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Research Paper

Towards a comprehensive social and natural scientific forest-recreation monitoring instrument—A prototypical approach

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ABSTRACT

Forest policy planning and broad-scale management is often based on forest inventory data in many countries. However, the importance of social aspects such as aesthetic and recreational values is increasing, especially in urban areas, and need to be considered in forestry practice. We conducted a forest visitor survey at selected National Forest Inventory (NFI) sample plots in order to test whether this would be a way of integrating the social dimension of forest with national forest inventories toward a more comprehensive forest monitoring instrument, focusing on forest recreation and aesthetics. Visitors were asked to rate the visual attractiveness of the NFI plot and the surrounding forest. Multi-level modeling combining both plot-related inventory data and visitor-related questionnaire data showed that perceived forest attractiveness is determined by both social and physical factors. We conclude that it is worth further developing this method with the aim of implementing forest visitor surveys at a subset of NFI plots during routine field assessments, and, thus, significantly improving monitoring of forest recreation.

1. 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). Forest management traditionally relies, besides other tools, on forest inventory data to address planning issues (Rudis, Gramann, Rudell, & Westphal, 1988). In order to meet the increasing recreational needs of urban populations, new multidisciplinary approaches to forestry are needed (Konijnendijk, 2003). Sheppard, Achiam, and D'Eon (2004) emphasize the relevance of integrating aesthetics and other social dimensions into forest certification. Rudis et al. (1988) point out the growing need to link public aesthetic perceptions with forest inventory parameters. What is needed is a planning and inventory tool bridging both aspects of forestry: the natural scientific, wood production and biodiversity related physical side, as well as the social dimensions.

One possible theoretical model describing this bridge between physical and social factors is proposed as the so-called "confluence model" in Hegetschweiler et al. (2017). According to the confluence model, physical factors such as characteristics and facilities of forests and other green spaces form the basis for the supply of cultural ecosystem services as defined by the Millenium Ecosystem Assessment (MEA, 2005). Social factors characterizing the population determine the demand for cultural ecosystem services offered. Use of services provided and subsequent benefits generated by the use of these services is a result of a spatial match between the physical and social factors (Hegetschweiler et al., 2017). The benefits that people draw from recreating in the forest are undisputed and several authors have reported positive effects of general health and well-being (Hartig, Mitchell, de Vries, & Frumkin, 2014; Martens, Gutscher, & Bauer, 2011; Russell et al., 2013). Management of natural areas, including forests, needs to better integrate social and biophysical components in order to maximize benefits to visitors while maintaining these areas as diverse, productive and sustainable ecosystems (Driver, 1996; Driver, Manning, & Peterson, 1996).

Assessment of forest characteristics, resource availability and

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evaluation of the state of forests has been traditionally carried out by National Forest Inventories (NFIs) (Tomppo, Gschwantner, Lawrence, & McRoberts, 2010) which also holds true for Switzerland. Modern NFIs use statistical sampling designs, mostly with plots on systematic grids covering whole countries (for a good overview of applied sampling designs see Lawrence, McRoberts, Tomppo, Gschwantner, and Gabler (2010)). Social aspects, including the increasing recreational function of forests, are often only marginally being considered by national forest inventories. Although the recreational function has been a topic of the Swiss NFI since the second survey (1993–95), only infrastructure for and damage by recreational use are investigated. The potential recreational demand and attractiveness of the forest are predicted using models based on physical data and forester surveys (Brändli & Ulmer, 2001). In the latter, questions about recreation, e.g., intensity, type and seasonality are asked (Brändli, 2010). Likewise, the Dutch Inventory interviewed policy makers for additional variables related to recreational use (Daamen & Dirkse, 2010). However, direct measures of people's attitudes, such as forest preferences or recreational satisfaction, and behavior, such as time spent in the forest, aesthetic perceptions or recreational activities, are completely lacking so far.

On the other hand, nationwide household surveys conducted in several countries on a regular basis provide valuable information about the relationship of the general public to the forest, usage patterns and motivations for forest recreation (Sievänen et al., 2008). Examples include the England Leisure Visits Survey ELVS (Ward, Grant, & Snowling, 2008); the Forest and Folk Project and Outdoor Life Project in Denmark (Jensen & Skov-Petersen, 2008); and the National Outdoor Recreation Demand and Supply Assessment LVVI in Finland (Sievänen & Pouta, 2008). In Switzerland, the socio-cultural forest monitoring WaMos (Waldmonitoring soziokulturell) has been conducted twice up to now − in 1997 (BUWAL, 1999) and in 2010 (Hunziker, von Lindern, Bauer, & Frick, 2012). While these assessments examine the social dimension of forest recreation, there is no spatial link to the physical forest.

Numerous studies have measured people's perceptions and preferences of landscapes and forests (Carvalho-Ribeiro & Lovett, 2011; Daniel & Boster, 1976; Kaplan & Kaplan, 1989). These normally work with verbal stimuli, photographs, digitally edited photographs or computer-generated images (Gundersen & Frivold, 2008). Many studies have focused mainly on certain forest management activities like thinning regimes, harvesting practices or the occurrence of dead wood (Hauru, Koskinen, Kotze, & Lehvävirta, 2014; Petucco, Skovsgaard, & Jensen, 2013; Ribe, 2009; Shelby, Thompson, Brunson, & Johnson, 2003; Silvennoinen, Pukkala, & Tahvanainen, 2002; Tyrväinen, Silvennoinen, & Kolehmainen, 2003). Others focused their research on forest characteristics like forest structure, visibility within the forest, forest age, growing stock, ground vegetation or diameter distribution (Brown & Daniel, 1986; Buhyoff, Hull IV, Lien, & Cordell, 1986; Chen, Sun, Liao, Chen, & Luo, 2015; Gong, Zhang, & Xu, 2015; Ribe, 1990; Silvennoinen, Alho, Kolehmainen, & Pukkala, 2001). A good overview of Scandinavian studies on preferences for forest structure can be found in Gundersen and Frivold (2008).

Most of the published studies we found were conducted in North America or Scandinavia, in regions where coniferous forests dominate. A comparison to Swiss conditions should be possible but species composition and forest management is distinctively different in Switzerland. One such example is that clear cutting is forbidden by law and selective logging is usually applied. On the other hand, Ribe, Ford, and Williams (2013) showed that forest perceptions vary between regions making generalizations difficult. In addition, forest visitors' forest preferences and perceptions can change based on the provision of information (Gundersen & Frivold, 2011; van der Wal et al., 2014).

In the following, we present a study describing the first step to develop an instrument to measure visual attractiveness of forests that integrates social and physical aspects and is closely related to or potentially part of an NFI. Visual attractiveness serves as one possible measure for recreational value and corresponds to the aesthetic service of the forest in terms of cultural ecosystem services (MEA, 2005). In the above-mentioned confluence model, visual attractiveness is the dependent use and benefit variable determined by physical factors assessed by the NFI and social factors assessed by socio-cultural forest monitoring. As mentioned above, NFIs assess physical forest characteristics using statistical sampling designs. In contrast, socio-cultural forest monitorings are usually carried out by household surveys investigating the social dimension of forest recreation. Both aspects need to be considered in 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 physical and social data. We are aware of two possible approaches. One 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. Then, forest data is fitted using regression models to predict the recreational value (or some other related score) of the forest (Edwards et al., 2011; Rudis et al., 1988; Vega-Garcia, Burriel, & Alcazar, 2011). The second approach is to take (parts of) the questionnaire from a household survey, e.g., the Swiss socio-cultural forest monitoring, use them in a forest visitor survey at NFI sample plots and relate recreational use and forest perceptions to on-site forest data. To our knowledge, this latter approach has never been tested and if valid could be applied to any sample based NFI. The advantage is that respondents can assess the changing experience of forest characteristics of real plots, instead of being restricted to what can be captured in photos. Research comparing field and photograph ratings in visual landscape assessments suggest caution in the use of photographic representations, even though this is common practice in landscape preference studies (Palmer & Hoffman, 2001). In addition, an on-site study providing same-point specific data concerning human-environment interactions there, may increase its applicability in urban planning (Kabisch, Qureshi, & Haase, 2015).

Our long-term goal − not yet the concrete objective in this pilot phase of method development here − is to predict the recreational value of forests using data from both social and physical monitoring instruments relevant to forest recreation. The social aspects include societal values, general psychological needs and specific forest preferences. The physical data include distance from home, forest characteristics and state of the forest. If the required data is available on a fine spatial scale, such a comprehensive model can provide indications of which forests are especially attractive for forest recreation. This can be a good basis for decisions in forest planning and management, e.g., to aid discussions in which areas to promote forest recreation and in which areas to potentially restrict recreation. Such measures might be necessary if human presence is not wanted due to a prioritization of wood production or nature conservation.

The actual objective of the herewith presented pilot study, however, was to develop a method for data collection and test whether it delivers interpretable and plausible results (even if not yet valid and reliable in terms of measurement), which could later lead to a wider sampling application in form of the above-mentioned monitoring tool to predict visual attractiveness as a partial measure for the recreational value of forests. Once this method is established, it could be used for numerous other measures of recreational value as well. To achieve this method-development objective, the following research questions had to be answered:

- How can a forest visitor survey be carried out so that data from the two monitoring instruments, NFI and the Swiss socio-cultural forest monitoring, can be combined in one statistical model?
- How might this data help enable prediction of visual attractiveness of forests combining physical forest characteristics with social data?

2. Materials and methods

2.1. Methodology

We conducted a forest visitor survey at selected NFI plots and used both social data and physical forest data to tentatively predict average perceived forest attractiveness as a prospective measure for the recreational value at these sites. To aid data analysis and clarify the measurement constructs, we devised a conceptual model in which the three dependent variables 1) perceived visual attractiveness, 2) recreational activities at the time of the interview, and 3) frequency of visits to the interview site were potentially influenced by a) socio-demographic factors, b) visitor's general preferences for forests regardless of the actual forest they were recreating in at the time of the interview, and c) physical forest characteristics. In this article, we focus on the relationship between the dependent variable visual attractiveness and socio-demographics, general forest preferences and physical forest characteristics. For the moment, we assume that visual attractiveness can be directly influenced by our independent variables. We are, however, aware that more complex relationships might exist. The methods of data collection and analysis may be transferable to other dependent variables as well.

2.2. Study area

The study was conducted in selected forests in the cantons Zurich (ZH), Aargau (AG) and Solothurn (SO) in Switzerland. All three cantons are densely populated and dominated by urban and peri-urban areas. Using aerial photographs, we selected NFI plots where the surrounding 25 ha of forest were similar regarding forest type and height structure, because visitors are likely to perceive a fairly large section of the forest. Therefore, we searched for areas in which the plot-data would be representative for the surrounding forest area as well. We stratified the selected NFI plots using a forest type map (BFS, 2004) and a vegetation height model (Ginzler & Hobi, 2015). Using the forest type map, we differentiated coniferous and broadleaf dominated forests with a resolution of 50 × 50 m, whereas the vegetation height model had a resolution of 1 × 1 m. The similarity between the NFI plot and the surrounding forest was based on tree heights, height variability and forest type with a 25-ha minimum area. All selected sites were located near residential areas and high or moderate recreational use of the forest had been predicted by the potential-visitation map of the NFI (Brändli & Ulmer, 2001).

After field inspection, the homogenous areas coming from the remote sensing stratification were still too heterogeneous when seen from the ground. The heterogeneity was mostly related to the forest height structure and species composition. Both are difficult to assess as our vegetation height model provides no information on the vertical structural diversity below the forest canopy. In addition, the forest type map is based on remote sensing data from the 1990′s. Since then the forest composition and its management have changed in many places. Thus, seven sites were chosen by expert decision to conduct an on-site forest visitor survey. The selected sites were homogeneous within the visible area around the NFI plot, but differed from one another in forest type (degree of mixture of coniferous and broadleaf trees) and stand structure. These differences were later verified by NFI-data (see Table 1).

2.3. Sample and survey

In May and June 2014, a standardized questionnaire was distributed at these sites, i.e., at the footpath nearest to the NFI plot, and completed on-site by 888 forest visitors (more than 100 at each site). The questionnaire (Appendix A) consisted of a subset of questions that had been asked during the 2010 household survey (Swiss socio-cultural forest monitoring, Hunziker et al., 2012), adapted to the on-site context. It had been pretested in the field twice to ensure the clarity of the questions and the optimal length. The questionnaire consisted of general questions concerning activities the respondents were undertaking in the forest at the time of the interview, frequency of visits and socio-demographics. The core part was the question asking respondents to look in direction of the NFI plot and rate the perceived visual attractiveness of the forest on a scale from 1 to 10 (Question 6). Respondents were also asked about their own inherent forest preferences, e.g., whether they generally preferred broadleaved or coniferous forest, irrespective of the forest they were being asked to rate (Question 9). Additionally, the respondents were shown photos of all the sites and asked about their preferences concerning each depicted forest (Questions 7 and 8). Because the study had originally been planned with 8 sites, of which one site had to be abandoned due to too few visitors, there were 8 pictures in the questionnaire. The photos were only used to learn more about visitor's inherent preferences in a more intuitive way, not to rate attractiveness, as the photos had not been taken in a standardized way and did not necessarily cover exactly the same viewpoint that the forest visitors had.

When collecting the data on physical forest properties, we encountered three major problems. One (already mentioned) was the heterogeneity of the forests generally found in most parts of Switzerland. The second was that visitors perceive a larger section of the forest than the 50 × 50 m NFI sample plot. The third was that the actual NFI plots were not always visible from the interview location on the nearest footpath. We tried to solve these problems by collecting data on physical forest properties in four systematically arranged 50 × 50 m plots in the field of view, each plot having the same design as a standard NFI plot (Fig. 1). This way we could cover a bigger area than one NFI plot alone which helped account for the heterogeneity of the forest sites as well as for the larger angle of vision that the forest visitors had. The data collected consisted of a subset of parameters normally examined in NFI plots (Keller, 2011) and included structure, size, height and age of the stand, stage of stand development, crown closure, cover of ground vegetation and shrub layer, tree species, degree of mixture of coniferous and broadleaved trees, root plates, stumps and lying dead trees (Table 1). The parameters were assessed by the same methods used in the NFI, i.e., by looking at the plots and noting down the respective values in a standard form. This expert assessment was conducted by an experienced NFI field technician. Table 1 shows the characterization of the forest sites according to NFI criteria. To check the reproducibility of the terrestrial sampling under different seasonal conditions, forest data were collected twice, with and without foliation.

2.4. Data preparation and analysis

A factor analysis with varimax rotation was conducted to reduce both general forest preferences and the ratings of the photos. General forest preferences were reduced to the three underlying factors “preference for large structures” (lying and standing dead trees, woody debris, rocks and rocky terrain, slopes and ditches), “preference for diverse forest” (high diversity of tree species, streams and ponds, shrubs and young trees) and “preference for open broadleaved forest” (forest clearings, predominantly broadleaved trees; Appendix B). Preferences for the forests shown in photos were reduced to three factors: “monotonous, predominantly coniferous forest”, “bright green, broadleaf forest” and “untidy forest” (Appendix C). Furthermore, all items dealing with dead wood in the broader sense (including standing dead trees) were combined to one factor “dead wood” (Appendix D).

Different ways were discussed on how to deal with the forest data from the four 50 × 50 m plots. One option would have been to take the arithmetic means from all four plots. This, however, does not take into account that forest characteristics close to the forest visitors would be perceived more strongly than characteristics far away. Considering this, another option would have been to use only the values from the plot

Table 1
Characterization of the 7 forest sites chosen for the visitor survey.

	Stand structure (0 = single-layered 1 = multi-layered)	Stand size (1 = 5–9 ares 2 = 10–49 ares 3 = > 50 ares)	Stand height (meters)	Stand age (years)	Number of tree species	Stage of stand development (1 = dominant DBH < 12 cm 2 = dominant DBH 12–30 cm 3 = dominant DBH 31–40 cm 4 = dominant DBH 41–50 cm 5 = dominant DBH > 50 cm)
Ebmatingen Hasenbuel (ZH)	multi-layered	ca. 50	22	65	3	ca. 40 cm
Aarau Hungerberg (AG)	single-layered	> 50	27	40	5	31–40 cm
Ebmatingen Wassbergholz (ZH)	multi-layered	> 50	35	90	4	41–50 cm
Zurich Dolder (ZH)	multi-layered	ca. 10	35	95	5	ca. 40 cm
Aarau Schachen (AG)	multi-layered	> 50	35	68	3	ca. 40 cm
Olten Kantonsschule (SO)	single-layered	> 50	10	15	5	12–30 cm
Untersiggenthal (AG)	multi-layered	ca. 50	30	90	4	ca. 40 cm

	Crown closure 1 = crowded 2 = normal 3 = loose 4 = spaced 5 = dissolved	Ground vegetation cover 1 = < 1% 2 = 1–9% 3 = 10–25% 4 = 26–50% 5 = 51–75% 6 = 76–100%	Shrub layer cover 1 = < 1% 2 = 1–9% 3 = 10–25% 4 = 26–50% 5 = 51–75% 6 = 76–100%	Degree of mixture (% conifers) 1 = 91–100% 2 = 51–90% 3 = 11–50% 4 = 0-10%	Root plates 1 = none 2 = former 3 = small 4 = large	Stumps and lying dead trees 0 = none 1 = present
Ebmatingen Hasenbuel (ZH)	crowded	ca. 25%	ca. 10%	91–100%	none	present
Aarau Hungerberg (AG)	normal	ca. 25%	< 1%	ca. 90%	present	present
Ebmatingen Wassbergholz (ZH)	crowded	ca. 1%	26–50%	ca. 90%	none	present
Zurich Dolder (ZH)	normal	ca. 50%	ca. 50%	ca. 50%	present	none
Aarau Schachen (AG)	normal	ca. 25%	ca. 75%	ca. 10%	present	none
Olten Kantonsschule (SO)	normal	ca. 10%	1–9%	0 – 10%	present	none
Untersiggenthal (AG)	spaced	76–100%	ca. 10%	ca. 50%	present	present

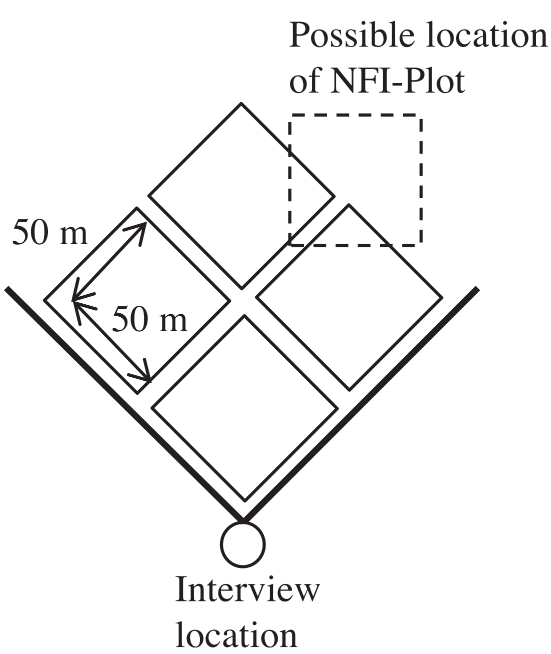

Fig. 1. Four temporary non NFI sampling plots in the forest section that respondents looked toward and evaluated in the questionnaire. The exact location of the NFI plot varied from site to site.

closest to the interview location. This approach does not consider the heterogeneity of the forest enough. Another question was whether or not to include the data from the actual NFI sample plot. Finally, the forest data from the four 50 × 50 m plots at each site were weighted according to the distance of the plot center from the interview location. The data from the actual NFI-plot was left out, because this sample plot is at a different location at each viewpoint. Thus, weighted means were calculated for all parameters and used in the subsequent analysis. Ordinal plot data was treated in the same way as interval data and decimals were rounded to the nearest whole number constituting a category. In case of presence/absence data the feature was listed as present if it occurred in any of the four plots.

Several NFI-variables were found to be highly intercorrelated, so a Principle Component Analysis (PCA) was conducted. The PCA reduced the variables to 6 dimensions (components). From each component, the variable with the highest loading was chosen for further analyses. These variables were stand structure, ground vegetation cover, degree of mixture, inner edge of stand, number of tree species, stand age, root plates, crown closure, stumps/lying dead trees and stand size.

We used linear regressions to determine predictors for the attractiveness of the forest section (field site) the respondents were looking at (forest liking on a scale from 1 to 10). In addition, we attempted to use multilevel modeling to investigate the reasons for forest attractiveness in more detail. Multilevel models vary at more than one level and are therefore suited to our research design, in which forest visitors (individual level) are nested within forest sites (group level). Several multilevel models were run. First, models were developed by adding one variable at the time or by including all variables at once and removing variables that explained the least variance one by one. However, because of the relatively large number of variables compared to the low plot sample size, both these approaches were not feasible and yielded low quality models according to the AIC values used to compare the models.

Our next attempt was a model in three hierarchical steps consisting of predetermined variables. The resulting basic model consisted of socio-demographic factors such as age and gender and forest-related factors such as importance of forest during childhood and forest ownership (first step). In the second step, general forest preferences were added. On the group level (third step), predictors were the forest characteristics that had been used to choose the sites (stand structure and degree of mixture) and crown closure as an important factor influencing light conditions and hereby influencing type, density and height of vegetation as well as people's perception of the forest. After each step, we tested whether the model improved as a whole. The order in which factors were added had no influence on the results.

The resulting model was interpretable and served as a first basis for our discussions. The weakness of the model was that the variables had been chosen more or less arbitrarily. Our final model was a linear mixed effect model fit by REML (restricted maximum likelihood) with a random intercept and an unstructured covariance matrix with perceived visual forest attractiveness (rating of the field site) as a dependent variable. The use of REML is recommended when the sample size on group level is low (Hayes, 2006). A model with a random slope could not be calculated due to convergence problems. The number of missing values in the dataset was low (< 5%) and missing data was dealt with by listwise deletion of cases. A model was run separately for each NFI-variable first to test which variables explained the most variance. These were stand structure, shrub layer cover, stand age and stage of stand development. Because stand structure and shrub layer cover are closely related, as are stand age and stage of stand development, another model was run only with stand structure and stand age. However, the most variance on group level could be explained by stand structure alone. As a next step, variables on the individual level (forest visitor level) were added one by one to test whether they explained any variance. At the same time, we tested whether the new parameter increased or decreased the variance explained by stand structure. Based on this we constructed the final model shown in the results (Tables 3 and 4).

Data analysis was conducted using SPSS, version 22.

3. Results

3.1. Initial remark

The main finding was that the chosen method delivered interpretable and plausible results. For multilevel modeling, a sample size of at least 30, better to have at least 50 level- 2- units are recommended (Nezlek, Schröder-Abé, & Schütz, 2006). Therefore, the effects found here are to be treated with caution. They primarily serve to promise the feasibility of the chosen procedure. Larger investigations with a random selection of sites rather than a few sites chosen to meet certain requirements are needed to achieve reliable results (See Discussion). Table 1 summarizes the forest characteristics of the seven sites and Table 2 the characteristics of the forest visitors interviewed.

3.2. Visual attractiveness of the forest

The forests were generally found to be attractive with most ratings at the upper end of the scale (Table 2). The multi-layered broadleaved riparian forest Aarau Schachen was liked best, followed by the multi-layered coniferous forest Wassbergholz in Ebmatingen. The single-layered *Picea abies* monoculture in Aarau Hungerberg and the likewise single-layered pole timber at Olten Kantonsschule were liked least.

Socio-demographic factors (age, gender, education) and forest-related factors (importance of forest during childhood, membership in an

Table 3
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	7.902	0.259	6	30.519		< 0.001
Estimates of covariance parameters						
Residual	2.599	0.124			20.892	< 0.001
Intercept (subject variance)	0.448	0.272			1.648	0.099

Intraclass correlation ICC = 0.488/(2.599 + 0.448) = 0.147.

Table 4
Multilevel model showing the relationship between physical forest properties of 7 forest sites, general forest preferences of visitors, forest-related factors and perceived visual attractiveness.

Parameter	Estimates	*SE*	*df*	*t*	*Wald Z*	*p*
Estimates of fixed effects						
Intercept	6.407	0.450	41	14.243		< 0.001
Stand structure	1.473	0.392	5	3.757		0.012
Preference for monotonous, predom. coniferous forest	0.389	0.054	814	7.178		< 0.001
Preference for bright green, broadleaf forest	0.215	0.054	814	4.015		< 0.001
Forest visited most often	0.244	0.111	817	2.191		0.029
Importance of forest during childhood	0.117	0.067	814	1.737		0.083
Environ. association membership	0.042	0.121	814	0.345		0.7
Forest ownership	0.246	0.116	815	2.118		0.034
Employment environ.sector	0.068	0.139	813	0.490		0.6
Estimates of covariance parameters						
Residual	2.360	0.117			20.152	< 0.001
Intercept (subject variance)	0.148	0.105			1.417	0.157

Variance explained = 1-(variance with predictors/Variance without predictors).
Group level variance explained = 1-(0.148/0.448) = 0.667.
Individual level variance explained = 1-(2.360/2.599) = 0.09.

Table 2
Summary of characteristics of the forest visitors interviewed at the seven sites.

Site	Number of visitors	Mean attractiveness on a scale from 1 to 10 ± SD	Mean travel time to the site (min.) ± SD	Average visit frequency
Ebmatingen Hasenbuel (ZH)	176	8.27 ± 1.53	39.86 ± 60.16	1–3 x/month
Aarau Hungerberg (AG)	112	6.69 ± 2.08	41.42 ± 67.90	< once a month
Ebmatingen Wassbergholz (ZH)	106	8.33 ± 1.41	43.94 ± 36.95	< once a month
Zurich Dolder (ZH)	134	8.08 ± 1.55	26.82 ± 27.71	1–3 x/month
Aarau Schachen (AG)	139	8.60 ± 1.37	32.30 ± 37.76	< once a month
Olten Kantonsschule (SO)	105	7.21 ± 1.97	10.95 ± 15.27	1–3 x/month
Untersiggenthal (AG)	116	8.11 ± 1.37	31.36 ± 41.16	1–3 x/month

	% females	Mean age ± SD	% members environ. associations	% forest owners	% environ. professionals
Ebmatingen Hasenbuel (ZH)	41.3	51 ± 16	27.6	25.9	18.5
Aarau Hungerberg (AG)	42.7	48 ± 17	22.7	32.1	20.0
Ebmatingen Wassbergholz (ZH)	39.2	49 ± 14	24.5	28.6	16.3
Zurich Dolder (ZH)	37.1	50 ± 16	36.6	30.3	15.2
Aarau Schachen (AG)	46.7	43 ± 17	29.1	38.1	22.0
Olten Kantonsschule (SO)	45.7	46 ± 20	25.2	30.8	15.5
Untersiggenthal (AG)	50.9	49 ± 13	28.7	46.1	20.0

environmental association, forest ownership, employment in the forestry or environmental sector) had no influence on visitors' rating of the forest section they were asked to evaluate (linear regression: adjusted $R^2 = 0.009$, $F(7) = 1.10$, $p = 0.4$), neither for all sites together nor for each site analyzed separately.

Regression analyses were conducted separately within each site's data to assess the influence of forest preferences on the liking of the forest. Forest visitor preferences did have an influence on visitors' liking of the forest section. Preferences also closely corresponded to the type of forest the visitors were recreating in. At almost all sites, the question of whether the respondents preferred coniferous or broadleaf forest played an important role on how much they liked the forest (Untersiggenthal: $\beta = 0.215$, $t = 2.07$, $p = 0.04$; Hungerberg: $\beta = 0.490$, $t = 5.44$, $p < 0.001$; Dolder: $\beta = 0.341$, $t = 3.77$, $p < 0.001$; Hasenbuel: $\beta = 0.218$, $t = 2.81$, $p = 0.006$; Wassbergholz: $\beta = 0.442$, $t = 4.55$, $p < 0.001$). This means that visitors questioned in broadleaved forests also preferred broadleaved forests, while visitors questioned in coniferous forests preferred coniferous forests. An exception was the broadleaf pole timber in Olten, where the forest was contingently liked less by people with a preference for large structures ($\beta = -0.423$, $t = -3.80$, $p < 0.001$). Similarly, in Schachen, a riparian forest, people with a positive attitude to dead wood liked the forest better ($\beta = 0.195$, $t = 2.26$, $p = 0.03$), whereas the forest in Olten was better liked by visitors with a negative attitude to dead wood ($\beta = -0.297$, $t = -3.06$, $p < 0.001$).

The results for multilevel regression analysis are shown in Tables 3 and 4. The unconditional model in Table 3 and the intra-class correlation (ICC) show that differences between forest sites accounted for about 15% of the variation in the dependent variable 'visual attractiveness of the forest'. Table 4 shows that on the level of the forest sites, stand structure, i.e., whether forests were multi-layered or single-layered explained 67% of the variance in visual attractiveness. Stand structure was a significant predictor. Visitors liked multi-layered forests better than single-layered forests. On forest visitor level, a preference for monotonous, predominantly coniferous forests as well as a preference for bright green, broadleaved forests were significant predictors for forest attractiveness. Visitors who didn't own forest patches themselves liked more the sites they were interviewed at. Furthermore, when the site was in the forest respondents visited most often, visual attractiveness was rated higher. Either forest visitors visit the forest most often because it corresponds to their preferences, e.g., for coniferous or deciduous forest, or they might visit it most often because the forest is quick and convenient to reach and visitors end up liking what they are used to. These forest visitor-related variables were, however, only able to explain about 9% of the variance in visual attractiveness on the individual level.

Because people rated visual attractiveness higher in forests they visited most often, we also tested whether the people rated the photo of the site they were visiting higher than the photos of the other sites in oneway ANOVAs with an LSD post-hoc test. This was only marginally the case for one photo depicting the riparian forest Aarau Schachen shown in question 8.4 in Appendix A ($F_{6,873} = 2.031$, $p = 0.059$). People interviewed at Schachen and Wassbergholz rated the photo of the Schachen forest higher than people interviewed at Untersiggenthal, Hungerberg and Hasenbuel.

The reliability of the attractiveness ratings in the field was evaluated by calculating the intra-class correlation for group and individual ratings (Palmer & Hoffman, 2001). The analysis showed a high reliability of the group's mean rating (intra-class correlation ICC for group (site) average = 0.95). ICC for individual rating was 0.14.

In short, how much visitors liked a certain forest section was determined in this pilot study by their own forest preferences and by on-site physical forest characteristics related to stand structure. Our main finding is, that fairly broadly defined forest characteristics as measured in NFIs can in principle contribute to explaining visual attractiveness of the forest. In terms of the confluence model described in the introduction, both the physical and social aspects contributed to the dependent variable visual attractiveness. In accordance with the research questions, the findings only serve to demonstrate how a forest visitor survey could be carried out in order to develop a model combining physical and social forest monitoring in the long run. The 15% variance explained by differences between forest sites encourage further investigation and improved models of how to achieve this aim by conducting test studies on a larger scale.

4. Discussion

A visitor survey can be carried out in order to integrate social forest monitoring into NFI-data. The pilot-tested method here turned out to be useful as well as feasible and should be elaborated towards developing a monitoring instrument measuring recreational values of forests that combines social and natural scientific aspects as suggested in the confluence model. The advantage of conducting a public field survey is that respondents evaluate forest characteristics in a realistic setting, looking at the actual plots in which the NFI-data are collected, which, at least in Switzerland, helps provide support for political decisions on a national level. A critical issue is that visitors perceive a much larger section of the forest than just a 50 × 50 m plot, even when they are asked to look in a certain direction. We tried to account for this by assessing the relevant parameters in four adjacent plots instead of only in one (see Section 2.3). This is in line with Fürst, Klins, Knoke, Suda, and Bitter (2004) who suggest recording universal stand type criteria for the surrounding area of each sample plot, arguing that classical inventory approaches are ideal for homogeneous, even-aged stands, but that near-to-nature forests fulfilling multiple functions require more complex survey methods. The same applies to Switzerland, where forests are managed according to the group-selection silvicultural system, leading to forests rich in diverse structures across small scale areas. A possible approach in more heterogeneous areas would be to determine the forest area visible from each footpath and assess the NFI-parameters in the whole visible area. This approach, however, still needs to be tested.

Stratification of NFI plots using remote sensing data to identify plots in larger homogenous areas was not successful. The main reason is the different planimetric point of view compared to the visitors' view. Remote sensing techniques describe and measure the land cover from above. Depending on the sensor, only the top or the upper parts of the canopy are visible. The perception of the visitor is from a frog-perspective. The variety of understory, herbal vegetation, deadwood, etc. can be high, even if the bird-view from remote sensing is uniform. The applicability of active sensor data, e.g., airborne laser scanning (ALS) which is able to penetrate the top canopy down to the ground should be tested in the future to come closer to the visitors' perspective of the forest.

Another point is that the impression of the whole temporal forest visit and experiential factors unaccounted for in this study might influence the respondents' answers. For example, people might be attracted to Aarau Schachen, a riparian forest along the river not because of the forest characteristics but because of the river. Likewise, the Wassbergholz forest features a lot of open spaces and its hilly terrain can be considered ideal for mountain biking. However, there are indications that respondents seemed able to rule out such factors to some degree when answering the questionnaire. For example the *Picea abies* monoculture on Aarau Hungerberg was the least liked forest, even though the interview location was near a viewpoint with a picnic site, a feature often appreciated by forest visitors (Kienast, Degenhardt, Weilenmann, Wäger, & Buchecker, 2012). The study was conducted in spring, when broadleaves were foliated. The results might be different if gained from a survey in wintertime, although the repeated measurements on NFI plots in spring and late autumn on the same plots showed no effects of seasonality (U.-B. Brändli, personal communication, August 24, 2015).

For this first study, we chose a subset of NFI variables on the supply side of the confluence model which we thought might be important for aesthetics and recreation. However, it is possible that other parameters play an even greater predictive role. Rudis et al. (1988) for example suggested that measures of visual penetration and screening by foliage and twigs should be incorporated into forest inventories, if these are to be of use for recreational value assessments. Vega-Garcia et al. (2011) assess fallen leaves and the presence of moss and fungi among other things in addition to standard inventory data, though in the analysis only the amount of fallen leaves on the ground along with the amount of dead wood, height of shrubs and visual penetration were predictors for aesthetic quality. The Swiss NFI plans to assess the cover of moss, lichen and ivy, primarily to evaluate habitat structures. Preference studies indicate that structural diversity is not only ecologically significant, but can be an important parameter for forest attractiveness (Ammer & Pröbstl, 1991; Ribe, 2009). Structural diversity can, for example, be achieved by having a mixture of old and young trees or by creating a mosaic of visually distinguishable stands (Ammer & Pröbstl, 1991; Axelsson-Lindgren & Sorte, 1987). Thus, it would be important to include measures of structural diversity as well as measures of visual penetration into forest inventories, as is done in the Swiss NFI, and possibly also in other inventories. Enjoying the smells and sounds of nature have been found to be important motivators for a visits to forests (Sotomayor, Barbieri, Wilhelm Stanis, Aguilar, & Smith, 2014). Methods might be developed on how to incorporate these aspects into a standard inventory.

The question remains which approach (on-site, off-site with photos or a combination of both) will lead to a more useful monitoring instrument that integrates social and physical aspects of forest recreation in accordance with the confluence model and that is part of or closely related to National Forest Inventories. This question could be answered using the same NFI plots for an additional field survey along with photos as stimuli for a household survey and then comparing and combining the results (Palmer & Hoffman, 2001). Results from preference studies can be a useful component in planning of multi-functional forest management if several studies with different methodologies are validated by similar results (Gundersen & Frivold, 2008). In a field survey, uncontrollable confounding factors as part of the setting are usually unavoidable. This can make it difficult to reliably find the effect of the measurable variables being tested. At the same time this is the advantage of field perception surveys as they measure the effect of the real situation where the measured factors of interest might have smaller perceptual effects than expected. In lab experiments, or when mediated by visualizations in questionnaires, the effects of interest can easily be over-estimated because respondents' attention can be artificially focused on the experimental setting and/or visualizations. Nevertheless, according to the review of Gundersen and Frivold (2008), photos can constitute a valid basis for preference studies of forests and landscapes and provide results correlated with those from on-site field presentations. Whether this also applies when trying to predict recreational value from social and physical factors needs more investigation, as suggested by Palmer and Hoffman (2001). These authors emphasize the need to validate photos by comparing ratings with assessments of the real settings photos are intended to represent. Another issue in field surveys is that the focus lies on forest visitors and excludes everyone who does not go to the forest but might also value forests for other legitimate reasons. At the same time, visitors who turn up at the interview location might be walking there because they like that particular forest and may be oversampled, resulting in high visual quality score bias with low variance across the sites examined (Gundersen & Frivold, 2008). This is in line with our findings that visitors' general forest preferences were highest for the type of forest they were interviewed in. With regard to the time and effort required for field and household surveys, Edwards et al. (2011) suggest an alternative approach in which Delphi interviewing of experts is used to assess the public's recreational value of different forest stand types. Such results can then be projected to a larger area. While this is undoubtedly a very economical alternative, it lacks clear validity and the detailed gain of knowledge enabled by actual public surveys. In addition, experts have been found to differ from the general public in their preferences for forests managed for recreation (Petucco et al., 2013).

5. Conclusions

We presented the results of a pilot study as a first step to develop a monitoring instrument to measure recreational values of forests that integrates their social and physical aspects according to the confluence model developed and underlined by a literature review in Hegetschweiler et al. (2017). Our approach to conducting a forest visitor survey at NFI sample plots revealed interpretable and plausible but preliminary results. We plan to further develop the method presented here and apply it to a larger number of NFI-plots and respondents with higher variability to improve our model's predictive power. The planned study should cover all forest types in the whole of Switzerland. In addition, more visitation-specific physical variables (e.g., presence of moss, fungi, informal trails and other small structures that are not included in regular NFI assessments but are relevant for recreation) need to be defined and tested to improve the predictive power of integrated physical-social models of forest attractiveness and thereby estimate the recreational value of forests. Winter conditions should also be taken into account. At the same time the validity of the on-site survey should be increased using a larger sample size of interview locations and people as well as increased standardization by using pre-defined sampling times, e.g., 2 h in the morning, 2 h at midday, 2 h in the afternoon and 2 h in the evening on a weekday and a weekend day in summer and winter. A further step will be to compare the results of such field surveys to household surveys using photos of the same sample plots and evaluate whether on-site surveys provide more valid and reliable results than household surveys. If so, a fully developed questionnaire for a visitor survey together with a set of forest parameters relevant to recreation could be used at a reasonably large subset of NFI-plots. The aim is to create a comprehensive forest monitoring instrument measuring recreational values of forest in which both social and physical aspects are equally monitored.

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Appendix A. Questionnaire used for the visitor survey (English translation)

How much do you like this forest?

Dear participant

Thank you for taking the time to complete this questionnaire. We would like to know which forest people like best. Your personal opinion is what interests us. There are no right or wrong answers. It will take you only about 5-10 minutes to fill in the questionnaire.

1. What are you mainly doing in the forest today? (Please only mark one answer!)

O	Having a walk / Hiking (without a dog)
O	Having a walk / Hiking with a dog/ Walking the dog
O	Jogging
O	Nordic walking
O	Cycling
O	Biking
O	Having a picnic / barbecue
O	Playing with children
O	Riding
O	Other: ______________________

2. Are you alone or accompanied today?

O	Alone
O	With one other person
O	With several people

3. How long did it take you to get from home or some other starting point (e.g., your workplace) to this forest?

_________ minutes

4. Is this the forest you visit most often?

O	yes
O	no

5. How often do you normally come to this forest outside holiday time?

	3-7 times a week	1-2 times a week	1-3 times a month	Less than once a month	Hardly ever
In spring, summer, autumn	O	O	O	O	O
In winter	O	O	O	O	O

Please answer the following question with respect to the forest you are in now:

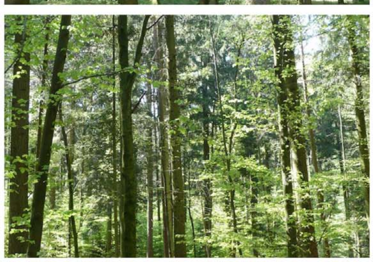
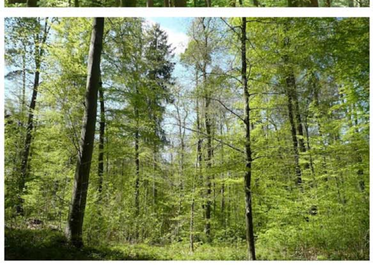
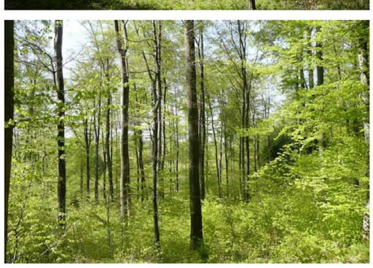
6. Please follow our instructions and look in the direction requested. How much do you like[1] the forest on a scale from 1 to 10?

O	O	O	O	O	O	O	O	O	O
1	2	3	4	5	6	7	8	9	10
Not at all									Very much

[1] In German we use the word "gefällt", which means to "visually like".

Why do you like/not like this forest?

7. **How much do you like the bits of forest shown in the pictures below? Please focus on the forest in particular.**

	Very much	Rather	Moderately	Hardly	Not at all
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O

8. **How much do you like the bits of forest shown in the pictures below? Please focus on the forest in particular.**

	Very much	Rather	Moderately	Hardly	Not at all
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O

Please answer the following questions with respect to forests generally:

9. Which kinds of forest do you prefer?

Forests with:	Strongly prefer	Rather prefer	Undecided	Hardly prefer	Don't prefer at all
Predominantly conifers.	O	O	O	O	O
Predominantly broadleaf trees.	O	O	O	O	O
Many different tree species.	O	O	O	O	O
Many bushes/shrubs and young trees.	O	O	O	O	O
Many clearings.	O	O	O	O	O
Mostly dense dark cover.	O	O	O	O	O
Many branches and piles of branches on the ground.	O	O	O	O	O
Many fallen trees.	O	O	O	O	O
Many standing dead trees.	O	O	O	O	O
Rocks or rocky places	O	O	O	O	O
Hollows / ditches/ embankments	O	O	O	O	O
Streams, ponds or pools.	O	O	O	O	O

10. Is there anything else that you especially prefer when you are in the forest, such as a particular colour, smell, noise …

____

____

____

Finally, a few personal details:

Gender?

O female

O male

Year of birth?

____

Your nationality?

____

Your postcode? / Place where you live?

____

Where (which country) did your parents grow up?

____

What was the last level of school you attended?

O None

O Primary/Secondary school/Junior high school

O Apprenticeship, Vocational training

O A-levels, Teacher training, Vocational school-leaving certificate

O Professional college, Art school

O University of Applied Sciences, Teacher training college

O Federal Institute of Technology, University

O Other: ________________________

How important was the forest for you in your childhood?

O	O	O	O	O
Very important	Quite important	Undecided	Not very important	Unimportant

Are you a member of an environmental or nature conservation organisation (e.g., Pro Natura, WWF or Greenpeace)?

O yes

O no

Do you or any of your close relatives own any forest?

O yes

O no

Does your job or training have anything to do with forest, nature, landscapes, the environment or ecology?

O yes

O no

Many thanks for taking the time to respond to this survey! We wish you an enjoyable time in the forest!

If you have other comments, please use the following lines.

____

____

____

Appendix B. Factor analysis with rotated factor loadings of forest preferences

Original item in questionnaire	Resulting factors with factor loadings		
	Preference for large structures	Preference for diverse forest	Preference for open broadleaved forest
Fallen trees	0.86	0.14	0.00
Standing dead trees	**0.83**	−0.04	0.05
(Piles of) branches on the ground	**0.78**	0.22	0.03
Rocks or rocky places	**0.58**	0.47	−0.02
Hollows, ditches, embankments	**0.54**	0.49	−0.12
High number of tree species	0.03	**0.71**	0.12
Streams, ponds, pools of water	0.17	**0.63**	0.10
Bushes, shrubs, young trees	0.17	**0.48**	0.38
Forest clearings	0.15	0.14	**0.80**
Predominantly broadleaf trees	−0.05	0.19	**0.53**
Dense and dark forest	0.19	0.37	**−0.51**
Eigenvalues	5.52	1.46	1.01
% variance explained	31.96	13.24	9.19

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy: 0.80.

Bartlett's test of sphericity: $\chi^2(55) = 2180.22$, $p < 0.001$.

Appendix C. Factor analysis with rotated factor loadings of forest preferences deduced from rating of forest pictures

Original item in questionnaire	Resulting factors with factor loadings		
	Monotonous, predominantly coniferous forest	Bright green, broadleaf forest	Untidy forest
Picture 7.1	0.87	0.06	−0.07
Picture 8.2	**0.73**	0.16	0.14
Picture 7.2	**0.73**	0.01	0.18
Picture 7.4	−0.11	**0.86**	0.14
Picture 7.3	0.10	**0.77**	0.20
Picture 8.1	0.32	**0.60**	−0.09
Picture 8.4	−0.05	0.09	**0.87**
Picture 8.3	0.30	0.14	**0.78**
Eigenvalues	2.56	1.55	1.16
% variance explained	31.94	19.40	14.53

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy: 0.60.
Bartlett's test of sphericity: $\chi^2(28) = 1608.64$, $p < 0.001$.

Appendix D. Factor analysis with rotated factor loadings for the factor "Dead wood"

Original item in questionnaire	Factor "Dead wood"
Fallen trees	0.85
(Heaps of) branches on the ground	**0.81**
Standing dead trees	**0.76**
Picture 8.4	**0.71**
Picture 8.3	**0.66**
Eigenvalue	2.90
% variance explained	58.08

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy: 0.80.
Bartlett's test of sphericity: $\chi^2(10) = 1493.48$, $p < 0.001$.

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