or coniferous forest, irrespective of the forest they were being asked to rate. Additionally, they were asked about their reasons for and against visiting forests. The questionnaire ended with socio-demographic questions (age, gender, education, postal code of place of residence, parents' country of origin, forest ownership, profession, membership in environmental organisations, disabilities and number of children in household) and questions related to the importance of forest in the respondents' childhood (membership in scouts and other youth groups, regular forest visits with school or kindergarten, non-organised play in forests).

Data preparation and analysis

A factor analysis with promax rotation was conducted to reduce general forest preferences, motives for visiting and reasons for not visiting forest (tables in the supplementary materials, S5-S7). This procedure reduces complexity in data and detects underlying constructs based on the contributing variables (Frick et al., 2018). The result is a set of factors into which the variables are grouped, which can then be interpreted and named as underlying constructs. Factor loadings indicate the correlation between the single variables and the factors and, therefore, how much of the variable is explained by the factors (Frick et al., 2018). We chose promax rotation to allow for correlations between the resulting factors, as social constructs are rarely completely uncorrelated (Field, 2009).

General forest preferences were reduced to the following five underlying factors (Table S5):

- "Preference for wilderness" (lying and standing dead trees, woody debris, rocks and rocky terrain, dark and dense forest)
- "Preference for a high vegetation cover" (presence of moss, presence of ivy, high ground vegetation cover)
- "Preference for diverse forest" (high diversity of tree species, mixed forest, i.e. deciduous and coniferous trees, a lot of shrubs and young trees, forest clearings, mixture of large and thin tree trunks)
- "Preference for an adventurous forest" (informal trails, trees suitable for climbing, big trees with large trunks)
- "Preference for monoculture" (only coniferous trees or only deciduous trees)

Motives for visiting forest were reduced to the following three underlying factors (Table S6):

- "Freedom" (to smoke and drink, to consume drugs, to be unobserved in one's activities, to have sex, to be able to listen to loud music and make a noise)
- "Social reasons (to meet friends, to meet one's girl-/boyfriend, to spend time with one's family, to have fun)
- "Contemplative reasons" (tranquillity, enjoy nature, health reasons)

Reasons for not visiting forest were reduced to the following three underlying factors (Table S7):

- "Health risks" (fear of diseases transmitted by animals, fear of poisonous plants, dislike of mosquitoes and other insects, fear of ticks, hay fever)
- "Fear" (fear of being assaulted, fear of getting lost, fear of dogs, fear of having an accident, fear of meeting weird people, fear of being alone)
- "Uninteresting" (leisure time is spent outside forest, boredom, friends don't visit forest, too far away)

We then used multilevel modelling to determine predictors for the attractiveness of the forest depicted on the photos. Multilevel models vary at more than one level and are therefore suited to our research design (Ferron et al., 2006), in which forest visitors (individual level) are nested within forest sites (group level), see also Hegetschweiler, Plum, et al. (2017). As each respondent evaluated six photos, we developed a cross-classified multilevel model fit by REML (restricted maximum likelihood) with a random intercept and an unstructured covariance matrix with perceived visual forest attractiveness (rating of the forest on the photo) as a dependent variable. The number of missing values in the dataset was low (< 5%) and missing data was dealt with by listwise deletion of cases. To find out which NFI variables explain variance, a single model was calculated for each. Most of the variance was explained by stand structure, shrub layer cover, ground vegetation cover, lying dead trees, standing dead trees, geomorphological objects, traces of logging (including tree trunks lying at the edge of the forest road), the presence of ferns and the presence of ivy. Ground vegetation cover and cover of berry bushes correlated highly with stand structure, thus were omitted from the model. The variable "standing dead trees" was also omitted, due to rare occurrence. In addition, we determined for each photo whether it had been taken on a sunny day or not and added it as a variable. Foliation was also added as a variable. Even though we took care to choose photos with fully foliated trees, there were a few photos with partly foliated trees.

As a next step, variables on the individual level (respondents) were added one by one to test whether they explained any variance. At the same time, we tested whether the new variable increased or decreased the variance explained by the NFI-variables.

Twenty-eight photos had been taken in the lowlands and 22 photos in mountainous regions. Average attractiveness of the forests was the same for lowlands and mountains (mean lowlands = 6.79, SD = 2.07; mean mountains = 6.84, SD = 2.10; t = -0.958, df = 6004, p = 0.3). Because some NFI-variables only occurred in mountainous regions, i.e. geomorphological objects, and others only in the lowlands, i.e. tree trunks at the edge of the road, partly foliated trees and ivy, we calculated separate models for the lowlands and the alps using the same procedure as described above. This also allowed us to check if the model was valid for only a subset of the data and look at similarities and differences.

Data analysis was conducted using SPSS, version 23 (SPSS, 2015).

Results

Photo interpretation

Regarding the research question of deriving forest characteristics from photos in a consistent way, the evaluation of the photo interpretation revealed that for most variables the level of agreement between the two evaluators was high (>50%) for almost all variables (Table 1). Exceptions were the shrub layer cover (40% of photos) and crown closure (24% of photos). Crown closure was also the variable with the most differences that were >1 class. Presence/absence data were easiest to deduct from photos. Average DBH ranged from 3-55 cm (SD 0–7.5). Visibility ranged from 6–125 m (SD 0–99). The high standard deviations of the latter indicate the difficulty in estimating visibility from photos. Average moss cover ranged from 0–12.5% of the picture (SD 0–8.5), ivy cover from 0–20% (SD 0–5) and fern cover from 0–42.5% (SD 0–22.5). Due to the big differences between the two evaluators and the resulting high standard deviations, we recoded moss-, ivy- and fern cover into presence/absence data.

Table 1. Number (percentage) of photos for each NFI-parameter for which the estimation of two evaluators was the same, one class apart or more than one class apart.

Variable	Estimation the same	Estimation 1 class apart	Estimation >1 class apart
Ground vegetation cover*	31 (62%)	18 (36%)	1 (2%)

(6 classes)			
Shrub layer cover* (6 classes)	20 (40%)	26 (52%)	4 (8%)
Cover of berry bushes* (*Rubus*/*Vaccinium sp.*, 6 classes)	35 (70%)	11 (22%)	4 (8%)
Stand structure* (4 classes)	35 (70%)	10 (20%)	4 (8%)
Stage of stand development* (5 classes)	31 (62%)	15 (30%)	4 (8%)
Degree of mixture (% deciduous trees)* (4 classes)	42 (84%)	7 (14%)	1 (2%)
Crown closure* (8 classes)	12 (24%)	21 (42%)	17 (34%)
Geomorphological objects* (11 classes)	39 (78%)	6 (12%)	5 (10%)
Stumps >30 cm diameter** (yes/no)	38 (76%)	12 (24%)	
Lying dead trees >30 cm DBH** (yes/no)	47 (94%)	3 (6%)	
Standing dead trees >20 cm DBH** (yes/no)	47 (94%)	3 (6%)	
Woody debris >3 cm diameter** (yes/no)	39 (78%)	11 (22%)	
Root plates >30 cm height** (yes/no)	37 (74%)	3 (6%)	
High variability of DBH***, at least 2 classes, smallest class 7-12 cm (yes/no)	41 (82%)	9 (18%)	
Presence of moss*** (yes/no)	35 (70%)	15 (30%)	
Presence of ivy*** (yes/no)	47 (94%)	3 (6%)	
Presence of ferns*** (yes/no)	49 (98%)	1 (2%)	
Traces of logging*** (yes/no)	40 (80%)	10 (20%)	
Tree trunks at the edge of the road*** (yes/no)	48 (96%)	2 (4%)	

*NFI-parameters
**Adapted NFI-parameters
***Additional parameters

Predictors of perceived visual attractiveness

The results for multilevel regression analysis are shown in Tables 2 and 3. The unconditional model in Table 2 and the intraclass correlation coefficient (ICC) show that differences between depicted forests accounted for about 24% of the variation in the dependent variable "visual attractiveness of the forest", thus justifying the use of multilevel modelling.

Table 2. Unconditional multilevel model without predictors testing for variance in the dependent variable visual forest attractiveness on forest (group) level.

Parameter	Estimate	SE	df	t	Wald Z	p
Estimates of fixed effects						
Intercept	6.816	0.127	58	53.687		<0.001
Estimates of covariance parameters						
Residual	2.244	0.045			49.767	<0.001
Intercept (subject variance forest)	0.715	0.149			4.804	<0.001
Intercept (subject variance individual)	1.453	0.082			17.679	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Intraclass correlation coefficient ICC = $\frac{\text{Between group variance}}{(\text{Between + within group variance})} = \frac{u_{oj}}{u_{oj} + \varepsilon_{ij}} = \frac{0.715}{(0.715+2.244)} = 0.242$

Table 3. Multilevel model showing the relationship between physical forest properties of forests on 50 photographs, general forest preferences of respondents, motives for visiting and reasons for not visiting forests and perceived visual attractiveness.

Parameter	Estimates	SE	df	t	Wald Z	p
Estimates of fixed effects						
Intercept	6.059	0.547	91	11.074		< 0.001
Stand structure	0.214	0.169	41	1.268		0.2
Lying dead trees	-0.936	0.285	41	-3.289		0.002
Tree trunks at edge of road	-1.065	0.364	41	-2.929		0.006
Foliage	0.847	0.281	41	3.020		0.004
Sun/no sun	0.258	0.177	41	1.457		0.2
Shrub layer cover	-0.205	0.155	41	-1.322		0.2
Ivy on the trees	-0.431	0.245	41	-1.757		0.086
Ferns	-0.681	0.373	41	-1.822		0.076
Preference for wilderness	0.262	0.042	977	6.190		<0.001
Preference for diversity	0.120	0.045	977	2.687		0.007
Contemplative motives for visit	0.175	0.046	978	3.787		<0.001
Fear of forest	-0.131	0.041	977	-3.153		0.002
Age	0.005	0.003	977	1.752		0.080
Importance of forest in childhood	0.178	0.060	978	2.945		0.003
Non-organized playing in forest	-0.209	0.116	978	-1.802		0.072
German-speaking	-0.679	0.193	978	-3.519		<0.001
French-speaking	-0.371	0.197	978	-1.884		0.060
Italian-speaking						

Estimates of covariance parameters					
Residual	2.242	0.045		49.448	<0.001
Intercept (subject = forest)	0.345	0.081		4.264	<0.001
Intercept (subject = respondent)	1.225	0.073		16.821	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Variance explained per level = $1 - (\frac{Variance\ with\ predictors}{Variance\ without\ predictors})$

Group level variance explained = $1 - \left(\frac{0.345}{0.715}\right) = 0.517$

Individual level variance explained = $1 - \left(\frac{1.224}{1.453}\right) = 0.158$

Table 3 shows that on the level of the different forests, stand structure, lying dead trees, tree trunks lying at the edge of the forest road, shrub layer cover, ivy (*Hedera helix*) on the trees and the presence of ferns explained variance in visual attractiveness. Lying dead trees, tree trunks at the road edge and foliation were also significant and the presence of ferns marginally significant predictors for visual attractiveness. Lying dead trees and tree trunks due to logging left at the road edge before transport had a negative effect on visual attractiveness. Fully foliated trees increased visual attractiveness as did ferns growing in the understorey. In contrast, ivy growing on the trees was perceived negatively. Concerning stand structure, multi-layered, all-aged/all-sized and clustered forests were preferred to single-layered forests. However, a moderate shrub layer cover was perceived as more attractive than a high cover.

Although having nothing to do with the actual forest, whether the photo had been taken on a sunny day or not also explained some variance as photos with sun were liked better. However, sunshine was not a significant predictor. Overall, these factors explained 49% of the variance in visual attractiveness on group level (forest level).

On the individual level, inherent forest preferences, motives for forest visits and reasons for avoiding forests explained variance in visual attractiveness and were significant predictors. Depicted forests were perceived as more attractive by respondents with a preference for diverse forests and a preference for wilderness. Respondents who frequented forests mainly for contemplative reasons also perceived them as more attractive. On the contrary, respondents with a fear of forests rated the visual attractiveness lower. The importance of forest in the respondents' childhood contributed to a higher rating of visual attractiveness. German-speaking respondents (central and northern part of Switzerland) rated visual attractiveness lower than French-speaking (western part of Switzerland) and Italian-speaking respondents (southern part

of Switzerland). Overall, these social factors were able to explain 16% of variance in visual attractiveness on the individual level.
The reliability of the attractiveness ratings was evaluated by calculating the intraclass correlation coefficient for group and individual ratings (Palmer & Hoffman, 2001). The analysis showed a high reliability of the group's mean rating (intraclass correlation coefficient ICC for group (forest) average = 0.95). ICC for individual rating was 0.15.

The multilevel regression for lowland forests (Tables 4 and 5) revealed slightly different predictors for visual attractiveness than in the overall model. The unconditional model in Table 4 and the intraclass correlation coefficient (ICC) show that differences between depicted lowland forests accounted for about 26% of the variation.

Table 4. Unconditional multilevel model without predictors testing for variance in the dependent variable visual forest attractiveness on forest (group) level for forests in the Swiss lowlands.

Parameter	Estimate	SE	df	t	Wald Z	p
Estimates of fixed effects						
Intercept	6.775	0.172	30	39.352		<0.001
Estimates of covariance parameters						
Residual	2.228	0.065			34.165	<0.001
Intercept (subject variance forest)	0.770	0.216			3.565	<0.001
Intercept (subject variance individual)	1.415	0.098			14.422	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Intraclass correlation coefficient ICC = $\frac{0.770}{(0.770+2.228)} = 0.258$

Table 5. Multilevel model showing the relationship between physical forest properties of forests in the Swiss lowlands on 28 photographs, general forest preferences of respondents, motives for visiting and reasons for not visiting forests and perceived visual attractiveness.

Parameter	Estimates	SE	df	t	Wald Z	p
Estimates of fixed effects						
Intercept	4.719	0.607	66	7.771		<0.001
Degree of mixture (% deciduous trees)	0.288	0.096	20	2.994		0.007
Stand structure	0.351	0.283	20	1.240		0.2
Tree trunks at edge of road	-1.229	0.259	20	-4.735		<0.001
Foliage	0.829	0.208	20	3.986		0.001
Sun/no sun	-0.293	0.225	20	-1.298		0.2
Shrub layer cover	-0.366	0.171	20	-2.139		0.045

Ivy on the trees	-0.633	0.209	20	-3.024		0.007
Preference for wilderness	0.138	0.049	940	2.825		0.005
Preference for deciduous trees	0.106	0.053	929	2.020		0.044
Preference for bushes and shrubs	0.215	0.048	944	4.467		<0.001
Contemplative motives for visit	0.140	0.050	957	2.772		0.006
Fear of forest	-0.059	0.046	938	-1.295		0.196
Age	0.007	0.003	950	2.164		0.031
Importance of forest in childhood	0.118	0.067	944	1.764		0.078
Non-organized playing in forest	-0.254	0.128	932	-1.981		0.048
German-speaking	-0.589	0.214	931	-2.758		0.006
French-speaking	-0.354	0.218	927	-1.623		0.105
Italian-speaking						
Estimates of covariance parameters						
Residual	2.225	0.065			34.009	<0.001
Intercept (subject = forest)	0.160	0.058			2.769	0.006
Intercept (subject = respondent)	1.233	0.091			13.615	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Variance explained per level = $1 - \left(\frac{Variance\ with\ predictors}{Variance\ without\ predictors}\right)$

Group level variance explained = $1 - \left(\frac{0.16}{0.77}\right) = 0.792$

Individual level variance explained = $1 - \left(\frac{1.233}{1.415}\right) = 0.129$

For lowland forests, the percent of deciduous trees was a significant predictor. The higher the percentage of deciduous trees, the higher the rating of visual attractiveness. Corresponding to this, the higher the respondents' preference for deciduous trees, the higher they rated the attractiveness of the depicted lowland forests. The preference for diversity did not explain variance in the attractiveness of lowland forests and was therefore left out of the model. However, a high preference for bushes and shrubs led to a higher rating of attractiveness for these forests. The variance explained by forest characteristics amounted to 80% on group level. Social factors explained 13% of variance on individual level.

Tables 6 and 7 show the multilevel model results for forests in mountainous areas.

Table 6. Unconditional multilevel model without predictors testing for variance in the dependent variable visual forest attractiveness on forest (group) level for forests in the Swiss mountains.

Parameter	Estimate	SE	df	t	Wald Z	p
Estimates of fixed effects						

Parameter	Estimates	SE	df	t	Wald Z	p
Intercept	6.887	0.174	23.939	39.474		<0.001
Estimates of covariance parameters						
Residual	1.785	0.061			29.021	<0.001
Intercept (subject variance forest)	0.608	0.194			3.139	0.002
Intercept (subject variance individual)	1.995	0.125			15.925	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Intraclass correlation coefficient ICC = $\frac{0.608}{(1.785+0.608)} = 0.254$

Table 7. Multilevel model showing the relationship between physical forest properties of forests in the Swiss mountains on 22 photographs, general forest preferences of respondents, motives for visiting and reasons for not visiting forests and perceived visual attractiveness.

Parameter	Estimates	SE	df	t	Wald Z	p
Estimates of fixed effects						
Intercept	4.009	0.723	26	5.544		<0.001
Degree of mixture (% deciduous trees)	0.805	0.479	14	1.679		0.115
Stand structure	0.203	0.156	14	1.303		0.2
Sun/no sun	1.134	0.236	14	4.796		<0.001
Shrub layer cover	-0.261	0.234	14	-1.113		0.3
Geomorphological objects	0.282	0.228	14	1.236		0.237
Woody debris	-0.502	0.188	14	-2.678		0.018
Lying dead trees	-0.309	0.237	14	-1.304		0.2
Preference for bushes and shrubs	0.082	0.052	926	1.575		0.1
Preference for woody debris	0.180	0.060	928	3.004		0.003
Preference for lying dead trees	0.148	0.057	922	2.593		0.010
Contemplative motives for visit	0.237	0.054	918	4.360		<0.001
Fear of forest	-0.211	0.052	919	-4.089		<0.001
Importance of forest in childhood	0.187	0.063	917	2.984		0.003
German-speaking	-0.619	0.237	952	-2.616		0.009
French-speaking	-0.416	0.245	956	-1.693		0.091
Italian-speaking						
Estimates of covariance parameters						
Residual	1.792	0.062			28.696	<0.001
Intercept (subject = forest)	0.118	0.052			2.256	0.024
Intercept (subject = respondent)	1.624	0.111			14.618	<0.001

SE = standard error, df = degrees of freedom, t = obtained t-value (significance test of fixed effects in the model), Wald Z = Wald test statistic (significance test of random effects in the model)

Variance explained per level = $1 - \left(\frac{Variance\ with\ predictors}{Variance\ without\ predictors}\right)$

Group level variance explained = $1 - \left(\frac{0.118}{0.608}\right) = 0.806$
Individual level variance explained = $1 - \left(\frac{1.624}{1.995}\right) = 0.186$

Forests in the mountains consist of coniferous trees, interspersed by deciduous trees in the lower parts. These mixed forests were slightly preferred to the pure coniferous stands. Stand structure again explained some variance. Multi-layered, all-aged/all-sized and clustered forests, being preferred to single-layered forests. Clustered forests (spatial distribution of trees into groups) can only be found in the mountains. In these areas, forests can also contain geomorphological objects such as large rocks and bands of rock and the presence of these was positively evaluated by the respondents. In contrast to lowland photos, woody debris significantly lowered visual attractiveness. Corresponding to this, the preference for woody debris explained variance in visual attractiveness. As in the overall model, lying dead trees were perceived negatively. Correspondingly, a preference for lying dead trees was a significant predictor for attractiveness. Tree trunks at the edge of the road did not occur in mountainous forests, foliage was not relevant, as mountain forests are evergreen and ivy was not present on the photos. Thus, these parameters were not included in the model. For the mountainous forests, forest characteristics explained 81% of the variance on group level, while social factors explained 19% of the variance on individual level.

Table 8 gives an overview over the predictors for visual attractiveness in all three models. On group (forest) level, stand structure and sunshine were predictors in all models. On individual (respondent) level, the same applies to contemplative motives, fear, importance of forest in childhood and language region of the respondents. Some differences between mountains and lowlands were found in the inherent forest preferences – different preferences predicted visual attractiveness in the different regions.

Table 8. Overview of predictors for visual attractiveness of forests on 50 photographs in an overall multilevel model, a model for lowland forests and a model for mountain forests.

Predictors	**All photographs**	**Lowlands**	**Mountains**
Group (forest) level variance explained	*49%*	*80%*	*81%*
Degree of mixture		x	x
Stand structure	x	x	x
Lying dead trees	x		x
Tree trunks at road edge	x	x	
Foliage	x	x	
Geomorphological objects			x

Woody debris			x
Sun/no sun	x	x	x
Shrub layer cover	x	x	x
Ivy on the trees	x	x	
Ferns	x		
Individual level variance explained	*16%*	*13%*	19%
Preference for wilderness	x	x	
Preference woody debris			x
Preference lying dead trees			x
Preference deciduous trees		x	
Preference for diversity	x		
Preference bushes/shrubs		x	x
Contemplative motives	x	x	x
Fear of forest	x	x	x
Age	x	x	
Importance of forest in childhood	x	x	x
Non-organized playing	x	x	
Language region	x	x	x

Considering all three models (all photos, lowlands and mountains), the presence of tree stumps, the presence of root plates, the presence of moss, average DBH, high variability of DBH, crown closure, visibility range and the stage of stand development did not explain any variance in visual attractiveness. Concerning the social parameters, preferences for a high vegetation cover, for adventurous forests and for monocultures did not explain variance in the three models. Social reasons and perceived freedom in the forest as reasons for forests visits and health risks and boredom as reasons for not visiting forests also had no influence on visual attractiveness. The same applies to most socio-demographic factors (gender, education, urbanity of residence, country of origin, forest ownership, profession, membership in environmental organisations, disabilities and number of children in household). Regular visits to forests with youth groups, school or kindergarten also did not explain variance, were however correlated to the importance of forest during childhood.

Discussion

The first goal of our study was to test a new method of integrating data from National Forest Inventories into socio-cultural forest monitoring. In accordance with the confluence model mentioned in the introduction, social factors such as preferences and motives as well as physical forest characteristics had an influence on the perceived visual attractiveness of forests.

Photo interpretation

In response to our second research question, the evaluation of the photo interpretation showed that for almost all categorical variables a high level of agreement was reached between the two experts. Schroeder and Anderson (1984) came to a similar conclusion in their assessment of features directions. Therefore, the experts tried to estimate crown closure by looking at stem density on photographs by two researchers. Notable exception was crown closure. Crown closure is normally estimated in the field by directly looking at the forest canopy and assigning the canopy to one of eight categories. However, the canopy was not captured on the photos taken in the four cardinal and ground vegetation and shrub layer cover, which are directly influenced by crown closure via the amount of sunlight reaching the forest floor. This approach was not accurate enough. Since 2019, the NFI uses 360-degree cameras instead of the photos in the four cardinal directions. On these 360-degree photos, it is possible to see the canopy, so possibly we will be able to deduct crown closure from photos more reliably in future, an important development, as crown density has been found to influence scenic beauty (Chen, Sun, Liao, Chen, & Luo, 2016).

The level of agreement between the two evaluators was also relatively low for shrub layer cover. The shrub layer is defined as the layer between 0.5-3 m height, and the evaluators found the estimation of the 3-dimensional shrub layer cover difficult on 2-dimensional photos, especially when looking at hilly terrain (Düggelin & Fischer, personal communication, April 2019).

Estimating visibility in meters from photographs was not successful, as the high standard deviations of our visibility distances indicate. Ribe (2009) also inspected photos to estimate the depth of visual penetration, but kept to the categories high, medium and low, which worked better than attempting to determine a numerical value, but is not very accurate. It might be necessary to measure visibility at the site where the photographs are taken from, e.g. by using a screenometer (Rudis, 1985), a Vertex ultrasound instrument (Nielsen et al., 2012) or terrestrial laser scanning (Murgoitio, Shrestha, Glenn, & Spaete, 2014).

Based on the results from the photo interpretation, we can conclude that deriving physical forest characteristics from photos was successful for most categorical variables we used, with the exception of crown closure and to a lesser extent shrub layer cover. The estimation of numerical variables however, requires a degree of precision not possible when using photos as a substitute for on-site measurements. This poses some limitations on the selection of variables to be used in such a study. The NFI contains a lot of numerical measurements, of which several could be relevant for recreation and visual attractiveness. Examples include stand height, stand age, number of stems per hectare, amount of dead wood, sizes of any elements such as root plates, rocks, etc. Most numerical variables were not considered in our study from the beginning and those that we did use were either recoded into presence/absence data (moss-, ivy- and fern cover) or were included with average values but did not show any effect (average DBH, visibility range). For latter variables it is not clear, if there really was no effect or if the estimates derived from the photos were not accurate enough.

Predictors of perceived visual attractiveness – physical forest characteristics

The third aim of the study was to compare predictors of visual attractiveness to other findings to check the plausibility of our approach. Recent work indicates that there are connections between forest characteristics and perceived cultural ecosystem services (Baumeister, Gerstenberg, Plieninger, & Schraml, 2020), forest benefits (Meyer, Rathmann, & Schulz, 2019) and the choice of forest sites for recreation (Agimass, Lundhede, Panduro, & Jacobsen, 2018). The three multi-level models revealed that lying dead trees, tree trunks at the edge of the road as a sign of logging activities in the lowlands and woody debris in the Alps had a negative effect on visual attractiveness. This finding is in line with numerous studies showing that traces of forest management, logging residues and dead and decomposing wood are highly disliked attributes (Eriksson, Nordlund, Olsson, & Westin, 2012; Nielsen et al., 2012; Tyrväinen et al., 2003), although reverse effects have been found (Hauru et al., 2014). Dead wood is perceived as highly ambivalent and can be positively or negatively connotated, depending on the cultural and geographical context (Pastorella et al., 2016) or on sociodemographic parameters such as age, gender and number of children (Rathmann et al., 2020). Furthermore, not only the presence of dead wood, but also the amount, type and decomposition grade can influence the evaluation (Rathmann et al., 2020) and these factors could not be captured in the present study. Lying dead trees were negatively perceived on mountain photos, but not on lowland photos. This could possibly be due to the knowledge about the protection function of mountain forests against natural hazards, which is rated as one of the most important forest functions by the Swiss population (Hunziker et al., 2012) and which cannot be fulfilled by dead trees. Concerning the understorey, in all three models a moderate shrub layer cover was preferred to a high cover. This is in line with current literature suggesting that a medium understorey and ground vegetation height enhances the aesthetic experience, although a low understorey is preferred for recreational purposes (Giergiczny, Czajkowski, Zylicz, & Angelstam, 2015; Wang et al., 2017). The presence of moss did not explain variation in visual attractiveness, in contrast to Nielsen et al. (2012), but moss might also have been hard to see on the photos. Stand structure explained variance in visual attractiveness, with multi-layered, all-aged/all-sized and clustered forests being preferred to single-layered forests. This is also in line with other research showing that uneven stands with groups of trees (clusters) or a mixture of trees of different sizes receive the best attractiveness scores (Carvalho-Ribeiro & Lovett, 2011; Giergiczny et al., 2015; Gundersen & Frivold, 2008). Stand structure is certainly an important factor, but in our study not as relevant as some of the other factors discussed above. All in all, our approach of using photos in a survey and deriving forest characteristics from the photos delivered results comparable to numerous other studies.

Predictors of perceived visual attractiveness – social factors

When considering all sites, contemplative motives for visiting forests explained variance in visual attractiveness, whereas social reasons and freedom-related motives did not. If visitors frequent forests for contemplative reasons such as enjoying nature and tranquillity, it is important what the forest is like. However, if people go to the forest for social reasons, its appearance is of minor importance. Concerning freedom-related motives, it is probably most important that the forest offers some cover and a feeling of privacy, rather than aesthetic beauty. Fear of forests had a negative impact on perceived visual attractiveness, while health risks and finding forests uninteresting did not explain variance. Research has shown that perceived safety in urban parks and forests varies according to the physical features of the park (Schroeder & Anderson, 1984). The importance of the forest in the respondents' childhood was a significant predictor for perceived visual attractiveness. This is in line with Hunziker et al. (2012) who showed that the attractiveness of the forest visited most often increased with the importance of forest during childhood. Similar to related studies (Chen et al., 2016; Eriksson, Nordlund, Olsson, & Westin, 2012), most socio-demographic factors had no influence on perceived visual attractiveness. In contrast, gender, age, housing style and education had an effect on the evaluation of scenic beauty in Tyrväinen et al. (2003). Respondents from the German-speaking part of Switzerland evaluated the depicted forests more negatively than respondents from the French- and Italian-speaking parts. This finding is partly consistent with Hunziker et al. (2012), where forest attractiveness was rated highest by Italian-speaking respondents, followed by German- and French-speaking respondents. These findings might be attributed to cultural differences in the perception of nature in the three language regions of Switzerland (Brechbühl & Rey, 1998). However, the exact reasons for the pattern we found remain unclear.

Linking socio-cultural forest monitoring with the National Forest Inventory

Overall, deriving physical forest characteristics from photos was successful for a number of categorical variables. The respective parameters turned out to be reliable predictors for perceived visual attractiveness of the forest and the results were in line with other field and photo studies. Interpreting photographs and using them in an online survey turned out to be an economical alternative to field measurements of forest characteristics or even to conducting the whole survey in the field. One advantage of an off-site study is the possibility to include non-forest visitors as well, and not only forest visitors that might be walking there because they like that particular forest. It is also easier to integrate various aspects of people's relationship to the forest other than recreation, as it is the purpose of the Swiss socio-cultural forest monitoring (Hunziker et al., 2012). In an on-site study, in contrary, respondents are likely to be there for recreational purposes, hence giving a certain focus to the study.

One big disadvantage of using visualisations is that the effects of interest can easily be over-estimated because respondents' attention can be artificially focused on the visualisations and the differences they expect to see (Hegetschweiler, Plum, et al., 2017). Field surveys, on the other hand, measure the effect of the real situation, where the measured factors of interest might have smaller perceptual effects than expected. A field study offers more possibilities to incorporate all sensual dimensions, i.e. sounds, scent of nature, the feel of certain elements, not only visual aspects, but it also increases confounding variation in the answers, due to context depending factors, such as weather condition and time at the interview. Another limitation of our study was that the photos had been taken purely for documentation purposes and not with the intent of being used in a survey. In order to properly implement the use of photos with underlying NFI-date in socio-cultural forest monitoring, the photos would have to be taken in a standardized way suitable for being employed in a survey. Ideally, photos should be taken in such a way, that only one stand is visible on the picture. This is necessary to ensure that the respondents really evaluate the stand the data was taken from. In the NFI, only data from the main stand on the sample plot is recorded. On the eight photos in our study with two stands, we cannot be absolutely sure that the respondents were evaluating the main stand which we took the data from. It is possible that having several different stands next to each other in a larger forest area is important to forest visitors, however, in order to gain information on this, other methods need to be employed.

Conclusions

In our study we tested a new method of integrating photographs from the Swiss NFI-database into an online survey and deriving forest characteristics directly from the photos rather than measuring them in the field. Deriving physical forest characteristics from photographs proved to be successful for a number of categorical variables and could be an economical alternative to resource-intensive field studies, as long as no numerical values are needed. As stipulated by the confluence model, our study revealed that both social and physical factors influence perceived visual attractiveness of forests. The results are in line with other studies conducted on-site and off-site, implying that our method delivers reliable results and could be a way of combining data from the National Forest Inventory with socio-cultural forest monitoring. For a real evaluation, we recommend conducting a field study in combination with an online survey with photos from the same field study sites. This would enable to compare the ratings of the same sites in different contexts (field or online) and evaluate whether off-site surveys with visualisations provide results comparable to field surveys. If so, updated visualisations of NFI-plots could be routinely included in each round of socio-cultural forest monitoring together with a standard set of physical variables relevant for recreation and visual attractiveness to be derived from the photos, thus enabling an effective integration of National Forest Inventory data into socio-cultural forest monitoring.

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