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forest management

Agreement in Tree Marking: What Is the Uncertainty of Human Tree Selection in Selective Forest Management?

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New methods for sustainable forest management are being introduced in Ireland and other countries worldwide. These require different approaches to thinnings. This study explored how different levels of expertise in managing forest ecosystems affect the way individuals approach the task of selecting trees before and after training. Both experts and novices responded differently when provided with the same task. Before training, when presented with the task to carry out a thinning without specific instructions, experts applied the method of thinning they were most familiar with. When trained in one of these alternative thinning methods, novices successfully applied this method, whereas the experts did not. The level of agreement as to the choice of trees for removal was generally surprisingly low and among experts it was highest before training and declined most after training. Prior knowledge in managing forest environments affected how participants approached the task; the longer an expert applies a task in a particular way, the harder it is to change this strategy. This is crucial information, suggesting that if new approaches to selective forest management are to be successfully implemented, more effort should be made to convince experts and/or training should focus on individuals who have yet to become familiar with using a specific approach. The results of this study also suggest that the success rate of applying new methods should be monitored. This will ensure the application of forest management most suited to a given environment.

Keywords: agreement, continuous cover forestry, experts, novices, training

Arising from concerns about potentially negative environmental impacts, there is currently a political as well as a practical desire in Ireland and many other European countries to move away from traditional plantation forestry to continuous cover forestry (Pommerening and Murphy 2004, Vítková and Ní Dhubháin 2013). Continuous cover forestry (CCF) is a more natural approach to forest management based on selective thinning and harvesting as opposed to rigid plantation management involving distinctive phases of planting, mechanistic thinnings, and clear-felling.

The practice of continuous cover forestry is also believed to have the potential to deliver multiple objectives (Vítková 2014), e.g., to enhance biodiversity, facilitate recreation, and maintain high landscape and amenity values while producing timber (e.g., Schütz 2002, Légaré et al. 2011, Edwards et al. 2012). In addition, continuous cover forestry is supposed to have the ability to increase forests' resilience to sustain potential outbreaks of pests and diseases and to mitigate the adverse effects of climate change. However, the implementation of continuous cover forestry requires skilled forest managers and field staff.

In this context, marking trees to manipulate competition is a crucial prerequisite for implementing sustainable forest management plans. Every plan is carried out through hands-on decision-making by more or less skilled field staff. Therefore, selecting trees for removal in favor of others is an important task, because an inappropriate choice of trees may cause unsuitable changes in the forest environment that may be hard to reverse. Tree marking in selective thinning and harvesting operations is an important aspect of forest management, because poor implementation at this step of the process can offset the output of the best available models and the most detailed planning. We have to accept that there are clear limits to the precision of treatments implemented in the field.

von Gadow (1996), reflecting on changes in forests, stated that modifications of forest structure caused by such practical decision-making are not always taken very seriously in the scientific literature, although they often have a far greater effect on forest development

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than natural growth and natural disturbances. Consequently, environmental monitoring must also consider the human factor in conservation and forest management.

Skills, experience, and expertise play an important role when it comes to the practical implementation of management instructions or prescriptions in the field through tree marking. Haerem and Rau (2007) have studied the influence of expertise and task complexity and provided answers to the question of why expertise should be studied. There may be many reasons to do so but from a practical perspective, expertise has been researched to develop training that yields improved skills (Farrington-Darby and Wilson 2006, Haerem and Rau 2007). Expertise has been of interest in the behavioral studies of decisionmaking processes and judgment ability, as experts are believed to exhibit the highest levels of performance (Shanteau and Stewart 1992). Research on expertise and professional performance has been reported from different domains such as medicine (e.g., Schubert et al. 2013), occupational therapy (e.g., McCluskey and Lovarini 2005), computer programming (e.g., Adelson 1984), sports (e.g., McPherson 1999), teaching (e.g., Bullough and Baughman 1995, Castañer et al. 2013), and writing (e.g., Hartig and Lu 2014). However, studying expertise in sustainable forest management has so far been largely neglected with a few exceptions, such as Zucchini and von Gadow (1995) and Pommerening et al. (2015).

Behavior of Experts and Novices

There are many definitions of an expert in the associated literature (Shanteau 1992), and in this study, an expert is considered someone who possesses knowledge gained through experience and training in a particular field (Spence and Brucks 1997). Therefore, an expert has sufficient experience and breadth of knowledge to do a good job. In the context of this study, we use the term "expert" to represent "experienced practitioner." A novice (or novice practitioner), on the other hand, is someone with no (or very little) prior knowledge and experience in a given task.

Ericsson and Lehmann (1996) reviewed studies on experts' performance in music, sports, chess, auditing, and computer programming along with other domains, concluding that there are "reliable differences" between the performances of experts and novices. They also found that experts do not always outperform novices in all aspects of a given task. Shanteau (1992) suggested that experts may do better than novices in domains with a high degree of objectivity and repetitive routines as opposed to those domains that are more subjective, involving decisions about human behavior. Furthermore, Spence and Brucks (1997) found that experts did not become any more accurate in their task performance when provided with structural aid. Their efficiency actually decreased, whereas novices made more accurate decisions when provided with such aid. Both experts and novices have been found to accomplish the same task differently, but not necessarily incorrectly (e.g., Larkin et al. 1980, Adelson 1984, Spence and Brucks 1997, Haerem and Rau 2007).

Theory and Hypotheses

Thinning has been an important method of managing forests, as it is commonly used to influence natural competition processes in forests for meeting conservation or production objectives. Before removal, trees that are supposed to be cut are often marked by field staff using spray paint or ribbons to ensure that the harvester or chainsaw operators remove the trees intended for removal. This marking can involve a fairly complex decision process in which various aspects have to be taken into account to comply with management objectives.

Plantation forest management has been carried out almost exclusively using several low thinning methods. Low thinning (or thinning from below) involves the removal of small-sized trees of lower quality from a forest stand, encouraging the growth of the remaining trees (Cameron 2002). In contrast, crown thinning is a thinning method that is commonly preferred in continuous cover forestry for a number of reasons. As part of crown thinnings (or thinnings from above), the competitors of frame trees (i.e., vigorous trees of better quality) are marked and removed. Frame trees (also referred to as future crop trees) are maintained for their specific characteristics (e.g., economic or conservation value) for a long time until final harvesting (or even beyond). At the time of final harvesting only the frame trees are left in the forest. As trees actively competing with frame trees for light, water, and nutrients usually are about the same size, crown thinning leads to the removal of larger trees compared to low thinning (Cameron 2002). Both low and crown thinning are thinning types and determine different types of structure of the residual forest.

Crown thinnings have a number of advantages to low thinnings as they usually lead to a higher diversity of forest structure, which is important for forest ecosystems to buffer disturbances and to offer different habitat types. Higher diversity of forest structure can also potentially reduce management costs through processes of biological automization (Pommerening and Murphy 2004). From an economic point of view, crown thinnings increase financial returns and help to cofinance forest management.

A recent survey of forestry professionals in Ireland found that a lack of knowledge (and expertise) among professionals is the most important constraint for adopting continuous cover forestry (Vítková et al. 2015). This finding acted as the catalyst for this study.

The objective of this study therefore was to analyze how varying levels of expertise in managing forest ecosystems affect the way that humans approach the task of selecting trees before and after specific training. To break this objective down into more specific questions, we tested the following five hypotheses.

In Britain and Ireland, most forestry staff, due to their training and education, have a habit of marking trees according to the principles of low thinnings. Accordingly our first hypothesis is that when given the task of marking a stand of trees for thinning, experts will use the approach they are most familiar with, i.e., low thinning. Hence, the following:

Hypothesis 1: Forestry experts will mark trees for a low thinning when presented with the task of marking a forest stand for thinning (without instructions).

Since novices, on the other hand, have no previous knowledge of forest management practices, our second hypothesis is

Hypothesis 2: Novices will mark trees for an indifferent thinning when presented with the task of marking a forest stand.

Learning is considered to be a substantial part of the process of becoming an expert (Brown et al. 2011). Adelson (1984) found that novices easily adopt a new strategy because they have no prior knowledge of the given domain. This indicates that training has an important role in the acquisition of new concepts by novices and we therefore hypothesized that

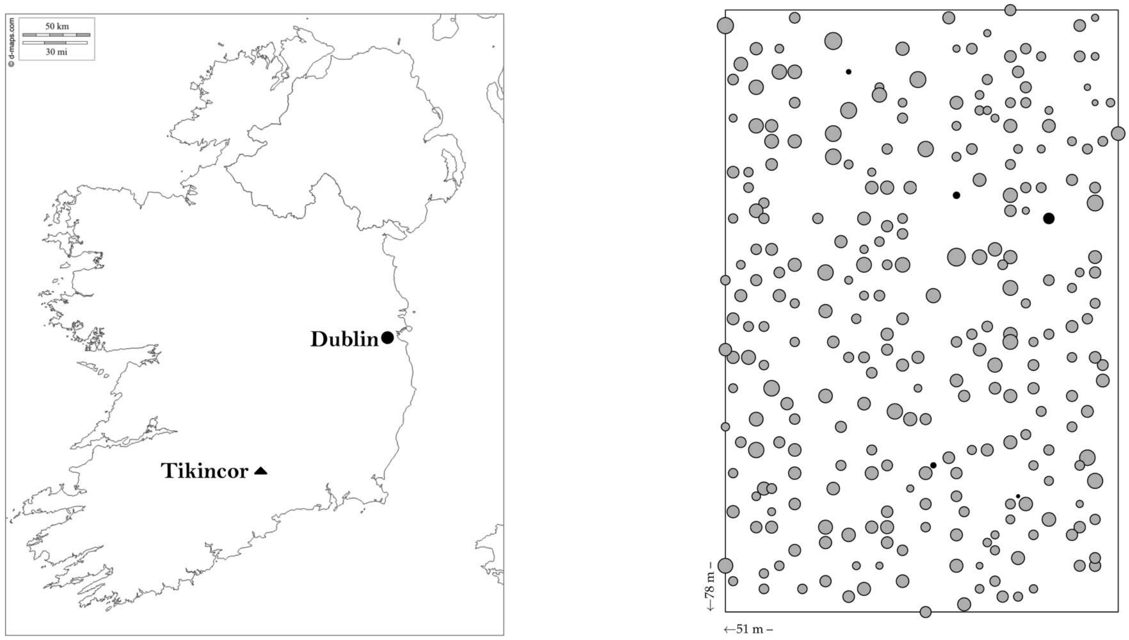

Figure 1. Map of the location of the Tilkincor experimental plot (County Tipperary) in Ireland (left) and plot map (right). Circles representing tree locations were scaled according to stem diameters. Gray circles show the locations of Sitka spruce trees; black circles show those of birch and rowan trees.

Hypothesis 3: After training in how to conduct a crown thinning, novices will tend to mark trees for a crown thinning.

The quality of management practice may be improved as a consequence of learning that leads to changes in behavior (Grol and Grimshaw 2003). However, in their study on prior knowledge and complacency in new product learning, Wood and Lynch (2002) reported that those with higher prior knowledge learn less about a new method and expose conservative behavior when presented with information about the new method. Crown thinnings have rarely been used in Ireland so far; hence, it is reasonable to consider it as a new method. Thus, we hypothesize that

Hypothesis 4: After crown-thinning training, most experts will not mark trees for crown thinning.

Shanteau (2001) reviewed studies on disagreement among experts when presented with the same task. The evidence he compiled showed that experts do not always agree when making decisions. He attributed this disagreement to structural factors such as the absence of an optimal solution, different level of decision, presence of multiple outcomes, unpredictable solutions with evolving constraints, and still evolving science. Disagreement among experts has been reported from various domains; for example, from medicine (e.g., Delahunt 2006), teaching (e.g., McLeod et al. 2009), and forensics (e.g., Mossman 2012). Based on the above evidence we hypothesize that

Hypothesis 5: Experts will show lower levels of agreement than novices with regard to the decisions they make when marking trees for thinning.

Materials and Methods

A 0.4-ha experimental plot was established in Tikincor Forest (County Tipperary, Ireland) in the spring of 2013 to test the above-stated hypotheses. All trees within the experimental plot were numbered, their dbh[1] measured, and their x, y coordinates recorded. The mean stem diameter in the plot was 29 cm. There were 728 trees/ha, which equals to a basal area of 47 m^2/ha. The experimental plot was dominated by Sitka spruce (*Picea sitchensis* [Bong.] Carr.) with a minor component of rowan (*Sorbus aucuparia* L.) and birch (*Betula pendula* Roth). Figure 1 shows the location of the experimental plot in Ireland and a map of the plot.

Test Persons

Before the marking experiments, a group stratification of all test persons was performed based on their registration information. The purpose of the stratification was to minimize the variation in terms of expertise within the groups as opposed to between them. As a result, four groups of test persons (each group comprising four individuals) were formed, i.e., complete novices, transitional novices, intermediate novices, and experienced experts. The group size of four also reflected the maximum number of individuals who could work in the experimental plot without influencing each other. Individuals belonging to the group of complete novices were selected on the basis of having no forestry education or forestry experience but having an interest in nature. The group of transitional novices consisted of forest owners owning forestland managed according to the principles of continuous cover forestry (Vítková et al. 2013). The four forest owners lived close to the experimental plot, and none of them had formal forestry training. Individuals who formed the group of intermediate experts were foresters who were not experienced in practicing thinnings, as this practice was not part of their job. Members of this group gained a university degree in forestry. The group of experienced experts included experienced forest managers who routinely carried out thinnings as part of their daily work. Members of this group also hold a university degree in forestry.

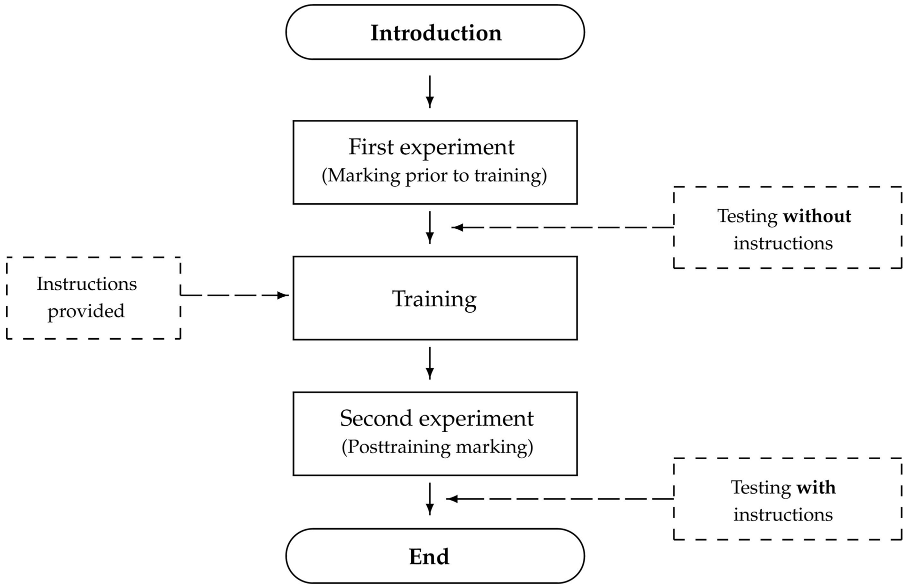

Figure 2. Experimental design.

Design of the Training Experiment

The knowledge and experience varied among individual test persons from none to relatively experienced. The design of the experiment is presented in Figure 2. All test persons were provided with general information about the experimental plot, which included details such as the species composition, plot dimension and area, number of trees in the plot, basal area, standing volume, mean tree height, and mean tree diameter (for details see the online Supplemental Appendix 1[S]). The test persons were also informed about the general purpose of thinnings, e.g., that they are practiced to improve the quality and growth of the remaining trees. At this stage of the experiment, we deliberately did not provide specific instructions other than that the test subjects were asked to mark for a thinning they believed was most appropriate for the given forest stand.

The test persons then proceeded to the first experiment and recorded the tree numbers of all trees they wished to remove on the sheet shown in Supplemental Appendix 1. They were also cautioned not to talk to other test persons during the exercise to avoid mutual influence, which can lead to a biased outcome of the experiment.

Once the first experiment was conducted, all test persons were given training in crown thinning. All test persons were informed that crown thinning is a selective thinning where frame trees are selected and retained and their competitors are marked for removal. The participants were notified that frame (or future crop) trees are trees of superior quality with straight stems, light branching, and good vigor. They should have no visible damage or defects but rather healthy foliage and good crowns. They were further informed that frame trees are those yielding a potentially higher financial return when harvested and contribute to the next forest generation through seeding. Frame trees usually are chosen from the group of dominant and codominant trees.

The participants were advised to start in the corner of the experimental plot and to mark the strip of the trees between two adjacent extraction racks. At the far end of the experimental plot, the test persons should cross the extraction rack, turn and again mark the strip of trees within the next two adjacent extraction racks. The participants were further informed that frame trees should not be selected in the vicinity of forest roads and extraction racks, as there is a higher chance of them attracting harvesting damage.

Similar to the first part of the experiment, the participants were then asked to mark the experimental plot again; this time, instructions were given and these supported the idea of a crown thinning. Everybody was provided with exactly the same information. The test persons were requested to identify 80–120 frame trees per ha and to release them from possible competition by removing 1–3 trees in the vicinity of frame trees. They were instructed to record all frame trees and all trees marked for removal. The instructions and field sheets the test persons were provided with are given in Supplemental Appendix 2. For comparison, Vanclay (1989) published an example of complex tree marking rules in tropical forests. Supplemental Appendix 3 details the information on crown thinnings that was given to the participants before the second experiment.

We deliberately decided to perform both experiments in the same forest plot so that the trees used for marking carried exactly the same (passive) probabilities of getting marked as opposed to a design with two different plots. Unpublished data from training events in Germany and Switzerland have often demonstrated that even highly skilled forestry staff do not tend to stick to previous tree-selection choices, even when asked to repeat the marking with exactly the same instructions.

Trainers

The training was delivered by two forestry professionals who both have a university degree in forestry with >20 years of experience in forest management, particularly in thinning. One of the trainers works for a semi-state organization focusing on forest management, and the other one is employed by a company managing privately owned forests.

[S] Supplementary data are available with this article at http://dx.doi.org/10.5849/forsci.15-133.

Methods of Assessment

Thinning Intensity

Thinning intensity is important in forest management, as it affects the development and structure of a forest stand. Thinning intensity is a characteristic of impact and can be measured in terms of number of trees or the amount of volume/basal area to be removed. Including thinning intensity in the analysis yielded a good comprehension of how test persons of varying levels of expertise approached the task they were asked to complete. The thinning intensity was defined by the proportion of basal area removed (von Gadow et al. 2012). This was denoted as rG (Murray and von Gadow 1993)

$$rG = \frac{G_{\text{rem}}}{G_{\text{tot}}} \tag{1}$$

where G_{rem} represents the basal area removed and G_{tot} is the total basal area.

SG Ratio

Low thinning or thinning from below is characterized by the removal of suppressed and subdominant trees (Cameron 2002). Hence, trees removed during this operation tend to be of small size. On the contrary, crown thinning focuses on an early selection of vigorous, better quality trees, i.e., frame trees, and on releasing them from competition by removing trees around them. Hence, larger trees tend to be removed when a crown thinning is applied. The hypothesis testing required an objective measurement of what type of thinning was carried out by individual test persons. This was achieved by calculating the *SG* ratio, which is an objective indicator of the type of thinning used as it reflects the diameter distribution of the trees selected for removal as well as that of those retained. It is defined by von Gadow and Hui (1999) as

$$SG = \frac{N_{\text{rem}}/N_{\text{tot}}}{G_{\text{rem}}/G_{\text{tot}}} \tag{2}$$

where N_{rem} and N_{tot} represent the number of trees removed and the number of trees before the removal, respectively, and G_{rem} and G_{tot} denotes the basal area removed and total basal area before the removal, respectively. An SG ratio <1 denotes that a crown thinning was used, because less relative N than relative G was removed (mean diameter removed $>$ mean diameter before removal [$dg_{\text{rem}} > dg_{\text{pre}}$]). An SG ratio >1 indicates the application of a low thinning, because more relative N than relative G was removed (mean diameter removed $<$ mean diameter before removal [$dg_{\text{rem}} < dg_{\text{pre}}$]). When $SG = 1$, the intervention is indifferent, because G_{rem} is close to the mean G. Indifferent thinning (or neutral thinning) often results from a nonselective choice of trees such as mechanical or line thinning or is a consequence of a natural disturbance where all trees have an equal chance of being removed (Kerr and Haufe 2011).

Agreement in the Selection of Individual Trees

An index of agreement or concordance B was modified from Zucchini and von Gadow (1995) to quantitatively assess the degree of agreement and disagreement among individuals. We based the modification of the index by Zucchini and von Gadow (1995) on the construction principle of Clark and Evans's (1954) aggregation index.

The agreement index assessing the level of agreement was constructed as follows

Table 1. Summary of *t*-tests of *SG* ratios for the groups before and after training.

Group	*SG* ratio	*df*	*t* value	*P* value
Marking before training				
Complete novices	1.0	3	0.578	0.603
Transitional novices	1.1	3	2.130	0.123
Intermediate experts	1.2	3	3.426	0.042
Experts experienced	1.4	3	10.791	0.002
Posttraining marking				
Complete novices	0.9	3	−1.294	0.286
Transitional novices	0.9	3	−3.480	0.040
Intermediate experts	1.0	3	−0.930	0.421
Experts experienced	1.1	3	1.042	0.379

$$B = \frac{\sum_{k=1}^{K} |2x_k - n|}{K \cdot \sum_{x=0}^{n} |2x - n| \cdot \binom{n}{x} \cdot \hat{p}^x \cdot (1 - \hat{p})^{n-x}}, \tag{3}$$

where n denotes the number of test persons, K represents the number of trees in the experimental plot, and x denotes the number of test persons that mark a particular tree. $n - x$ is the number of test persons who do not mark a particular tree. X_k denotes the number of test persons who marked tree k with $\hat{p}$ denoting the mean number of marked trees calculated from all test persons. In this index, we divide the sum of absolute differences of all trees and test persons by the expected sum of absolute differences. The expectation is based on the binomial probability function.

Independent decisions (or a lack of agreement) are indicated by values of $B \sim 1$. A tendency toward agreement is indicated by $B >$ 1. Increasing disagreement, on the other hand, prevails if $B < 1$. Perfect disagreement is represented by $B = 0$. The index indicated that the trend participants within individual groups tended to follow during the marking for thinning before and after the training.

Data Analysis

SG ratios were tested for normality using the Kolmogorov-Smirnov test. This confirmed that the distribution of the sample data was not different from that of a normal distribution. *t*-tests were used to test whether the mean *SG* ratios of the test person groups were as hypothesized.

The agreement data were tested using the χ^2 test to determine whether the observed decisions on marking trees for thinning were significantly different from completely independent (unrelated) decisions based on the binomial distribution.

Data handling and calculations were performed with the open-source statistical software R (R Development Core Team 2015).

Results

Marking before Training

When presented with the task of marking a forest stand for thinning, both groups of experts marked a low thinning as $SG > 1$ ($p < 0.05$); i.e., the trees selected for removal had smaller mean diameter than the mean diameter of the entire stand before marking (Table 1). In addition, experienced experts seemed to carry out a less intensive thinning as the basal area they removed was smaller than that of intermediate experts (Figure 3A). This, however, was not supported statistically ($p > 0.05$). Both groups of novices, on average, performed an indifferent thinning, as their *SG* ratios were shown not to differ from 1 (Table 1). They also removed a similar proportion of basal area.

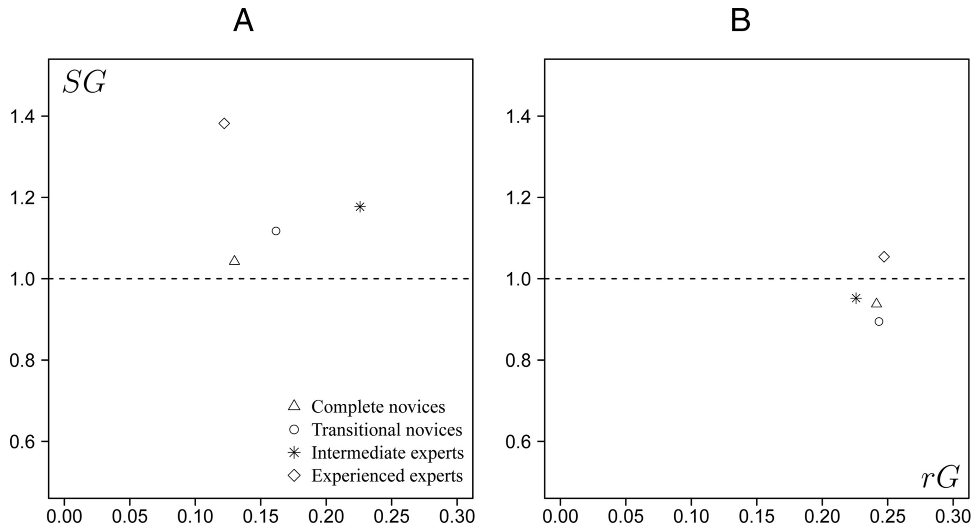

Figure 3. The relationship between *SG* ratio and mean basal area removed before (A) and after (B) training in crown thinning.

Table 2. Index of agreement for individual test person groups accompanied by χ^2 values used in testing the difference between observed and expected values.

	Marking before training				Posttraining marking			
Test person group	*B*	χ^2	*df*	*P*	*B*	χ^2	*df*	*P*
Complete novices	1.038	4.028	2	0.1332	1.058	8.881	3	0.0310
Transitional novices	1.035	14.059	3	0.0028	1.133	45.341	3	>0.0001
Intermediate experts	1.255	101.665	3	>0.0001	1.116	51.537	3	>0.0001
Experts experienced	1.147	55.391	2	>0.0001	1.079	12.546	3	0.0137

Posttraining Thinning

After training in how to conduct a crown thinning, both groups of novices seemed to mark a crown thinning (Table 1), but this was only statistically supported by the group of transitional novices ($p < 0.05$).

Both groups of experts did not appear to mark for a crown thinning when provided with training and instructions on this type of thinning; however, this could not be proven statistically ($p > 0.05$) (Table 1). The experienced experts still marked for a low thinning and, as a result of the training, applied a more intensive thinning instead (Figure 3B).

Level of Agreement

Across all groups and the two marking experiments there was little agreement. The index of agreement showed that the individual groups, with the exception of the group of complete novices, made decisions that were significantly different from independent ones when marking trees for thinning before the training (Table 2). In particular, both groups of experts showed greater tendencies toward agreement than the novices. The intermediate experts had the highest level of agreement with 16 and 12% of the trees marked by two and three members of this group, respectively. The transitional novices, for whom the lowest index of agreement was recorded, had only 14 and 4% of the trees marked by two and three group members, respectively (Figure 4A–D).

None of the test groups appeared to make independent decisions when marking after the training (Table 2; Figure 4E–H), with the transitional novices exhibiting the greatest level of agreement. In contrast, agreement among the experts declined, particularly among the intermediate experts. Only 21% of the trees were chosen by two or three test persons in this group (Figure 4G).

Discussion

Thinning before Training

The results supported the expectations that the performance of experts would be different from that of novices. The results also confirmed that, before training, experienced foresters applied the approach to marking that they were familiar with; i.e., they marked for a low thinning (Hypothesis 1), whereas novices applied an indifferent thinning, which is close to a random selection of trees (Hypothesis 2). Within the groups of experts, differences were noted in the intensity of their marking. The experienced experts suggested the removal of half of the basal area marked by the intermediate experts. It has often been observed that the greater the basal area removed during a thinning, the greater the risk of the trees remaining postthinning being blown over after storms (Ní Dhubháin et al. 2001). However, this is a complex matter, as the wind risk also heavily depends on past thinning history and on the size and morphology of the trees removed and of the residual trees. This may explain why the more experienced experts were more conservative regarding the intensity of thinning. This finding supports Haerem and Rau's (2007) contention that individuals with varying levels of expertise tend to pay attention to different aspects of a given task. It further demonstrates that experts with more experience show a deeper understanding of the subject matter, which is consistent with the findings of Adelson (1984), who reported that more experienced individuals tend to look at the deeper structure of the task. The less experienced ones, on the other hand, focus on the surface structure

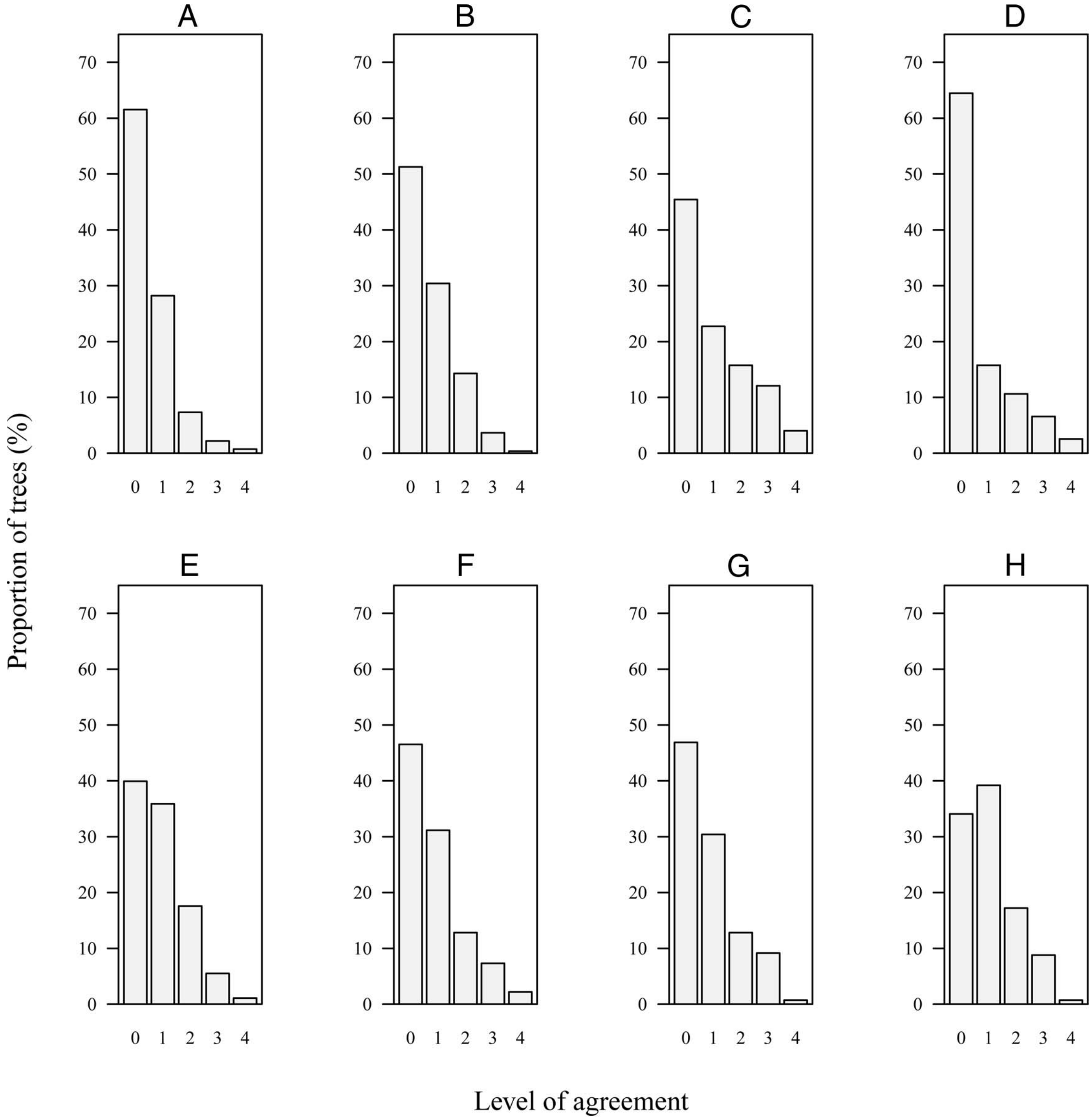

Figure 4. The level of agreement (number of marks per tree) among individual test person groups during the first marking experiment is represented for complete novices (A), transitional novices (B), intermediate experts (C), and experienced experts (D). The second marking experiment is shown for complete novices (E), transitional novices (F), intermediate experts (G), and experienced experts (H). The number on the *x* axis represents the number of marks per tree assigned by the test persons in the different groups.

of the task and do not necessarily take the wider context into consideration.

Posttraining Marking

Posttraining differences in the actions of novices and experts were also noted. We found that novices appeared to follow the training instructions as they marked for a crown thinning, whereas the expert groups did not (Hypothesis 3 and 4). These findings agree with those of Liu et al. (2000), who found that novices have a greater tendency to follow procedural protocols than those with more experience. Similarly, Kuipers and Grice (2009) reported on changes in individuals' behavior when exposed to a specific protocol, finding significant changes in novices' behavior.

There are several possible reasons for these findings. For example, as Wood and Lynch (2002) concluded, prior knowledge has a negative effect on learning new information about a new product. They further suggested that a person's prior knowledge can lead to poor performance, arising from a presumption of similarity of new and old knowledge. It may be that the experts in our study assumed that their old knowledge and experience of low thinning would be adequate to tackle the new approach of using crown thinning and, hence, may not have paid attention to the instructions or interpreted them loosely. Wood and Lynch (2002) further found that although experts may be tempted to apply a new product (and techniques or methodologies), they may also be quite likely to apply it incorrectly due to being overconfident in their expertise. This may have caused the experts to do what they "felt" was right, given the conditions of the forest stand, regardless of the instructions provided. However, it is important to follow prescriptions closely; especially when a novel type of managing forest ecosystems is desired to deliver all the objectives proposed.

Applying a crown thinning would have required the experts to move out of their comfort zone. As Mazmanian and Mazmanian (1999) suggested, committing to a different strategy requires individuals to willingly agree to the changes implied. It also requires them to comprehend that there are areas of their expertise that may need to be expanded in the light of new knowledge and/or experience (Vachon and LeBlanc 2011). If resistance to moving away from their comfort zone contributed to the experts in this study continuing to use their traditional approach, it may be necessary to "sell" the new approach to thinning more effectively.

Although establishing new routines and priorities takes years (McCluskey and Lovarini 2005), lack of time and continuity in professional education appear to be the main barriers to using these new routines (Vachon and LeBlanc 2011). Teaching "an old dog new tricks" may be difficult because those with longer expertise may find it harder to use the thinning type in which they lack expertise. Nevertheless, a study by Helmkamp et al. (2004) focusing on safety awareness among forest logging experts concluded that the training influenced the experts as their knowledge was reported to have improved after the training. Exposure to training and getting instructions on how to mitigate certain hazards at work yielded changes in experts' routines at work. Such results indicate that depending on the nature of a task, experts may be more inclined to adopt new methods as opposed to others. In addition, this may be especially pronounced in the case of less experienced individuals as they may be more inclined to take on a new type of management. Forestry is reputedly a conservative profession, and there can be resistance toward adopting new forestry practices. Such resistance may be reduced through appropriate training.

Level of Agreement

According to our Hypothesis 5, it was expected that experts would show lower levels of agreement than novices, as previous research has reported that professionals do not always agree when making decisions (e.g., Delahunt 2006, McLeod et al. 2009, Mossman 2012). However, our findings did not entirely support this expectation. Both expert groups were shown not to be making independent decisions, and the highest values of the agreement index were recorded for the two expert groups before training. After the training, the level of agreement among the experts dropped; in contrast, the level of agreement increased among the novices. These findings suggest that familiarity with a task influences the level of agreement. The experts practiced low thinning in the pretraining exercise. This is the approach that they were most familiar with and confident about using; hence, it is not surprising that the highest agreement levels with regard to tree marking were recorded for these groups. This consistency in performance throughout the group supports the findings of, e.g., Ericsson et al. (1993) and Charness et al. (2005) that repetitive performance of a task results in better competence.

After the training, the experts not only failed to implement the thinning type they had received training for but they also exhibited lower levels of agreement. This suggests that the training created a level of uncertainty among the experts as to which trees to select for removal and for retention. This can be explained by the fact that the choice of trees for removal according to a low thinning is different from that in a crown thinning; in the former, small-sized trees of lower quality from a forest stand tend to be removed, and in the latter, trees competing with vigorous, good-quality trees are marked and removed. This may have led to the phenomenon noted by Camerer and Johnson (1991) that experts may develop configural rules that may be inaccurate when provided with an unfamiliar task as they are created under rare conditions. In future experiments, it may also be interesting to compare the effect of different kinds of training ranging from purely theoretical indoor to very practical, hands-on outdoor sessions, although this comparison is experimentally and logistically not easy to handle.

Conclusions

This study yielded valuable information in terms of how individuals with different levels of expertise respond to an environmental management task when provided with the same instructions. With the notable exception of Zucchini and von Gadow (1995), this article is the first attempt to study expertise in forest management. Along with other studies (e.g., Vítková et al. 2013, 2015), it also helps to draw a more accurate picture of the knowledge needs among forestry experts in the context of implementing crown thinning and continuous cover forestry.

The study highlights the general low agreement in tree selection across all test persons and the two experiments. Given the importance of silvicultural training in forestry education, this is somewhat surprising. The results also highlight the challenges posed when expert managers are required to alter professional behavior and problem-solving strategies that they are familiar with and suggests that more intensive training may be needed to ensure that this practice is effectively adopted. This may especially be the case of more experienced individuals where more motivation may be necessary when a new way of environmental management unfamiliar to them is introduced. These experienced individuals will require training more often and will need more persuasion and incentives than less experienced individuals. It further suggests that training of young forestry staff, unburdened with experience and tradition, would be more effective in delivering new approaches to forest management and that training in new concepts should also enter education early before old myths have taken hold.

Finally, tree marking is a skill that has a key role to play in influencing stand structure and ensuring sustainable forest management. Yet, its role is underestimated, and its use in countries with a long tradition in plantation forestry is declining. If continuous cover forestry approaches are to be adopted to a greater extent, greater recognition of the role of tree marking and investment in the training of foresters in this activity will be required. The results of this study suggest how this investment would be more effectively targeted.

Endnote

1. Dbh refers to the horizontal measurement of a tree's stem diameter and is taken over-bark at 1.3 m above ground level.

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