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Continuous-cover management and attractiveness of managed Scots pine forests

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Abstract

Forest management, characterized in many Northern countries by the predominance of clear cutting and growing even-aged and -sized trees, has simplified the structure of boreal forests. Consequences include alterations in cultural ecosystem services, such as forest attractiveness, i.e., combined aesthetic and recreational values. Continuous-cover forestry might mitigate these effects through the use of selection and gap cutting, but these methods have been little studied, particularly from the attractiveness viewpoint. We used photo surveys to assess Finnish citizens' perceptions of attractiveness of in-stand sceneries of Scots pine (*Pinus sylvestris*) forests logged using different methods. (1) The attractiveness scores, given by respondents, declined steadily from unharvested forest through continuous-cover methods to seed-tree and clear cutting. (2) Respondents with a negative attitude to forest management gave lower scores than respondents with a positive attitude, but the declining slopes of attractiveness against logging intensity were similar. (3) In unharvested and less intensively managed stands, summer photos received higher scores than corresponding winter photos. (4) Background variables (gender, education, living environment, memberships in recreational or nature NGOs, forestry profession and forest ownership) had negligible effects on the scores. We recommend the use of continuous-cover logging methods in settlement and recreational areas.

Key words: continuous-cover forestry, gap cutting, selection cutting, aesthetic value, recreational value

Introduction

Most North European forests are managed for wood production but increasingly often also for biodiversity and public use. An intensive era of clear-cutting dominance began in the 1950s (Storaunet et al. 2005, Siiskonen 2007). In this regime, mature trees are usually completely removed, followed by regeneration through site preparation, sowing or planting, tending of the emerging cohort of even-aged trees, and often relatively short logging rotation. An underlying rationale of this regime is economy based, especially volume growth and ease of harvesting. Ecological consequences include structural simplification and losses of many features important for biodiversity, such as dead and very old trees (Siitonen 2001, Nilsson et al. 2002, Bergeron 2004). These alterations are the main reasons for hundreds of forest species being subject to the risk of extinction in Fennoscandia alone (Berg et al. 1994, Kålås et al. 2010, ArtDatabanken 2015, Hyvärinen et al. 2019). Negative ecological effects have thus far dominated criticisms on forest management, but also losses of many social values, such as nature tourism, recreational and aesthetic benefits, are increasingly often addressed (Bliss 2000, Gundersen & Frivold 2008, Puettmann et al. 2009).

Ecological, economic and social sustainability can perhaps be achieved through continuous-cover forest management (e.g., Franklin et al. 1997, Kuuluvainen & Grenfell 2012, Fedrowitz et al. 2014). This regime applies logging methods other than clear cutting and thus varies the amount and spatial distribution of retained trees, and the size of harvested openings. The logging methods include selection cutting, gap cutting and modifications of clear cutting, all characterized by maintaining a significant proportion of trees throughout the logging cycle (e.g., Puettmann et al. 2009, Koivula et al. 2014). Experimental evidence suggests that even modest retention of living trees in harvested blocks is beneficial for biodiversity (Koivula & Vanha-Majamaa 2020). Also, based on landscape preference research, retention methods may be preferred over clear cutting by citizens who use forests for aesthetic pleasure, recreation, hunting or collecting (Ribe 1989 and references therein).

Managed forests are commonly expected to support economy and biodiversity, but also social values, such as aesthetic perception, recreation and nature-based tourism (e.g., Tyrväinen et al. 2003, 2014, 2017). In Finland, the so-called everyman's rights permit, e.g., hiking, skiing, and picking berries and mushrooms for anyone in nearly any private and public land (Anon. 2019). Finns commonly assess forests based on aesthetics and many other qualities, including easiness of moving (Tyrväinen et al. 2017), and spend a lot of time there. About 96% of Finns visit nature regularly, on average 2-3 times per week (Sievänen & Neuvonen 2011). The choice of logging method, therefore, appears important particularly in areas adjacent to settlement or allocated for recreational use. Clear cutting decreases the aesthetic and recreational values of forests (e.g., Karjalainen 2006, Tyrväinen et al. 2017, Arnberger et al. 2018), whereas logging methods with high amount of retained trees – such as selection cutting – are considered socially more acceptable (Ribe 2005, Putz et al. 2008). Citizens prefer forests with diverse tree ages, species and sizes (Silvennoinen et al. 2001, 2002, Tyrväinen et al. 2017) with not too densely spaced trees (Ribe 1989, Silvennoinen 2017). These results may be interpreted so as to contradict the so-called savannah theory that postulates that citizens – independent of their nationality, education, or cultural and social background – prefer savannah-like, semi-open environments that provide both prospects and shelter, possibly due to human evolutionary origin (Appleton 1975, Falk & Balling 2010). However, preference to particular environments may also depend on personal and cultural expectations about resources in them (e.g., Kaplan & Kaplan 1989). In Northern Europe, for instance, boreal forests have been a crucial human source of food, fur, firewood, handcraft material and shelter for thousands of years (Haggrén et al. 2015). Thus, no single environment is likely to represent an optimum for all needs, conditions and times. As Falk and Balling (2010) put it, "human landscape preferences is [sic] best understood as a continuous progression of aesthetic ideals, tempered by social convention, passed on from one generation to the next through human culture".

Here, we present results of a citizen questionnaire based on photos showing in-stand sceneries of mature pine forests (hereafter “views” for brevity) managed with several logging methods that varied in the amount and spatial distribution of retained trees. Respondents rated each view based on how attractive they felt it was. With "attractiveness" we refer to the anticipated fulfilment of positive expectations a person associates with the views. This term thus contains aesthetic and recreational values, which are strongly correlated (Hull et al. 1984, Karjalainen 2006). The basis is on a psycho-physical method where the interest is on preferences of respondents (e.g., Zube et al. 1982). The aim is to explain preferences by factors (variables) visible in the photos (e.g., Edwards et al. 2012). We thus attempt to quantify attractiveness while acknowledging that it likely consists of a mixture of psychological and cultural factors (Tress et al. 2001). The studied pine forests are suitable for our assessment as, prior to logging, they were structurally simple, with little undergrowth vegetation or variation in microhabitats and topography. Our study provides new insights into the continuous-cover forest management, and a novel aspect for assessing the respondents’ attitudes to forest management in impacting the attractiveness perception.

We address the following questions.

1. Does the attractiveness depend on logging method or logging intensity? Earlier research suggests that the attractiveness of pine forest might decline (Hull & Buhyoff 1986) or increase after thinning (Silvennoinen et al. 2002), however the savannah theory predicts an intermediate peak of attractiveness along the logging-intensity gradient. On the other hand, if environmental preference rather depends on personal and cultural expectations related to, for example, resources (e.g., Kaplan & Kaplan 1989), then other types of response may be expected.

2. Does the respondent's attitude to forest management affect the attractiveness rating? Compared to neutral or positive attitude, negative attitude predicts lower attractiveness scores of views showing logged forest (Kearney & Bradley 2011). We also intuitively predict that respondents with a positive attitude indicate smaller differences between logging treatments than those with a negative attitude.

3. Does the season in a photo (summer or winter) affect the attractiveness rating? Recently Tyrväinen et al. (2017) reported that intensively harvested forests look more attractive in winter than in summer photos.

4. What is the contribution of the respondents' background in determining the attractiveness rating? Here, we explore the impacts of each respondent's age, gender, education, settlement type, memberships in outdoor and nature NGOs, and possible forestry profession and forest ownership.

Materials and methods

Logging treatments and photo materials

We collected data on Finnish citizens' perceptions of forest attractiveness using photos that represented a variety of logging methods. These were taken in 2017 in rural, mostly state-owned areas, in mature managed Scots pine (*Pinus sylvestris*) dominated Vaccinium-type forests (Ahti et al. 1968) in the municipalities of Lieksa, Kontiolahti and Joensuu, Eastern Finland (Supplementary online materials). Prior to logging, the dominant canopy trees in these forests were about 70-100 years old pine, with occasional birch (*Betula*) or Norway spruce (*Picea abies*) trees as a mixture. The field and bottom layers of these forests were dominated by *Vaccinium vitis-idaea*, *V. myrtillus*, *Calluna vulgaris* and *Empetrum* *nigrum* dwarf shrubs, *Cladonia* lichens and *Pleurozium*, *Dicranum* and *Hylocomium* mosses. Logging operations had been done 2009-11 using a variety of methods of increasing tree-removal intensity. We compared mature reference forest (Reference) with (1) selectively cut forest with about 60-70% retention of initial tree volume (Selection); (2) gap cutting with multiple openings of r = 15-20 m and 20% of initial tree volume retained in the openings (Gap 20); (3) gap cutting with multiple openings of r = 15-20 m and 5% retained in the openings (Gap 5); (4) partially clear-cut (patch-cut) forest with multiple openings of r = 25-30 m and 20% retained in the openings (Patch 20); (5) partially clear-cut forest with multiple openings of r = 25-30 m, and 5% retained in the openings (Patch 5); (6) clear-cut forest with 20% retention (Clear 20%); (7) seed-tree cut forest with 10-15% of trees retained evenly (Seed); (8) clear-cut forest with 5% retention (Clear 5%); and (9) ordinary clear-cut forest with up to 3% retention as required by the Programme for the Endorsement of Forest Certification (Clear 3%). We refer to the Reference forests and the nine logging methods as "treatment" below. See Fig. 1 for examples and Supplementary materials for all treatments. Logging residue decreases the attractiveness of forest sceneries (Ribe 1989, Silvennoinen et al. 2002, Gundersen & Frivold 2008), which was not an issue in our study as residue and slash had been removed shortly after logging because treatments 1-6 and 8 were in recreational forests (where clear cutting is avoided), or residue had decayed well and vegetation already covered the bottom and field layers, before taking the photos. Moreover, no heavy site preparation had been applied.

We used panoramic photos that had a 5 x 14 aspect ratio, each created by combining five vertical images. The initial images had been taken in late winter (winter views) and mid-summer (summer views) using a full-frame digital SLR camera with a 50 mm lens. Images taken with such lens are consistent with relative distances between objects as seen by naked eye, and combinations of such images capture variation in horizontal and vertical directions better than single photos. All images had been taken in sunny weather between 10 AM and 2 PM to standardize lighting conditions. Each treatment was represented by at least two image pairs (winter and summer), except Gap 20% for which only one site and thus one summer-winter pair was available (Supplementary online materials). We had initially 194 photos from which we selected 48 (24 views in both summer and winter conditions) as being as representative for the treatments as possible, based on our experience of about 40 years and expert assistance (see Acknowledgements).

Questionnaire form

We made a questionnaire by using the 48 panoramic photos showing the treatments in summer and winter conditions (Supplementary online materials). We requested each respondent to "*indicate your personal opinion about each view in the photos below, according to how well they correspond to your wishes and expectations regarding forests (recreational use, nature related hobbies, scenic values, etc.)*", using a ten-step scale, from 0 = does not correspond to wishes and expectations at all to 10 = corresponds perfectly. The photos were randomly ordered to account for the effects of respondents getting tired toward the end of the questionnaire or detecting study-related patterns in the photos. The respondents were not informed about the study purpose or the logging treatments in the photos. However, they were told that all photos showed managed pine forests. We refer to the given integer scores (0-10) as attractiveness. This scale is a modification of the Likert scale (e.g., Joshi et al. 2015), which produces sufficiently detailed information for analysis (e.g., Tyrväinen et al. 2017). – The respondents were not requested to justify the evaluations, and their identities remained unknown to us.

In addition to the 48 photos, the questionnaire also contained sections for background information (Table 1). The most important piece of information from our study perspective was the attitude to forest management, in which each respondent was asked "*Your attitude toward forest management* *(regeneration cutting, thinning operations) at commercial forest land (where logging is commonly applied)*", from -2 (clearly negative) and 0 (neutral) to +2 (clearly positive). We pooled the initial negative categories (-2 and -1) to "negative" and positive categories (+1 and +2) to "positive" because of small numbers of the extremes (-2 and +2). Additional, requested information (Table 1) contained the respondent's gender (none indicated "*other, or do not want to say*" so this was a binary male/female), age class, education, type of settlement, county of residence, and whether the respondent considers themselves a forestry professional, owns forest or someone in their household is a forest owner, and whether the respondent is a member of an outdoor or recreation NGO, or nature or conservation NGO.

Random and Online surveys

We targeted the study to 15-75 years-old Finnish citizens. We collected data using two surveys. The first is referred to as Random survey below. Here, we obtained a random sample of 1,500 Finns from the population information database of the Finnish Population Registry Center. We mailed a paper copy of the questionnaire to the 1,500 potential respondents in early 2018, with options to return a paper copy or to fill the same questionnaire in the internet. We received initially 396 responses, of which 93% were paper copies (response rate 26%). The second is referred to as Online survey below. This was identical to the Random survey and was done using the SurveyMonkey software (www.surveymonkey.com). We distributed the Online survey in the spring of 2018 via Facebook, Twitter and mailing lists of selected national institutions. For this purpose, we contacted Suomen Latu – The Outdoor Association of Finland, Central Federation of Agricultural and Forestry Producers (MTK), The Finnish Association for Nature Conservation (Suomen Luonnonsuojeluliitto), BirdLife Finland, The Martha Organization (Martat), Metsähallitus, and two research organizations (Natural Resources Institute Finland and Finnish

Environment Institute). Initially, 1,579 persons responded to the Online survey. This approach is likely to produce a biased sample of the Finnish population; however, we were interested in the similarity of attractiveness opinions between different kinds of respondents and not the overall population.

In terms of representativeness, the Random survey matched the Finnish demographic data rather well (Table 1), except in that 51-65 years-old respondents were overrepresented (chi-square statistic 5.37, df = 1, $p < 0.05$). Moreover, as anticipated, the Online survey departed more from the demographic data: the two younger age classes were over- and the two older age classes were underrepresented, and people with an academic degree were overrepresented (chi-square statistics 4.25-59.12, df = 1, $p < 0.05$). Both approaches matched the demographic data in gender, settlement type and area of residence (chi-square statistics <3.80, df = 1, $p > 0.05$).

Data analysis

We included a total of 1,491 respondents who had given full background information (Table 1; 350 from Random and 1,141 from Online survey). The (1,491 respondents x 48 photos) scores were the response variable in analysis.

We were particularly interested in three explanatory variables (see the study questions in Introduction): (1) logging method or logging intensity (the treatments sorted according to increasing intensity of tree removal), (2) respondents' attitude to forest management (neutral, negative or positive), and (3) season a given photo had been taken (summer or winter). We refer to these as Treatment, Attitude and Season unless specified otherwise. We use Treatment as a categorical or a continuous variable, depending on analysis (see below).

We subjected the scores to a Generalized Linear Mixed-effects Model (GLMM; Zuur et al. 2009) by applying the quasi-binomial family with logit link function. As the scores ranged from 0 to 10, we converted them to proportions (0.0-1.0) prior to analysis. We used two models: (1) Treatment as a categorical variable, and (2) Treatment as a continuous integer variable (the treatments ranked according to logging intensity) combined with interaction terms Attitude x Treatment and Season x Treatment. We did not include interaction terms into Model 1 to avoid complex interpretations; for example, Attitude x Treatment alone would have produced 18 test statistics. To further examine interactions in Model 2, we calculated regression coefficients separately for the three attitude categories and for the two seasons by plotting raw data and fitting a regression slope against Treatment. – In both models, we included respondent ID (the 1,491 respondents) as a random variable to account for the inter-dependence of scores given by each respondent.

We were also interested in the respondents' background in potentially impacting the scores. Therefore, we included nine additional variables into Models 1 and 2 (Table 1): each respondent's (1) gender, (2) age class (random), (3) education, (4) settlement type (rural area or small town, or large town), and (5) area of residence (18 counties, random; in Table 1 these are combined into four region classes due to limitations in available demographic data); and whether the respondent (6) considers themselves a forestry professional, (7) is a forest owner or their household includes a forest owner, (8) is a member of an outdoor or recreational NGO, and (9) is a member of a nature or conservation NGO.

We ran the analyses using R 3.6.1 software (R Core Team 2019) with lme4 1.1-21 (Bates et al. 2015), lmerTest 3.1-0 (Kuznetsova et al. 2017), MASS (Ripley et al. 2019), car 3.0-3 (Fox & Weisberg 2011) and ggplot2 3.2.0 (Wickham 2009) packages.

Results

Effects of logging methods or logging intensity on attractiveness scores

Statistics for the main effects in Models 1-2 were broadly similar, and an earlier run based on Gaussian family produced nearly identical results (not shown), which reflect the robustness of our results. Both models indicated a highly significant and negative effect of logging on the attractiveness scores (Table 2a-b). Generally, the more intensive the method, the lower the attractiveness of a forest view (Fig. 2).

Effects of forest-management attitude on attractiveness scores

Models 1 and 2 both detected a significant effect of Attitude on the attractiveness scores (Table 2a-b, Fig. 2). Generally, irrespective of logging treatment, respondents with a positive attitude ranked the views higher, and respondents with a negative attitude ranked the views lower, than neutral respondents (Fig. 2). On average, the scores of respondents with negative Attitude were 0.8-0.9 units lower, and those of respondents with positive Attitude were 0.6-0.7 units higher, than the scores of respondents with neutral Attitude (Table 2). Model 2 detected a significant interaction between Treatment and Attitude, indicating different slopes between Attitude categories against logging intensity (Table 2b). A comparison of regression slopes revealed that the declining slope by neutral respondents was slightly steeper than those of positive or negative respondents, which were similar (Fig. 3).

Effects of season on attractiveness scores

As predicted, Models 1 and 2 both suggested that summer views received on average 0.2 units higher scores than winter views (Table 2). However, according to Model 2, Season interacted with Treatment (Table 2b). Regression slopes revealed that the views differed more in summer than in winter photos, as reflected by a steeper slope in the former (Fig. 3). Concretely, the more intensively managed forests, such as clear-cuts, appeared more attractive in winter than in summer photos, whereas the attractiveness was the other way around in the reference and less intensively managed forests.

Exploration of the effects of the respondents' background

Assessments of the respondents' background in Models 1 and 2 revealed that all of the background variables, except gender, had significant effects on the scores (Table 2a-b). On average, scores were about 2.1 units lower in the Online than in the Random survey. Scores given by nature/conservation NGO members were about 2.0 units lower, and those given by outdoor/recreation NGO members were 0.2 units higher, than those given by non-members. Also settlement type, education, forest profession and forest ownership each had significant effects. On average, respondents from rural areas and small towns gave 0.4 units higher scores than respondents from large cities, academic respondents gave 1.1 units lower scores than non-academics, and forest professionals and forest owners gave respectively 0.6 and 0.7 units higher scores than the other respondents.

We also ran an exploratory model that included interactions between Treatment and all exploratory variables to check for possibly inconsistent treatment responses between variable categories (Model 3; Table 2c). Generally, these effects were often significant but small, as the category-specific Treatment slopes varied between -0.33 and -0.39 (except for forest professionals; see below). The Treatment slope was slightly steeper for respondents of Random than Online survey, females than males, nature NGO members than non-members, academics than non-academics, and rural-area and small-town respondents than city respondents. The slopes were similar between forest owners and non-owners and between outdoor NGO members and non-members. A particularly large difference was between forest professionals and non-professionals (-0.29 and -0.37, respectively). Moreover, the overall Treatment slope was slightly steeper in Model 3 than in Model 2 (Table 2b-c), and the main effect of education was non-significant in Model 3, underlining the importance of the interaction between Treatment and education.

Discussion

We assessed the attractiveness of forest views within mature, managed pine forest stands based on photo questionnaires distributed among Finns. Our main findings were as follows: (1) forest-view attractiveness declined steadily with intensification of logging; (2) the steepness of this decline was little affected by the respondents' attitude to forest management, but the attitude determined the range of attractiveness scores; (3) summer photos were generally ranked higher than winter photos, except in the most intensive logging treatments; and (4) explorations of background variables – respondent age, settlement type, memberships in nature or outdoor NGOs, education, forest profession or ownership – suggested small yet often significant effects on attractiveness perceptions.

Logging decreased the attractiveness of pine forests

Our models suggest that increasing clearing size and decreasing amount of retained trees – as surrogates of increasing logging intensity – decrease the attractiveness of pine forests, supporting earlier research (Ribe 1989, Tyrväinen et al. 2017). Reference mature managed forest was considered the most attractive, whereas selection-cut, gap-cut and patch-cut forests were less attractive, though still considerably more attractive than seed-tree or clear-cut forests. This general result suggests that continuous-cover forest management, or methods of uneven-aged management, better maintain the attractiveness than seed-tree or clear cutting. This finding supports Hull and Buhyoff (1986) and O'Brien (2006) and contradicts the savannah theory that would have predicted an intermediate logging-intensity peak. However, other types of forest, such as the darker Norway spruce, might produce such peak within the studied logging gradient. Another noteworthy aspect is that gap or patch cuts would perhaps have appeared more attractive had the whole stands, and not just views showing clearings, been considered. Thus, most of these stands had been left unharvested, but unlogged fractions were only partly visible in the images. Also the relative merits of aggregated versus dispersed retention cannot be assessed with present data. These aspects, along with other elements characteristic of pristine forests, warrant research in the future.

Differences in attractiveness scores may not allow a straightforward interpretation about the relative differences between logging treatments, or whether there was a threshold level below which the respondent felt that they did not want to visit the forest in the photo. However, a drop from about 5.7 (reference and selectively cut forests) to 2.4 (clear-cut forests) strongly suggests that the attractiveness of these forests differs considerably. Thus, wherever attractiveness should be accounted for – private forest owners who value aesthetics or recreation, or peri-urban forests as well as areas allocated for recreation or nature tourism – forests should be managed with methods that retain a substantial amount of trees, such as selection or gap cutting.

Respondent attitude impacted the attractiveness scores, but not the rank order of treatments

We found that respondents with neutral forest-management attitude identified a wider range of attractiveness scores across management intensities than the other respondents, as suggested by the slightly steeper regression slope between scores and logging intensity. Within any given treatment the respondents with a negative attitude (466 respondents) gave lower scores than those with a neutral or positive attitude (571 and 454 respondents, respectively), supporting Kearney and Bradley (2011). Contrary to our expectations, the slopes were similar between respondents with negative and positive attitudes. This similarity may have occurred because the respondents knew that all photos showed managed forest. This fact, along with the respondents' own observations concerning the photos, may have prevented many negative respondents from giving top scores to any of the photos. Indeed, as indicated in occasional written comments, many would have preferred near-natural, structurally more diverse forests.

The attitude patterns may be linked with personal values, such as appreciation of biodiversity, or education (McFarlane et al. 2006, Tyrväinen et al. 2014, Thorn et al. 2019). Among respondents with a membership in nature or conservation NGO, 49% (333 out of 681) had a negative and 20% (134) had a positive attitude to forest management. Respective percentages among non-members were 15 (122 out of 810) and 52 (422). Hence, these respondent groups appeared predictable on average but heterogeneous overall. Likewise, 40% of respondents with an academic degree indicated a negative attitude to forest management; 76% of these respondents were members of nature or conservation NGO. Earlier studies have shown that nature- or conservation-oriented and higher educated people experience forest management more often negatively and appreciate more natural state of forests than the average respondent (e.g., Dearden 1984, Kardell 1990, McFarlane et al. 2006, Buijs et al. 2009). Knowledge about natural processes and an understanding of their spatio-temporal dimensions affect the nature experience (e.g., Carlson 1995, Rolston 1998).

Season impacted the attractiveness scores

We detected a wider range of attractiveness scores for the summer than for the winter views, as indicated by the steeper regression slope (Fig. 3), and summer views were also generally considered more attractive, except in the most intensive treatments. Season had a particularly strong effect on the attractiveness of the less-intensively managed forests (selection and gap cutting) that thus corresponded better the wishes and expectations of respondents. Similarly, in a survey of tourists arriving in Finland, snow cover had a positive effect on the attractiveness of open and semi-open forests, as snow cover mitigates the effects of forestry operations (Tyrväinen et al. 2017). Another explanation is that in winter season, distinguishing clear cuts from other open environments, such as farmland, peatland or even ponds and lakes, is more difficult. Snow also efficiently covers logging residue, although this was not an issue in our study (see Material and methods).

Experience on conditions shown in photos is not solely a result from physiological characteristics of the location, but also by culture and experience (Berleant 1992). Most Finns have experience-based knowledge about the seasonal variation in the looks of managed forests of different successional phases. Such knowledge may be lacking from non-Finns, such as tourists arriving from remote countries. However, a recent study suggests that assessments of Finnish summer and winter forest sceneries done by Finns and international tourists are rather similar (Tyrväinen et al. 2017).

Respondent background had generally negligible effects on attractiveness scores

As we have shown here, evaluations of forest sceneries are not solely based on external features of the environment, but also on the values, knowledge and experiences of the observer (e.g., Carlson 1993, Hepburn 1996). Although our study design was intended for only evaluating management methods and forest-management attitude, the additional variables (Table 1) also often had detectable effects on attractiveness scores. These probably resulted from the relatively large sample size (number of respondents x number of photos) which helped to reveal effects that contributed very little to the explained variation in our data. Still, these effects may not have been accidental, as another model with a random variable (random numbers 0-100) had no effect (analysis not shown). In line with our results, respondent age, biological knowledge, education, dependence on forests and stakeholder group had minor effects on citizen attitudes to salvage logging of bark-beetle infested forests (Thorn et al. 2019). Due to biases in our data concerning age classes, education and NGO memberships, further research would be needed to assess the importance of these factors. For example, increasing levels of education and biological knowledge, and pro-environmental world views, may predict positive attitudes to natural patterns and processes (McFarlane et al. 2006). Importantly, however, the background variables did not affect the modeling outcome regarding our main variables (logging method, attitude and season).

The respondents' gender had no detectable effect on attractiveness scoring. The response similarities between genders may seem contradictory to social media or political speech that sometimes assumes females to be more emotionally driven than males. According to our results, apparently at least impacts of forest management, and regeneration cutting in particular, are experienced in similar ways. Of course, our female or male respondents may not represent all respective people in Finland, let alone other geographic regions, but this possibility concerns all social studies. Moreover, membership in nature and conservation NGOs, or academic education, predicted lower and membership in outdoor or recreation NGOs predicted higher attractiveness scores, which may have resulted from the respondents' general ability to quickly see that all photos had been taken in managed forests. Thus, an inclusion of very old or pristine forests might have produced different results. However, this inclusion would have been technically challenging, as structural features vary considerably more in pristine than in ordinary managed forests, including tree sizes and densities, weakened and dead trees, and so on (e.g., Esseen et al. 1997).

Caveats, and conclusions

Our results are limited to managed pine forests, and our assessments concerned only the size and level of retention in clearings, and not, for example, citizen opinions about pristine forests or uneven-aged management. The reason for the latter is that logging operations had been done once in even-aged mature forest, whereas uneven-aged management would require applying partial harvesting repeatedly for decades. From a research perspective our forests nevertheless had the advantage of being structurally simple; they mostly only varied in clearing size and retention level and not in, for instance, topography, water beds, tree species, size or density, microhabitat types, or quality and amount of dead trees. Distinguishing such factors would be important but require different research set-ups.

A possible source of error in our questionnaire was to request the respondents to simultaneously assess two different things: wishes and expectations. We believe, however, that most respondents managed to consider these together while filling the questionnaire. Another important note is that we used photos showing within-stand views, whereas landscape views (Arnberger et al. 2018), in situ assessments, or other forest types might produce different results.

Our results suggest that low-intensity forest management should be applied particularly in areas intended for recreation or tourism, or in forests within settlement areas, if the goal is to maintain qualities associated with attractiveness. Such approach may also have biodiversity benefits: if more than half of the trees from the initial volume are retained, late-successional species assemblages may be maintained (e.g., Atlegrim & Sjöberg 1996, Koivula 2002, Matveinen-Huju & Koivula 2008, Work et al. 2010, Vanha-Majamaa et al. 2017, Hjältén et al. 2017, Joelsson et al. 2017, 2018). Another important message is that it seems possible to combine economically viable forest management and attractiveness, assuming that the opinions of recreational users, forest owners and local inhabitants are acknowledged (see also McFarlane et al. 2012, 2015). Concretely, this would mean larger-scale use of methods of continuous-cover forest management, such as selection or gap cutting.

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Table 1. Background information on respondents in random (Random; 350 respondents) and online (Online; 1149) surveys, collected in the present study, as compared with demographic data (Demo) obtained from the Finnish Population Register Center; values are percent.

Variable	**Category**	**Random**	**Online**	**Demo**
Attitude to forestry	Neutral	37.6	30.8	
	Negative	8.0	37.9	
	Positive	54.4	31.3	
Gender	Male	46.4	48.7	48.9
	Female	53.6	51.3	51.1
Age class, years	15–30	12.1	11.1	21.1
	31–50	24.1	40.7	29.5
	51–65	35.1	34.1	23.8
	65+	28.7	14.1	25.5
Education	Elementary school to college	90.1	45.8	90.1
	Academic (university)	19.9	54.2	19.9
Settlement type	Rural or small town (up to 15,000 inhabitants)	29.2	30.3	29.2
	Large town (>15,000 inhabitants)	70.8	70.0	70.8
Area of residence	Metropolitan Finland	25.7	31.0	28.8
	Rest of S Finland	24.1	18.9	21.6
	W Finland	25.2	23.3	25.6
	E or N Finland	25.0	26.9	24.0
Other details	Forestry professional	3.3	12.7	
	Forest owner in household	39.5	43.1	
	Member in outdoor/recreation NGO	8.7	32.4	
	Member in nature/conservation NGO	7.2	57.6	

Table 2. GLMM outputs for attractiveness scores given by respondents to 48 forest-view photos; each model contained random and fixed variables.

a. Model 1 *					
Random effects					
Variable		**SD**			
Respondent ID		0.81			
County		0.56			
Age class		0.86			
Residuals		0.33			
Fixed effects					
Variable	**Category**	**Estimate**	**SE**	***t***	***p***
Intercept		0.92	0.10	9.11	0.000
Attitude	Negative	-0.88	0.09	-9.74	0.000
	Positive	0.69	0.09	8.05	0.000
Treatment	Select	-0.19	0.01	-16.34	0.000
	Gap 20	-0.57	0.02	-34.40	0.000
	Gap 5	-0.62	0.01	-46.63	0.000
	Partial 20	-0.66	0.01	-50.21	0.000
	Partial 5	-0.83	0.01	-62.21	0.000
	Clear 20	-1.17	0.01	-86.40	0.000
	Seed	-1.31	0.01	-96.19	0.000
	Clear 5	-1.65	0.01	-131.89	0.000
	Clear 3	-1.95	0.01	-163.24	0.000
Data set	Online	-0.62	0.10	-6.52	0.000
Gender	Female	0.00	0.07	0.03	0.979
Education	Academic	-0.16	0.07	-2.20	0.028
Settlement	Rural or small town	0.16	0.08	2.05	0.041
Outdoor NGO	Member	0.32	0.08	4.06	0.000
Nature NGO	Member	-0.44	0.08	-5.37	0.000
Forest professional	Yes	0.36	0.12	3.11	0.002
Forest owner	Yes	0.17	0.07	2.35	0.019
Season	Winter	-0.09	0.01	-14.74	0.000

b. Model 2 †					
Random effects					
Variable		**SD**			
Respondent ID		0.93			
County		0.69			
Age class		0.63			
Residuals		0.33			
Fixed effects					
Variable	**Category**	**Estimate**	**SE**	***t***	***p***

Intercept		1.11	0.10	10.99	0.000
Attitude	Negative	-0.77	0.09	-8.39	0.000
	Positive	0.58	0.09	6.63	0.000
Treatment	Continuous	-0.24	0.00	-122.89	0.000
Data set	Online	-0.63	0.10	-6.52	0.000
Gender	Female	0.01	0.07	0.08	0.936
Education	Academic	-0.16	0.07	-2.18	0.030
Settlement	Rural or small town	0.16	0.08	2.03	0.043
Outdoor NGO	Yes	0.32	0.08	4.06	0.000
Nature NGO	Yes	-0.44	0.08	-5.33	0.000
Forest professional	Yes	0.35	0.12	3.04	0.002
Forest owner	Yes	0.17	0.07	2.29	0.022
Season	Winter	-0.39	0.01	-35.89	0.000
Treatment x Attitude	Negative	-0.03	0.00	-12.33	0.000
	Positive	0.02	0.00	10.21	0.000
Treatment x Season	Winter	0.06	0.00	33.43	0.000

c. Model 3 ‡					
Random effects					
Variable		**SD**			
Respondent ID		0.92			
County		0.59			
Age class		0.73			
Residuals		0.33			
Fixed effects					
Variable	**Category**	**Estimate**	**SE**	***t***	***p***
Intercept		1.21	0.10	12.01	0.000
Attitude	Negative	-0.74	0.09	-8.10	0.000
	Positive	0.57	0.09	6.54	0.000
Treatment	Continuous	-0.26	0.00	-87.84	0.000
Data set	Online	-0.87	0.10	-9.03	0.000
Gender	Female	0.10	0.07	1.43	0.153
Education	Academic	-0.13	0.07	-1.79	0.073
Settlement	Rural or small town	0.13	0.08	1.70	0.089
Outdoor NGO	Yes	0.32	0.08	3.95	0.000
Nature NGO	Yes	-0.38	0.08	-4.67	0.000
Forest professional	Yes	0.31	0.12	2.65	0.008
Forest owner	Yes	0.18	0.07	2.41	0.016
Season	Winter	-0.39	0.01	-36.01	0.000
Treatment x Attitude	Negative	-0.04	0.00	-13.83	0.000
	Positive	0.02	0.00	10.37	0.000
Treatment x Season	Winter	0.06	0.00	33.54	0.000
Treatment x Data set	Online	0.05	0.00	18.76	0.000
Treatment x Gender	Female	-0.02	0.00	-10.69	0.000

Treatment x Education	Academic	-0.01	0.00	-2.86	0.004
Treatment x Settlement	Rural or small town	0.00	0.00	2.18	0.030
Treatment x Outdoor NGO	Yes	0.00	0.00	0.47	0.637
Treatment x Nature NGO	Yes	-0.01	0.00	-4.57	0.000
Treatment x Forest prof.	Yes	0.01	0.00	2.49	0.013
Treatment x Forest owner	Yes	0.00	0.00	-1.21	0.225

* Logging treatment was a categorical variable, and only main effects of explanatory variables were considered.

† Logging treatment was a continuous integer variable (“logging intensity”), and interaction terms between logging treatment and attitude toward forestry (positive, neutral or negative) and season (summer or winter) were included.

‡. Logging treatment was a continuous integer variable, and all possible interaction terms between treatment and other fixed variables (compare Table 1) were included.

Figure legends

Fig 1. Example forest views used in our photo questionnaire. Summer views are on the left, winter views are on the right. Treatments are, from top, selection cutting, gap cutting with 20% retention, patch cutting with 20% retention, and clear cutting with 5% retention. For all photos, see Supplementary materials.

Fig. 2. Attractiveness scores given by respondents to photos showing different logging treatments, arranged according to increasing logging intensity. Respondents with positive, neutral or negative attitude to forest management in managed forests shown with different column styles. REF = unharvested reference forest; SELE = selectively cut forest; GAP = gap harvested forest (retention of 20% or 5%); PAT = patch cut forest (retention of 20% or 5%); CLR20 = clear cut with 20% retention; SEED = seed-tree cut forest; CLR5 = clear cut with 5% retention; and CLR3 = clear cut with up to 3% retention.

Fig. 3. Linear regressions for attractiveness scores given by respondents to photos showing different logging treatments; rank order of logging intensity. Top: respondents with positive, neutral or negative attitude to forest management in managed forests are shown with different lines. Down: slopes for winter and summer photos shown separately. R = regression slope.

Fig. 1

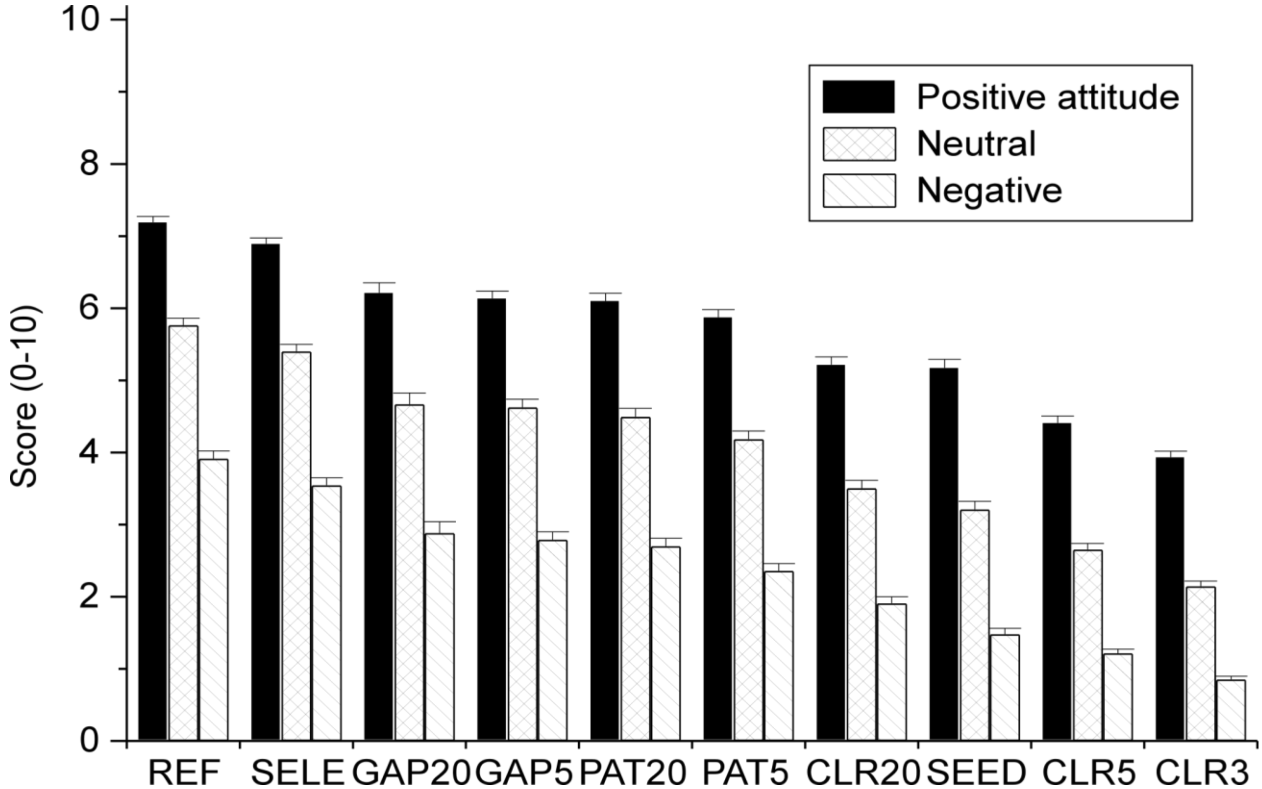
Score (0-10)
0
2
4
6
8
10
Positive attitude
Neutral
Negative
REF
SELE
GAP20
GAP5
PAT20
PAT5
CLR20
SEED
CLR5
CLR3

Fig. 2

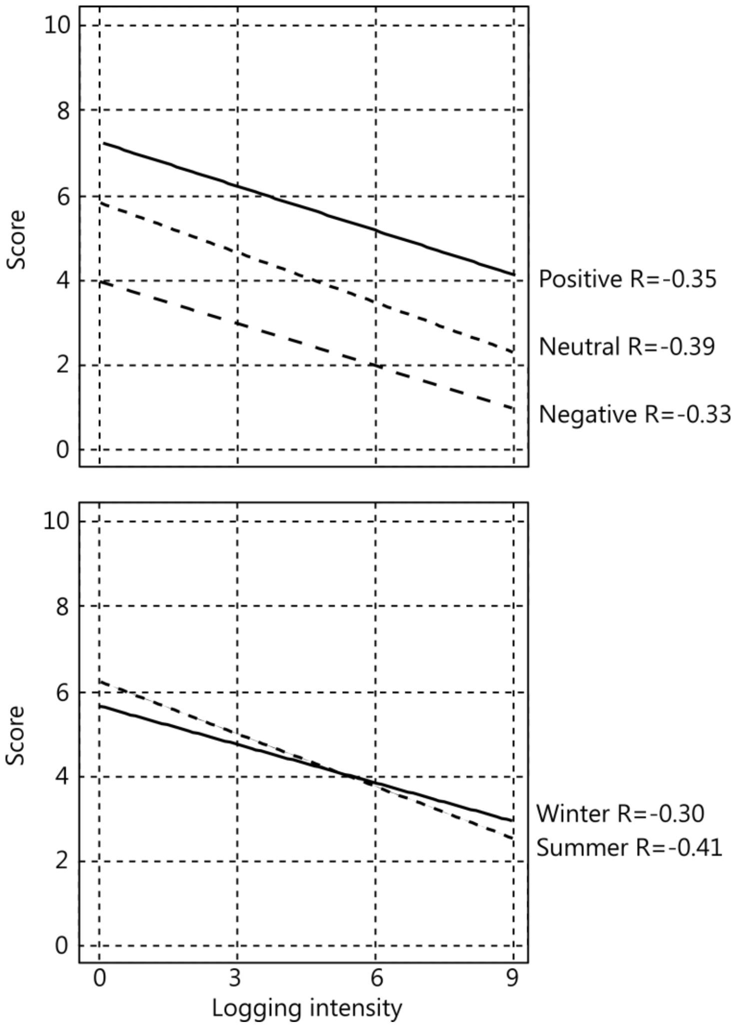
Score
Positive R=-0.35
Neutral R=-0.39
Negative R=-0.33
Score
Winter R=-0.30
Summer R=-0.41
Logging intensity

Fig. 3