RESEARCH

Decision Making in Tree Selection – Contemplating Conflicting Goals via Marteloscope Exercises

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The implementation of biodiversity conservation measures in forests managed for timber production usually implies trade-offs between ecological and economic objectives. In continuous cover forestry these trade-offs emerge at the scale of selecting individual trees for timber harvesting or habitat retention. Tree selection determines both the economic viability of timber management and the prevalence of tree-related microhabitats, considered a multi-taxon indicator of forest biodiversity.

Recent studies find that tree selection is influenced by several factors, such as individual management preferences and goals, professional education and institutional context. To gain a deeper understanding of tree-selection practices in the context of retention forestry, we analyse four tree-selection exercises on silvicultural training sites (Marteloscopes) performed by groups with different professional backgrounds: conservationists, foresters, and students of each. Based on qualitative data from participant observations and group discussions, we explore their decision-making strategies, reasoning, and practices. Our analysis provides novel insights into decision-making processes when implementing conservation measures, especially with regard to dealing with trade-offs and uncertainties.

Our findings indicate that tree-selection decisions are not merely the result of cognitive and rational weighing processes. They can be understood as practices requiring experience, professional routine, and intuition. These practices differ across professional cultures. Despite these differences, the participants of the analysed Marteloscope exercises developed an understanding of the other stakeholders' motivations and restrictions. The setting stimulated a change of perspective that built awareness in many of the participants of their own routines and biases. This may facilitate professional cooperation, cross-disciplinary learning, and the implementation of biodiversity conservation.

Keywords: integrated forest management; biodiversity conservation; retention forestry; professional practices; learning; habitat tree

1 Introduction

Forests provide a wide range of goods and ecosystem services and are nowadays subject to diverse demands. Changing societal expectations have broadened management objectives, reflected in corresponding multi-purpose forest management concepts (Gustafsson et al., 2012; Kraus and Krumm, 2013; Messier et al., 2014). Integrated forest management refers to approaches aimed at accommodating multiple forest ecosystem services without segregating uses or giving priority to wood production (Kraus and Krumm, 2013; Winkel, 2008b; Winkel and Jump, 2014). Implementing such integrative approaches can be challenging as it often implies dealing with trade-offs. Providing timber for the market versus protecting habitats for biodiversity is a particularly pronounced example for potentially conflicting goals in integrated forest management. Management optimized for timber production frequently results in intensive biomass use, homogenous forest structures; this is often related to a lack of older trees and deadwood, which is associated with biodiversity loss (Messier et al., 2014).

Retention forestry is an integrated conservation approach in which biodiversity-relevant structures, including trees providing microhabitats, are intentionally retained at the time of harvest (Gustafsson et al., 2012). These habitat trees may have a high economic value, hence their retention means a considerable economic loss. Selecting habitat trees requires resolving trade-offs between wood production and biodiversity conservation. Though several policies have been introduced to foster this integration, actual implementation remains a challenge (Gustafsson et al., 2020; Maier and Winkel, 2017; Winter et al., 2014). This is particularly true in the context of continuous cover forestry, where tree selection occurs on the single-tree level prior to harvest and is the most important management intervention. Here, forest practitioners have a particularly

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critical role. When selecting trees they decide about trade-offs between demands on forests – habitat retention or wood production (Cosyns et al., 2018). This paper focuses on these human decisions.

Although tree selection has a big influence on a forest stand's structural diversity, only recently have studies on tree-selection behaviour emerged, showing the relevance of several factors related to individual expertise and preference (Spinelli et al., 2016; Vitkova et al., 2016; Cosyns et al., 2018; Pommerening et al., 2018). Vítková et al. (2016) investigate tree marking in an experimental plot before and after specific silvicultural training. As novices learnt and implemented alternative thinning methods more readily than forestry experts, the authors conclude that forest practitioners are less likely to change forest management strategies the longer they have applied them in a particular way. Generally, the level of agreement about which trees to remove was low. This is confirmed by Pommerening et al. (2018), who analyse 36 Marteloscope experiments in the UK regarding the agreement of raters (mostly employees of the state forestry service) when applying different thinning methods, and find a low accordance rate. The question that remains unaddressed is how much in agreement forest managers must be to reach the same management goals. Spinelli et al. (2016) compare individual tree selections as performed by various forest professionals (foresters, loggers, and agronomists) and find no significant difference between the results achieved by these three groups. However, differences between individuals were substantial. The authors conclude that individual perspectives, practical experience with tree marking, and specific training play a major role in tree selection. Besides the inter-individual variability, Pommerening et al. (2015) emphasize that the same person marks trees differently at different occasions depending on, for example, weather, mood, and starting point in the forest. These studies on human tree selection are (mostly) limited to subjects with similar professional backgrounds and are based on purely quantitative research designs. They scrutinize tree-selection patterns but do not fully explore the factors influencing tree selection, including the emerging individual and professional variations, nor the underlying decision-making processes, arguments, and considerations.

Forest management and its decisions and actions have often been investigated assuming (economically) rational decision making that strives for utility optimization (Yousefpour et al., 2012). Clearly and unambiguously defined objectives as well as comprehensive evidence-based information are the two pillars of such rational decision making. Numerical criteria and quantified valuations are highly appreciated because they promise to make the outcome of forest management interventions predictable (Detten and Hanewinkel, 2017). As previous research has pointed out, these preconditions are hardly met in forestry, specifically if the objectives go beyond mere biomass production. There is a general uncertainty related to developments in complex ecosystems (Hoogstra, 2008). In many cases there is a lack of clearly defined objectives and of information – especially on long-term future developments (Oesten and Roeder, 2012). Multi-criteria decision models have been applied as they can account for both multiple uses of forests as well as multiple stakeholders each with their own views, objectives, and demands (Ananda and Herath, 2009; Mendoza and Martins, 2006; Segura et al., 2014). Most of these methods require decision makers to assign stable and clearly defined probability structures to the various outcomes and dynamics of stochastic variables (Yousefpour et al., 2012). Furthermore, foresters are assumed to act rationally, that is, they aim to efficiently optimize management actions in view of the best available evidence.

Sotirov et al. (2019) have recently analysed behavioural models of forest owner decision making. Their agent-based framework rests on the triplet of homo economicus, homo sociologicus, and homo psychologicus. The neoclassical model of homo economicus follows a 'logic of rational choice'. The individual decides based on rational and efficient cost-benefit calculations, which allow him or her to choose the alternative with the highest economic profitability. The behavioural model of homo psychologicus assumes that human behaviour is guided by pre-existing beliefs, values, and knowledge. Following a 'logic of cognition', human beings decide and act guided by their beliefs and values. Homo sociologicus (Dahrendorf and Abels, 2010) is a model following a 'logic of appropriateness'. People internalize certain rules and norms, often following them unconsciously. Due to the risk of social exclusion, this normative behaviour is difficult to change. While distinguishing these three behavioural models, Sotirov et al. (2019) emphasize that humans draw on different logics and that none of the aforementioned models alone guide decision making completely. This is in line with Detten and Faber (2013), who find that forest managers base decisions relating to climate change adaptation both on scientific knowledge and traditional heuristics derived from experience.

In their case studies on the effects of regulations on forestry practice, de Koning and Benneker (2013) find that local actors reshape introduced institutions, such as guidelines on appropriate forest use, so that they 'fit' the local rules, norms, and beliefs. The implementation of newly introduced institutions follows a 'logic of practice' (Bourdieu, 1990) rather than an institutional logic. Accordingly, Arts et al. (2013) describe a model of homo practicus that denies both the prevalence of overarching behavioural rules and an individual actor's autonomy in his or her agency. Consequently, outcomes are inevitably unpredictable and interrelate with people's perceptions, preferences, and practices as well as the social fields in which they are situated. This may also explain the individual variations in tree selection practices found in the aforementioned studies (Cosyns et al., 2018; Pommerening et al., 2018; Spinelli et al., 2016; Vitkova et al., 2016).

To conclude, there is evidence that forest managers' decision-making does not follow a strict rational or optimizing strategy, but is subject to a multitude of influences shaping individual perceptions, beliefs, values, and motives (Detten and Hanewinkel, 2017). This is why several authors argue for the importance of (qualitative) social science approaches when aiming to better understand human decisions and practices in forestry (Bennett et al., 2017; Charnley et al., 2017; Mascia et al., 2003; Törnqvist, 1997). While there is plenty of research investigating foresters' and forest owners' values and beliefs, only a few studies have empirically investigated forest management decision making in practice. This is despite suggestions to study decision making in naturalistic settings, for example by observing foresters' actions in experiments in which they are confronted with uncertainty and long-term perspectives (Hoogstra and Schanz, 2009).

Against this background, this study aims to investigate the argumentation and reasoning of groups with different professional backgrounds when selecting trees for retention and harvesting, and to explore influencing factors directly with the participants. Through accompanying and observing virtual tree marking on silvicultural training sites (Marteloscopes, see 2.1), we explore decision making in a real-life scenario. Data from group discussions following the exercises allow us to reconstruct patterns of action, shared opinions, and reasoning, as well as implicit knowledge and habituated practices applied in tree selection. These insights may provide a starting point for exploring possibilities to transfer (mutual) learning effects of forest management exercises into the everyday work of forest practitioners.

Section 2 presents the Marteloscopes as our study sites, the participants of the Marteloscope exercises and discussions, and the methods of data collection and analysis. Section 3 reports on our results seeking to answer the questions which strategies different professional groups apply when deciding about trees to be harvested or retained, and how they deal with trade-offs between timber production and forest biodiversity. In Section 4 we discuss our results, focusing on leverage points for reconciling trade-offs in integrated forest management, and we draw conclusions in Section 5.

2 Material and Methods

2.1 Marteloscope sites

Of the four studied tree-selection exercises, two took place in the Marteloscope Jägerhäuschen (North Rhine-Westphalia, Germany) and two in the Marteloscope Rosskopf (Baden-Württemberg, Germany). Both locations are part of a European network of Marteloscopes facilitated by the European Forest Institute (EFI, 2019). Marteloscopes are one-hectare silvicultural training sites that allow for practicing and simulating tree selection in the context of continuous cover forestry. All trees larger than 7 cm in diameter at breast height (DBH) are numbered and inventoried (Schuck et al., 2015). Their timber quality is estimated by the local forester. The trees' economic values (in euros) are then calculated based on the available volumes of timber of different quality classes multiplied by local wood prices. The trees' habitat values (in habitat points) are calculated as a composite index based on a method described in Kraus et al. (2018), which essentially combines information on the type and number of tree-related microhabitats (TreMs) on a given tree, including aspects such as their rarity and the time a specific microhabitat needs to develop. TreMs are assessed based on Kraus et al.'s (2016) catalogue of tree microhabitats. All Marteloscope inventory data are processed through a I+ software (EFI, 2018), which runs on tablets and displays an interactive map of the given forest stand. This allows participants of a Marteloscope exercise to perform virtual thinning on-site, directly learning about the ecological and economic effects of their interventions (Kraus et al., 2018).

The Marteloscope Jägerhäuschen (established in 2017) is located in a double-layered, 140-year-old stand of mainly large oak in the upper layer and smaller hornbeam in the lower layer that is protected under Natura 2000 (Louen et al., 2017). The Rosskopf Marteloscope (established in 2014) is comprised of a multi-layered, 105-year-old stand that belongs to the Freiburg City Forest and consists mainly of Douglas fir (originating from planting), beech, and silver fir (Kraus et al., 2015).

2.2 Marteloscope exercises and participants

The two exercises in the Jägerhäuschen Marteloscope took place, respectively, on two consecutive days in November 2017. Twelve participants took part in the first exercise: nine nature conservation professionals (called *conservationists* hereafter), two foresters, and one forestry student. Another 12 persons, who are all active in forest management (called *foresters* hereafter), took part in the second exercise. On both days, five additional persons were present: two Marteloscope experts guiding the exercises (called *trainers* hereafter) and three social scientists observing the sessions. Before starting the exercises, we informed all participants about the purpose of our research and about the confidential handling of personal data during data collection, analysis, and storage. All participants agreed to sign an informed consent document signifying knowledgeable consent. The exercises followed the same procedure on both days. First, the trainers gave a general introduction to the Marteloscope idea and site. Afterwards, the local forest enterprise head provided the following instruction that was formulated in accordance to local forest management practice: 'Removal of 50 m³ wood (low removal rate, harvest should include 10% high-quality timber) and designation of 10 habitat trees'.[1] Next, tablets were handed over to the participants and their use was introduced. Subsequently, participants formed two-person teams, walked freely for 90 minutes through the site and virtually selected trees on their tablets (one tablet per team).

The first exercise in the Rosskopf Marteloscope took place in February 2018 with a mixed group of students, from forestry science and environmental science. For all of them the exercise was part of a compulsory silvicultural course. Along with one university lecturer and one Marteloscope trainer guiding the exercise, two social scientists were present. After an introduction, the 45-minute virtual thinning exercise was undertaken in teams of 3–4 persons. In this case, the task was to virtually retain 10 habitat trees and harvest five Douglas firs. Compared to the other three exercises, the students had access to more data from the tree inventory. The monetary value, timber volume, and habitat points data recorded for each tree were accessible on the tablet.[2] After the exercise, six students agreed to participate in the discussion.

The second exercise in the Rosskopf Marteloscope was conducted in March 2018 with twelve foresters working for the state forestry administration of Baden-Württemberg. Two Marteloscope trainers guided the exercise and two social scientists observed and accompanied the participants. This time the task was to remove 30 m³ Douglas fir wood and 20 m³ beech wood and to designate 10 habitat trees. The participants formed two-person teams and had one hour to undertake a virtual thinning on their tablets. **Table 1** gives an overview of all Marteloscope exercises investigated for this study.

2.3 Participant observation and group discussion

The method applied in this paper follows from our interest to study forest managers' practices; it assumes these practices are largely routinised and therefore hardly to be verbalized. Consequently, in addition to discussions and interactions, observations were applied to access 'inexpressible' aspects as well as taken-for-granted meanings not explicated in conversation. We randomly accompanied different teams during the actual Marteloscope exercise, listened to their discussions, asked questions, and recorded our observations in field notes. Our observations include interactions among participants, between participants and trainers as well as participants and the forest stand as a 'real time activity' (Nicolini, 2017). As suggested by DeWalt and DeWalt (2011), we apply participant observation to develop a holistic understanding of the phenomena under study and its situated context. Following an interpretive research approach, we use unstructured observations allowing us to enter the field with less preconceptions about what we may observe.

All Marteloscope exercises were closed with a group discussion. In contrast to the more common focus-group method (Nyumba et al., 2018), group discussions focus on shared opinions that emerge in a group setting. The group as a whole is at the centre of attention, not its individuals. The process of communication and interaction gives insights into common patterns of orientation, understanding, and meaning that structure opinions and attitudes. The group discussion is thus not only a data generation instrument, but also a social situation generating opinions that exist in real-life settings (Bohnsack et al., 2010; Lamnek, 2005).

While the student discussion was led by the researchers in a forest shelter, the three other discussions were guided by the trainers and took place in the respective Marteloscope site, where two or three so-called 'conflict trees' of both high ecological and economic value were revisited. Thereby, the two Marteloscope trainers asked the teams about their general approach in tree selection and the more specific considerations when deciding about particular trees. This was supplemented by selected questions from the researchers seeking participant reflection on their decision making.

2.4 Data analysis

All discussions were audio recorded, transcribed verbatim, and systematically coded (Mayring, 2014). The analysis combines qualitative content analysis (Ibid.) and the reconstructive interpretation of key passages with selected interpretative foci (Kruse, 2015). Focusing on participants' arguments and on specific considerations when deciding about particular 'conflict trees', we analysed the data in two phases: Firstly, we assigned codes to text passages and developed a broad categorization of arguments. This categorization reveals different decision-making practices when facing trade-offs and uncertainty in integrated forest management. Secondly, we applied an interpretative lens and analysed specific arguments in key passages about 'conflict trees' and opposing strategies with the goal of reconstructing subjective sense-making processes in relation to tree selection (Ivanoff and Hultberg, 2006; Kruse, 2015). All steps of the data analysis were done by two researchers independently from each other, facilitated by exchange and interpretation meetings at regular intervals. Additionally, key passages were discussed in an interpretation group with other qualitative researchers. These iterative processes of data sharing, reflection, and interpretation serve to broaden the scope of viewpoints and to validate existing interpretations (Kruse, 2015; Reichertz, 2013; Steinke, 2015). The field notes resulting from the participant observations of different researchers serve as complementary data to assess implicit and non-

Table 1: Marteloscope exercises, participants, and group discussions.

Date	Marteloscope	Participants in group discussion (number*)	Discussion ID (duration)
Nov 2017	Jägerhäuschen	Nature conservation professionals (ecologists, biologists), foresters (state forestry administration) (12)	C1 (80 min)
Nov 2017	Jägerhäuschen	Foresters (state forestry administration), private forest owner (12)	F1 (75 min)
Feb 2018	Rosskopf	Students (forestry sciences and environmental sciences) (6)	S1 (40 min)
March 2018	Rosskopf	Foresters (state forestry administration) (12)	F2 (50 min)

* Except for the student group, the number of exercise participants was identical to the number of participants in the discussion.

verbalized aspects that may be decision-relevant for tree selection (Merriam, 2009).

3 Results: Decision Making in Tree Selection

3.1 The importance of visual assessments

Analysing the semantics of the participants' explanations of their tree-selection approaches, we find frequent use of words such as 'look around', 'seeing', 'getting an overview', 'train one's eye', 'keep an eye on' and 'point of view'. Although descriptions of what exactly is visually discovered and recognized remain vague, the initial act of looking around and seeing is crucial to gain an overview. It forms the basis of visual perception and evaluation of the forest stand and is therefore an important part of the decision-making process. At the same time, participants are well aware that ecologically valuable structures may be overlooked. In order to recognize relevant structures it is necessary to walk around a tree several times and to look at it from different perspectives and distances. Forest practitioners connect this exercise situation to real-life decision making and express some limitations regarding the comparability of the settings: 'I can't walk around every tree twenty times using binoculars. I admit that one or the other [microhabitat] will be overlooked' (F1). It hence remains uncertain 'whether I recognize something very special there – I have to say – would then probably be a coincidence' (F1). This is further aggravated by the lack of feedback on habitat tree selection. The involved forest managers report that they usually do not get to know if their selection met ecological objectives: 'what I've done ecologically, I never know, it's just not measured' (F2). This stands in contrast to monetary quantifiable outcomes of tree selection in terms of timber harvest. As long as there are no quantifiable indicators monitored for biodiversity, the challenge remains to balance economic returns from timber harvesting with conservation values (Winkel and Spellmann, 2019).

Regarding how participants acquire the necessary competence to recognize relevant microhabitats, all groups agree that, along with theoretical knowledge, practical training and experience is crucial. This is what the students lack: 'I think that we probably have enough theoretical experience, but we lack practical experience. We still need to get an eye for it [biodiversity-relevant structures]' (S1). 'To get an eye' for something is inevitably part of the practical training. Yet, one's eye can be trained emphasizing different aspects. The students' discussion shows that this prioritization occurs quite early during professional education: 'Those of us from nature conservation are trained to get an eye for it [conservation aspects] in any case. So whenever we're on excursions, we're shown: this is a TREE or an area, which is especially VALUABLE, and why it is ecologically valuable' (S1). The practical training takes place with a certain focus – in this case on ecologically valuable habitats – that inevitably shapes the resulting experiential knowledge. Accordingly, participants describe different visual practices. Biologists are portrayed as attentive observers with detailed knowledge hardly conceivable for non-experts. This stands in contrast to the foresters' broad knowledge. Foresters express that they would 'look at the whole thing' and 'have a certain feeling where something can hide or not' (F1). In a process not described in more detail, this 'certain feeling' develops 'over time', and ultimately 'you just have it' (F1). Intuition and long-term experience, combined with a holistic view, seem to compensate for the lack of detailed knowledge, forming a legitimate basis for decision making.

When it comes to tree selection, these different ways of viewing will inevitably influence visual assessments and subsequent decisions. As a forester puts it in a discussion session: 'I first look from below what's down there, and when I have … five or four solid cubic meters of saw timber at the bottom, then I look for nothing for a long time and think about using it' (C1). Hence, (s)he focuses on the lower part of the trunk to first of all evaluate the timber volume and quality. If this assessment promises a high economic value, habitat structures will only be considered if there is 'something very special up there, an aerie, for example' (C1). In turn, a participating conservationist expresses the opposite viewpoints: 'one can also look the other way around. You can also first look if there are large structures' (C1).

Expressions such as 'put on forestry glasses' (C1), 'see it from a different angle' (S1) and 'another perspective on things' (F1) show that participants are aware of different views between professional groups and their ideologies. Some of these statements suggest the possibility to adopt another perspective. In reality, however, this is a major challenge, because different perspectives are strongly pronounced and incorporated into daily routines and practices (see 4.3), which is reflected in the concern one of the conservationists expresses: 'my worry is if the whole ECONOMIC view sticks so much to the lower ten metres. That then perhaps the view upwards often … is omitted' (C1). As visual assessments are crucial for forest management decisions, routinised practices that are predominantly based on one or the other view may hamper the integration of conflicting objectives.

While visual lines of argumentation dominate all the discussions, it is remarkable that aesthetic criteria are not explicitly mentioned. Apart from expressions like 'nice habitat trees', 'nice large structures' and 'nice wood', terms that clearly emphasize aesthetic aspects are rarely used. Possibly, aesthetics are not perceived as a valid criterion to explain tree-selection decisions that are supposed to be rationally justifiable (see 4.1). Yet, describing a tree as the 'tree of trees' (C1) indicates that the participants' fascination for individual trees and their aesthetic value at least implicitly plays a role.

3.2 Dealing with trade-offs

This section focuses on how participants deal with trade-offs between production and conservation goals when selecting trees, and which criteria and strategies they apply in doing so.

Although the Marteloscope trainers emphasize that they did not intend to equate habitat points with monetary values when developing the training tool, the costs of retaining habitat points are frequently mentioned as an argument in the discussions. Minimizing the costs of a habitat point turns out to be an easy-to-understand, practical approach to deal with the presented trade-off challenge: 'there are trees where you would destroy much more habitat points earning significantly less money' (C1). In line with this approach, participants appreciate the presentation of both economic and ecological results after the exercise, emphasizing that conservation-related performance is rarely measured and evaluated in their management practice. While identifying themselves as 'border crossers [between] forestry and nature conservation' (F1), foresters usually cannot verify if 'I satisfied my own requirements, namely bringing ecology and economy together' (F1). Interestingly, there is a strong demand to 'give the ecological part a value, in some comparable form' (F1), referring to the economic value of wood: 'We must have some benchmark, since, on the other side, we as managers are measured financially' (F1). In other words, the participating public forest managers are demanding a quantifiable approach to account for and ensure the provision of biodiversity, reflecting the way they report timber targets and economic objectives for their operations.

In line with this preference for quantifiable indicators, accessible structural criteria were frequently applied when selecting trees for harvest or retention, yet for different reasoning resulting in different decisions. Arguing from an economic perspective, large DBHs are used as criterion for harvesting trees, particularly if they have already reached their target diameter, and risks, e.g. related to wood defects, were aimed to be avoided. In contrast, from an ecological point of view, large DBHs are used as an argument for retention, as the probability of a tree to develop microhabitat structures – according to ecological research – is supposed to increase with larger DBHs. This is one of the few arguments fiercely debated. One participant strongly insisted to get 'an explanation what SPECIAL ecological value it has just because it's so thick' (F1). After the trainers had highlighted the higher chances for the future development of habitat structures, his doubting question 'what it is exactly that may develop in the future due to the tree's big dimensions' (F1) remained unanswered. This debate not only reveals the relevance of individual targets, but also how different time horizons will eventually affect management decisions. Assuming that 'every tree will have habitat structures if you leave it long enough' (C1), especially conservationists perceive the development of microhabitat structures in the long-term as a valid argument to retain large trees as so-called 'future habitat trees' even if they currently do not have a notable habitat value. In contrast, foresters argue to harvest trees before those structures appear, structures that – from an economic perspective – are perceived as wood defects diminishing timber value. Within the foresters' groups this seems not to be a controversial issue. They explicitly agree upon the following statement: 'we have to start with the thick ones, which are ripe now, which are valuable now and where no Bechstein's bat lives yet, which is in fact the risk' (F1). Economically speaking, trees should be harvested before wood damages occur, which means that in current forestry practice 'trees are actually still young when we cut them' (C1).

This results in a major challenge for the integration of nature conservation in production forests, since foresters typically 'extract these habitat candidate trees from the very beginning' (S1). This approach prevents both the development of ecologically valuable structures and reduces the number of ecologically adequate habitat trees that may be retained. To address this problem, some participants express the demand to promote 'future habitat trees' and to label and protect them earlier than is currently the case: 'We should mark future habitat trees at least in our head. Just as there are crop trees for high-value wood, there should also be crop trees for habitat trees' (C1). Interestingly, foresters also use future microhabitat structures as an argument, but apparently only if the tree's economic value was considered as low. This is illustrated by a forester's argumentation for retaining a big, spirally grown oak: 'This has a really strong spiral grain. That means the [economic] value is very limited … this strong, steep branch back there might break off sometime, thus thinking a little bit into the future. This is the type of tree that could become a methuselah tree' (C1). In this case, it does not seem crucial that the tree's ecological value is not yet high, as retaining it does not imply waiving a potentially high income.

Several foresters stress that they do not search for specific microhabitat structures, while damages that apparently diminish timber value are considered relevant criteria for selecting habitat trees. Such trees were selected 'qualitatively from the worse end' (F2), emphasizing again the high relevance of monetary aspects. In contrast, conservationists state that they focus primarily on ecologically valuable structures and trees with large DBHs. Students additionally emphasize that they aim to retain a mixture of tree species. In the Jägerhäuschen exercises, conservationists exclusively selected oaks, whereas foresters included economically less valuable 'hornbeams, which are only considered a decorative accessory from a forestry point of view, but can have an incredibly high ecological value here' (F1). In the Rosskopf exercises, foresters refrained from retaining Douglas firs as they 'are simply not regarded as carrying any ecological value' (F2). This is confirmed by the students, who state that they are already trained during their studies to select Douglas firs as harvest trees and admit 'none of us would have retained a Douglas fir without the tablet' (S1) displaying the assigned habitat points of the respective trees. Commonly attributed tree species characteristics, which are not questioned anew during routinised practices, may thus be more decision-relevant than the specific characteristics of the given individual tree.

Strategies to deal with trade-offs range from the clear prioritization of goals to the attempt to achieve the best balance among all goals. Prioritization strategies become obvious when participants report that they search for specific criteria first and foremost while subordinating other criteria, clearly revealing the importance of different individual targets and preferences. Participants favouring an economic use focus on timber value and tree damages diminishing the economic value, while those favouring conservation focus on microhabitat structures, emphasizing their potential future development. Other participants place a strong emphasis on balancing goals. Since these economic and conservation objectives cannot be reconciled on one and the same tree, their strategy focuses on achieving a balance at the stand level: 'Although harvesting a single tree, you always keep an eye on the whole stand' (C1). The descriptions of the underlying weighing processes often sound like bartering: 'Considering what other high-quality structures can be found in the stand, we can sacrifice this tree economically, so to speak, and have thereby already achieved a relatively high economic added value allowing us to retain a larger number of other trees that are ecologically more valuable' (C1).

Dealing with trade-offs, the local stand context and its characteristics play an important role. If there are high amounts of both ecological valuable structures and economically valuable timber, balancing goals at the stand level is perceived as rather easy: 'You have no problems finding a sufficient number of habitat trees here in this stand. This is a luxury problem' (F1). In such cases, harvesting a 'conflict tree' can be justified by the high availability of ecological structures; the other way around, retaining a 'conflict tree' can be justified by the high amount of valuable timber in the stand. However, if microhabitats are rare and only occur on trees with high economic value, trade-offs may force participants to prioritize more strongly.

3.3 Dealing with uncertainty

Due to the complexity of forest ecosystems, changing environmental conditions and long-time horizons in forest planning, forest managers have to deal with great uncertainty in decision making. This implies both risks and opportunities.

Unlike in real-life forestry, the I+ software offers an on-site, databased representation of the implications of specific interventions in the Marteloscope. Participants appreciate this visualization as this 'direct feedback both on ecological and economic parameters allows a fact-based assessment of one's own intervention' (F1). Differentiating between 'felt' and 'measured' effects is perceived as crucial, since the measured impacts of those interventions 'may differ from what one feels' (C1). Participant reaction to the presentation of the exercises' results reveals a great longing for 'objectifying', 'fact-based verification', and 'data and facts', believed to facilitate dealing with uncertainty. This applies in particular to the ecological valuation, because in real work life, lacking feedback on the ecological outcomes of habitat tree selection generates even more uncertainty in dealing with trade-offs in integrated forest management. According to the participants, the visualization of outcomes 'makes things conscious' (C1), sensitizing them to the discrepancies between individual perceptions and assessments based on measured data. The latter create clarity and objectivity, distinguishing them from less reliable feelings perceived as an invalid basis for decision making. It is striking that participants hardly question the validity of the data provided by the I+ software, although trainers admit that the evaluation of single structures is arguable, and the purpose is only to 'give a direction … whereby it is secondary whether the value is completely correct or not' (C1). This reinforces the impression that participants feel a great need for a quantitative valuation of ecological aspects. This seems to be the case even if quantification is debatable with regards to details, and it might even obscure the uncertainty in decision-making, especially when a long-term perspective is taken up (Marteloscopes only present ad-hoc data).

The demand for fact-based data stands in contrast to our observation that participants hardly used the microhabitat catalogue, which displays all TreMs forming the basis of the ecological assessment of the I+ software. Instead, they mainly relied on their visual assessments and their experience-based determination of relevant TreMs. Only the students, who saw the habitat points during the exercise, reflected the discrepancies between their valuations and the habitat points shown on the tablet. At the same time, the strong influence of numerical data, often perceived as entirely objective, became clear: 'If it had a high score, then we took it. I think if we had really done that in practice, the choice would have been very different' (S1).

The desire to reduce uncertainty with the help of data and figures also becomes apparent when discussing silvicultural simulation models: 'it would be nice if you could get into modelling, where you can put the data collected here into a forest growth model and make the FUTURE visible' (C1). At the same time, participants are aware of the limitations of these models and doubt the practical feasibility of applying comprehensive simulations. One participant demands not to 'think so complexly but to really work on practicable input variables, with practicable evaluations, where you can tell the forest manager "your measures have such and such consequences"' (F1). Due to the need to compromise between complexity and accuracy, simulations and modelling will only partially reduce uncertainties and even risk producing spurious accuracy.

If local knowledge and long-term experiences are lacking, uncertainty increases. This becomes obvious when the foresters discuss Douglas fir, which is the most important introduced tree species in Germany: 'Douglas fir has been here for 110 years, 120 years. In comparison to oak, where we have really old historical sites, where certain structures have developed over several hundreds of years …, Douglas fir hasn't got that yet. We only know a few pests, bark beetles … So we don't know exactly what can happen' (F2). For example, being aware of the limited knowledge about which species will be attracted to Douglas firs in the future, decisions inevitably must be made under uncertainty. Only through long-term observation can actual outcomes be evaluated, which may then even 'change the discussion in the future a bit, if I can show such a [habitat] tree. That's not just the bad Douglas fir, it's also the GOOD Douglas fir' (F2). Despite challenges of uncertainties, this long-term orientation of forest management provides opportunities to observe and adapt: 'you have to look again after a few years anyway. And when then there are cavities, then it [the tree] remains' (C1). If a decision is postponed, the tree can be reassessed after a few years and decisions can then be made considering the newly observed developments: 'maybe a habitat value develops fast, maybe not. In the latter case you can still take [harvest] it after five years' (F2). Despite all uncertainties, in the long-term 'the decay is secured' (C1). A wait-and-see approach prevents candidate habitat trees from being harvested early and thus benefits conservation targets, which in turn shows the relevance of different time horizons in forest management (see 3.2).

4 Discussion: Leverage Points for Reconciling Trade-Offs

4.1 (Ir)rational forestry and conservation

In all four group discussions, it is noticeable that participants were finding it difficult to verbalize their arguments for decision making in tree selection. Even when they describe routines such as the prioritization of certain aspects, their descriptions often remain vague or refer to an intuitive, experience-based approach that cannot be defined precisely. Tree selection is not solely about conscious, rational choices resulting from a cognitive weighing process, but also intuitive practices – shaped by the individual self-conceptions as foresters or conservationists – that are not made explicit. Especially the students emphasize that their lack of experience makes tree selection difficult, although they feel they hold enough theoretical knowledge. Due to the complexity of the decision-making situation and time pressure in everyday work, forest managers have to decide quickly and need to rely on information immediately available, above all, their visual impressions, experience, and intuition. Indeed, this experiential approach has become so ingrained in silvicultural practice that the term 'Götterblick' (literally: 'glance of the gods') was coined in the German language to describe foresters' decisions based on experience with 'their' forests and not on formal empirical relationships (Puettmann et al., 2009). While emphasizing the importance of practical and local experience, it remains unspoken that actual decisions are usually based on a mixture of experiential and evidence-based knowledge (Bruin et al., 2015; Detten and Faber, 2013; Detten and Hanewinkel, 2017; Hoogstra, 2008; Yousefpour et al., 2012).

This is in contrast with the foresters' repeatedly expressed desire for objective and comparable data facilitating decision making and making outcomes predictable. Quantified valuations and measurements, considered as facts, which can be applied as decision criteria, are highly appreciated to overcome uncertainties and address risks in forest management (Detten and Hanewinkel, 2017; Puettmann et al., 2009). In our cases, especially the habitat points that quantify a tree's ecological value were emphasized as important for achieving a comparability of ecological and economic attributes of forests that may be in conflict with each other. Despite their different scales, participants use the figures displayed on the tablet for comparison, which seemingly facilitates the integration of ecological and economic goals. The ambivalence of intuitive practices and the ideal of rational, evidence-based decision making becomes very apparent in the exercises. In fact, the paradox of emphasizing both the importance of quantitative evidence and of professional experience – which is of rather qualitative nature – may be another reason for the participants' difficulties in verbalizing decision-making processes in tree selection. In the face of visualized facts, experience-based knowledge and routines seem arbitrary and illegitimate, and are very difficult to explain to others. Without any critical review, data presented by the I+ software are perceived as objective and seemingly superior to intuitive approaches. Related to this is the diagnosis of a profound societal 'trust in numbers' (Porter, 1995). Numbers seem impersonal and without needing much legitimation; they are taken to be a value-free portrayal of a given reality and thus have an affirmative effect. This is reflected in the history of forestry. The expansion of 'scientific forestry management' (Lowood, 1990; Scott, 1998) from the 18th century resulted in quantitative approaches aimed at the calculability, comparability, and control of forest uses for efficiency and profitability (Höhler and Ziegler, 2010). Forest management was scrutinized to transform 'all sorts of activities previously left to habit … into a science' (Bechstein, 1797, in Lowood, 1990). These historical developments formed management paradigms that seem to resonate still today, leaving little room for other rationalities.

In line with Bethmann et al. (2016), who identify a primacy of economic thought and reasoning in foresters' occupational socialization, we find that foresters rationalize ecological functions as management goals in economic terms. As professional forestry practice is still characterized by the dominance of measurable economic figures and targets (Maier and Winkel, 2017; Puettmann et al., 2009), quantifying ecological values may contribute to raising awareness for conservation goals and routinise their consideration and implementation in forest management. However, it must be considered that the generation, validity, and comparability of such data is hardly critically scrutinized by their users. Taken for granted without reflection, data may misdirect management decisions. As institutional changes are difficult to steer, the effects of quantifying ecological values on forestry practice are hardly predictable. Interventions may produce both intended an unintended consequences, based on local contexts and existing practices (Arts et al., 2014).

Besides the lack of comparable data, especially the participating foresters miss feedback on their performance regarding conservation objectives. In German public forest management, the selection of a certain number of habitat tree groups must be demonstrated, while their suitability to provide the required habitat function is not reviewed. As Maier and Winkel (2017) report, based on a larger empirical study on the German public forest sector, there is a perceived discrepancy in goals and incentives as well as monitoring regarding the implementation of such retention measures. According to them, it remains unclear if this discrepancy results from symbolic policy making, in which conservation objectives are emphasized at the policy level while timber production is emphasized through quantified targets at the management level, or from the difficulties in quantifying and measuring biodiversity values with acceptable transaction costs.

4.2 A look into the future

Forest managers need to consider long-term future developments. As it is not possible to have all the necessary information available – neither in Marteloscopes nor in real-life settings – the lack of predictability plays an important role in decision making. While forest models, simulations, and optimization calculations help to display and assess uncertainty theoretically, in practical forest management it remains omnipresent. Paradoxically, uncertainty leads to freedom of choice, offering the chance to break new ground because there is no absolute basis to assess if decisions are right or wrong. The challenge then is to justify decisions against both one's own organization as well as other societal actors advocating for different decisions (Detten and Hanewinkel, 2017).

Selecting and marking 'future habitat trees' (see 3.2) can be interpreted as a proactive approach to cope with uncertainty. This was applied in different ways in the investigated tree-selection exercises. What strategies are preferred not only follows individual preference; apparently it conforms to the predominant norms and values of participants' social and professional contexts, which is supposed to increase legitimacy (Osei-Tutu et al., 2014; Vainio, 2011). While the potential long-term development of habitat structures is generally perceived as a valid argument to retain trees with only a few current structures, selected habitat trees differ remarkably amongst the involved groups. Conservationists argue to support the development of TreMs when retaining large trees, which are more likely to develop and maintain a wide variety of habitat structures. In contrast, foresters use the potential future habitat value to justify the retention of smaller, economically uninteresting hornbeams whose ecological value is not high yet. This observation is in line with Puettmann et al. (2009), who caricaturise silviculturists as largely focusing on commercial tree species and using log and timber grading criteria for categorizing trees as 'good' or 'bad'. In contrast, ecologists admire structural, compositional and dynamic variability, which is why they see a purposeful complexity in natural forests. Yet, in our selection exercises they also seem to appreciate large-dimension trees.

Future developments can be seen both as a chance for habitat structures to occur and as a risk for timber value to diminish, so decision making is not necessarily impeded by a lack of knowledge but may rather be a problem of legitimacy (Detten and Faber, 2013). Decisions must comply with prevailing norms in order to be accepted in a particular social context. This explains why in practice forest managers tend to make widely established decisions that are in line with those of their peers (Detten and Hanewinkel, 2017).

4.3 Learning through a change of perspective

Managing forests for multiple ecosystem services involves various actors, resulting in different perceptions of complexity and trade-offs. These differences need to be considered when analysing decision-making processes, especially when aiming at facilitating stakeholder involvement (Bruin et al., 2015).

Puettmann et al. (2009) argue that silviculturists and ecologists still view forest ecosystems in fundamentally different ways. Professional ecologists usually hold very specific species knowledge, while foresters tend to describe themselves as generalists. Much can be learned from their interactions. Sharing and learning to appreciate different perspectives as well as using new tools will contribute to an improved understanding and management of multifunctional forests. Consistent with this, Detten and Faber (2013) conclude that learning experiences and experiments will expand the leeway in decision making and reveal a plurality of available strategies to deal with complexity and uncertainty.

Marteloscopes have been specifically developed as learning tools to increase knowledge about integrated forest management and to initiate this exchange among various actors (Pyttel et al., 2018). All four group discussions report learning effects. Conservationists gained a differentiated perspective on trade-offs in forest management by including economic criteria in their tree-selection strategies. Most of them faced the task of selecting trees for thinning and estimating their timber values for the first time. In contrast to their usual task of habitat mapping, they were confronted with conflicts that arise when aiming to generate income from the forest. They found it a valuable learning effect to equally consider ecological and economic values and trying to balance both throughout the forest stand.

Particularly the foresters appreciated that timber use was recognized as an essential forest function in the exercises. It seems important to them that non-foresters understand their self-image as forest managers balancing several forest functions. As a Finnish case study finds (Peltola and Tuomisaari, 2015), foresters' work is often driven and motivated by a sense of duty, implying liability. They expect themselves to integrate various goals, which is an important prerequisite to reconcile trade-offs in forest management. At the same time, both their occupational socialization and day-to-day practices are still dominated by economic procedures and targets. Therefore, 'a shift in attitude … may still often be needed' and the 'retention of habitat trees … is a challenge for forest managers because such trees do not match silvicultural economic schemes' (Bütler et al., 2013: 88). Indeed, foresters were particularly surprised to find that some of the hornbeams and Douglas firs are of considerable value according to the ecological assessment, in contrast to their previous perception and assessment of these species.

Decisions are often based on such previous knowledge and resulting preconceptions as well as habituated practices, which may originate during education, as the student discussion shows. In the analysed Marteloscope exercises, aspects of these professional cultures are revealed through the visualization, evaluation, and discussion of tree-selection results directly on-site. This setting facilitates rethinking about one's own routines and to consider alternative strategies in the interest of conflict resolution. In reality, however, this remains a challenge because routinised practices play a major role in forest management (Hoogstra, 2008; Peltola and Tuomisaari, 2015; Primmer, 2011), and silvicultural practices are strongly influenced by 'entrained thinking', tradition, and habit (Primmer and Karppinen, 2010; Puettmann et al., 2009). When forest managers work on their own and must decide under time pressure, routinised assessments are time-efficient, allowing orientation in situations of uncertainty, and hence usually go unquestioned. Thus, a greater recognition of conservation objectives in day-to-day decision making cannot be achieved by solely defining them in written guidelines. When policies are ambiguous – often the case in the complex field of integrated forest management for multiple forest ecosystem services – changes in practices cannot be easily triggered (Primmer and Karppinen, 2010). The educational focus on conventional forestry seems to lead to an 'imprinting' of the primacy of wood production goals in many forest practitioners (Puettmann et al., 2015). This is perpetuated through the importance of wood production for the economic outcome in forestry and a primacy of quantified monetary targets implementing multipurpose forestry (Maier and Winkel, 2017). If integrated forest management with an equivalent focus on other forest ecosystems ought to be implemented, awareness of other services needs to be increased both in education of junior staff and in regular, advanced silvicultural training of experienced experts. As the Marteloscope exercises show for the example of biodiversity conservation, practicing tree selection in groups with different expertise and professional backgrounds could be a suitable measure to this end. Compared to conventional learning environments, settings such as provided by Marteloscope exercises allow for meaningful experiences that may generate collaborative learning and shared practices (Wenger, 1998).

The students confirmed that decision making may even be facilitated through bringing together different perspectives and expertise. Studying either forestry or environmental sciences, their main interests complemented each other well, which was perceived to ease the integration of different management goals required in the exercise. One participant directly suggested to the trainers: 'Did you think about a third round with mixed teams? … the important part is COMMUNICATION.'

4.4 Study limitations

The insights of this study are based on empirical material from four Marteloscope exercises and group discussions each reflecting a unique decision-making context and site-specific settings. Other participants in other settings would have described different tree-selection practices. Due to the small sample, the value of our qualitative study lies in its depth, revealing multiple facets of decision-making reality. We are able to base our analysis on dense material from group discussions as well as on our individual observations, which allows us to identify non-verbalized practices of tree selections. This includes, for example, how participants move through the stand and how they perform an intensive visual inspection of specific trees and tree structures, with some of them using binoculars and some of them not. The intersubjective analysis of these different kinds of qualitative data yields a holistic perspective, allowing us to illuminate the decisive role of routines, individual views, and professional contexts for tree-selection decisions.

While Marteloscope sites provide the unique opportunity to accompany and observe forest practitioners in a real-life scenario, it is important to keep in mind the limitations when using Marteloscopes as research sites. Regarding forest biodiversity conservation, the Marteloscopes we have been using focus on the retention of habitat trees. Other important elements, such as standing and fallen deadwood, tree species diversity, age structure, ground vegetation, abiotic structures, and light conditions are not included. Furthermore, the ecological assessment of trees within a Marteloscope is based on TreMs as described in Kraus et al. (2016) without considering the trees' spatial positioning and connectivity. Thus, it needs to be considered that the forest practitioners' assessments of habitat values include more than the aspects covered by Marteloscope exercises. Furthermore, the exercises' tasks focus on timely measures, while long-term goals, such as the sustainable development of the stand, were not explicitly defined.

We cannot tell if and how decision making would change in comparison to our recorded data under real-life conditions, where, for instance, time constraints play a big role and forest managers usually perform tree selection and reasoning not in groups but alone. However, our qualitative data illuminates how they and their peer groups cope with trade-offs in tree selection and the underlying uncertainties that complicate decision making. Stimulated by the group discussion setting, our data largely show a strong identification of the participants with their respective professions. Thus, professional aims may have superimposed personal reasoning. Deepening the qualitative approach, for example through go-along interviews with individual participants during tree selection, would allow to better link observed tree-selection behaviour and underlying considerations, including individual reasons, in decision making. Further exploring how different professional and societal groups (including lay people) perceive and reconcile trade-offs between forest production, biodiversity conservation, and further forest ecosystem services may offer additional insights into practice.

Forest managers consistently emphasize the important role of specific stand contexts and their local experience, which is not directly transferrable to other forest sites. In order to gain a more nuanced understanding of decision making and dealing with trade-offs in integrated forest management at a larger scale it would be necessary to replicate the exercises in other forest types confronting forest managers with different challenges. Future research should also consider other tree selection procedures. In continuous cover forest management in Germany tree marking is done prior to harvest, whereas tree selection in Northern Europe and many regions of North America is often made directly by the harvester operators sitting in the machine cab. Thus, they are the ones who decide about the retention of trees in case that retention forestry is practiced. In contrast to our study participants, these practitioners have not only a different professional background, but also a different viewing angle on the forest. Because we find visual assessments to be highly relevant in tree selection decisions, contrasting these different perspectives and initiating an exchange about them may offer additional insights.

5 Conclusions

We have studied decision making in view of trade-offs between production and biodiversity in integrated forest management. More precisely, we have investigated the tree-selection decisions of actors with different professional backgrounds by means of qualitative methods, allowing us to reconstruct patterns of understanding, meaning, and reasoning that form the basis for decisions and practices.

For a long time, forest management decisions in many countries have been taken with timber production as the primary focus. For a similarly long time, forest management has been subject to various and partially conflicting societal demands. Increasing societal demands on forests to provide a wider range of goods and ecosystem services in many countries may intensify conflicts. Decision making in contemporary forest management will have to deal with multiple and conflictive frames. Together with the uncertainty inherent in ecosystem management, currently exacerbated by climate change, this will result in increasing challenges to determine appropriate action, especially when it comes to dealing with trade-offs and integrating varying timescales into decision-making processes.

In forest management much comes down to decisions about harvesting or not harvesting trees. In the context of continuous cover forestry, these decisions must be taken tree by tree. This paper shows that these decisions are embedded in differing ways of practicing and knowing about forest management, which are not always perceived as equally valid. This applies in particular to experiential knowledge and intuitive practices that deviate from the rational paradigm. Neglecting the important role of habits, routines, and social professional norms, optimization models and formal guidelines have little chance to be effective. More information does not necessarily facilitate decision-making processes. It is crucial to recognize and acknowledge different views and values and consequently, to be able to account for and respond to divergent demands towards forests and their ecosystem services. Direct interactions and communication among stakeholders from different social and professional contexts are essential to allow learning and to facilitate mutual understanding.

Marteloscope exercises are a very practice-oriented approach to stimulate such dialogue and learning. Our findings show that they not only make the different professional paradigms visible but allow for a direct exchange across such paradigms. Foresters may benefit both from showing their difficult task of deciding about trade-offs and from learning directly about other worldviews or professional cultures. Being confronted with one's own decisions and their outcomes as well as discussing with other actors can broaden individual views, which may support reconciling trade-offs or, at least, facilitate negotiation processes through an increased awareness of differing perceptions.

Promoting integrated forest management at the policy level can be an important strategy to deal with plural societal demands towards forests. The critical decisions, however, will often be taken on the concrete management level, where trees are cut or retained. Forest policy becomes visible in the shape of the forest. It is here where multiple views and different expertise need to be integrated. Understanding how practical forest management decisions are taken is essential for this process.

Notes

[1] All participants' quotes cited in this paper are translated from German into English by the authors. Authors' clarifications are in square brackets. Speakers' emphases are indicated by CAPITAL LETTERS.

[2] Within the three other exercises, participants had to assess timber volumes, monetary values, and habitat points without having this information before.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

BJ and RM conceived and designed the Marteloscope exercises and were present during the exercises to collect the qualitative data. Data analysis was performed by BJ, RM and AP. BJ wrote the paper draft and led the writing, while RM, AP and GW contributed to the writing with revisions.

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