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Students of Göttingen University selecting trees in a marteloscope near Reinhausen. Photo: Arne Pommerening

Towards Understanding Human Tree Selection Behaviour

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Understanding how humans select trees for professional and non-professional purposes is crucial to sustainable forest management.

Since the mid 1990s data collection methods and experiments have been designed to measure human tree selection behaviour.

This research fills the gap between natural sciences and psychology; it also constitutes citizen science at the same time.

First results indicate that agreement between different test persons is comparatively low.

Humans tend to behave conservatively when asked to select trees differently and disagreement increases in such situations.

Our research has brought to light that many people have wrong perceptions about their tree selection styles and that their marking behaviour can differ markedly when selecting the same trees repeatedly.

Research into human tree selection behaviour has great potential for novel, interdisciplinary studies.

In the preface of his textbook "Planning in a Forest Enterprise" from 1972 Gerhard Speidel wrote that the environment we currently live in owes much to the decisions of human beings. He concluded that "decision making is therefore among the most fascinating and most responsible activities in this world". Along the same lines Gadow (1996) asserted that "the modifications of forest structure caused by management often have a far greater effect on forest development than natural growth".

In the past, it was often assumed that humans marking trees for thinnings or as habitat trees, do this more or less precisely according to textbook opinions, forest plans or other instructions. However, the selection of supposedly "desirable", "undesirable" or indifferent trees for a given purpose, may that be timber production or conservation, is a challenging task for any human being and a serious limitation on the potential for Continuous Cover Forestry in some countries. Naturally, no matter how detailed instructions are, there is likely to be some variation between the decision making of different individuals. In addition to this variability between individuals it has also been noted that one and the same experienced person can mark trees in the same forest differently on separate occasions. As any human behaviour, also tree marking behaviour depends on weather, general mood and starting point in the forest to name but a few factors. This second variability component can be referred to as variability within individuals.

Idealised textbook forest management is for example often assumed in tree growth models that allow the forest manager to project the current forest state into the future. Such models are an essential tool for identifying the best course of action in long-term sustainable forest management. However, how many of these forecasts are really helpful if they do not account for the uncertainty introduced by human decision making?

There are a number of fundamental research questions associated with human tree selection behaviour. First, it is useful to establish how much agreement there is actually among test persons. After quantifying the general agreement, clusters of similar behaviour and outliers must be identified, in order to uncover those individuals that made the largest contribution to the lack of agreement. Covariates such as tree size, timber quality, habitat value but also personal background information can then help to explain individual behaviour. Finally, the question must be addressed if the lack of agreement matters or whether there is a sufficiently common pattern in the selection behaviour that is compatible with the corresponding forest management objectives.

Specific research questions include

- Can different tree selection behaviour be attributed to, for example, gender, age or occupation?
- Do forestry staff educated in different institutions select trees differently?
- Is there any geographic relationship?
- How do individuals respond to training and are willing to change their behaviour?
- What effect do tree species composition and structure have on tree selection?

Research in human tree selection behaviour has a large potential as it bridges natural sciences and psychology. In an ideal way it combines basic research with science that is highly relevant to the forestry sector at the same time.

Example results

There are many options for analysing data of human tree selection behaviour. In this section we briefly illustrate but a few possibilities. Marteloscope-based research involving human choices coded as binary data is new to forest science. Such data, however, are not uncommon in social choice theory, particularly in one of its applications, approval voting. In approval voting, voters approve of a certain number of candidates. In human tree selection research, the test persons are "voters" and the trees are "candidates". A tree selected may mean "approved". In contrast to elections, the number of voters is clearly smaller than the number of candidates (Stoyan and Pommerening 2015).

Origins

Research in forest growth and yield focused on ideal textbook treatments and delivered the first fundamental results in the 1950s. In the mid 1990s, Prof. Klaus von Gadow initiated a research group at Göttingen University in Germany investigating the tree selection behaviour of forest managers and machine operators in different forest ecosystems. The group designed a special survey method for data gathering which went by the names of *"thinning-event inventory"* and *"harvesting-event inventory"*. The key idea of this survey method was to schedule the data gathering at the time of tree marking prior to the actual tree removal. In contrast to traditional forest inventory methods, the thinning-event inventory captured both the initial forest stand conditions and the residual stand. The changes in forest structure could then be analysed and decisions could be revised if necessary (see Figure 1).

Towards the end of the 1990s, a group at AgroParisTech-ENGREF at Nancy (France) around Max Bruciamacchie realised the potential of this research idea for training and education in silviculture. The group at Nancy offered field-based training courses to forestry professionals and students. In these courses, the participants were then asked to mark trees for thinnings on a sheet of paper similar to a questionnaire. Their choices were analysed using specialised software or MS Excel and personalised result and feedback sheets were handed out to every participant at the end of the training session. In order to attach a new brand to this type of research plot the group at Nancy coined the name *marteloscope* (from French *martelage* – marking) for these training sites.

In the first decade of this century, the first author and his Tyfiant Coed project team at Bangor University used the marteloscope idea in a training project in Wales (UK).

The use of marteloscopes in training and education has since then spread from France to Switzerland, Britain and Ireland. Poore (2011) described the application of marteloscopes for education and training. The popularity of marteloscopes is on the increase, however, its original research purpose has only been pursued at few institutions including the Swedish University of Agricultural Sciences.

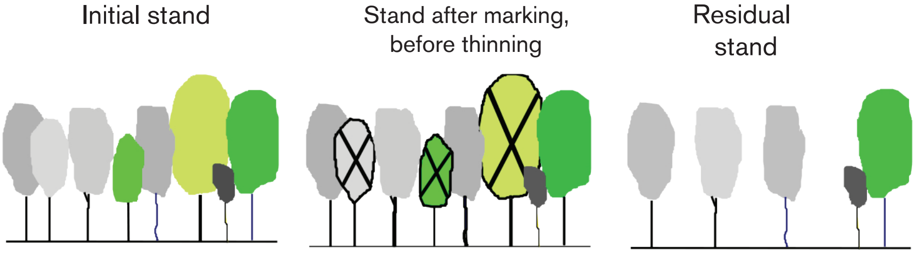

Figure 1. The principle of the thinning-event analysis: The initial stand, the stand after marking but before thinning and the residual stand are sampled and analysed at the same time (original drawing by Klaus von Gadow).

Simple statistics include bar charts showing the ordered proportions of trees marked by the test persons and the marking frequency of the trees (see Figure 3 for the Welsh marteloscope at Coed y Brenin in a mixed broadleaved-conifer woodland). Despite instructions the marking proportions range from 10 % to 48 % and test person #1 can be considered as an outlier, i.e. s/he shows a somehow extreme behaviour of selecting many trees. In class 0 (Figure 3, right), 30 trees have never been marked by any test person. Although this is seemingly a complete agreement, it is kind of pseudo or passive, since the agreement is in discarding these trees. Classes 14 and 15 are empty, i.e. the maximum score a tree has received

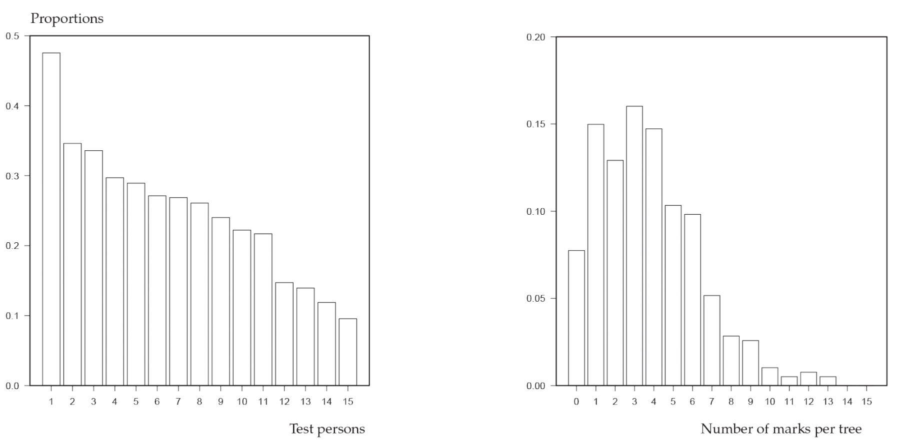

Figure 3. Bar charts of the marking activities of fifteen test persons in the Coed y Brenin marteloscope (left). The marking frequencies of the corresponding trees (right).

Marteloscope experiments

A marteloscope is typically set up as a research plot with rectangular boundaries. 100 × 100 m is often a suitable size, where the number of trees to be included should ideally be between 150 and 500 trees. A marteloscope of this size takes a test person approximately three hours to complete. The area should be sufficiently large so that the test persons do not influence each other's decision making. It can also be recommended to select a site where thinnings have not occurred during the last ten years, so that the thinning urgency is high. Every tree has a unique number, which is painted on the stem surface with waterproof paint as clearly as possible and should be visible from afar. If feasible, one could consider painting tree numbers twice on each tree from opposite directions for better identification. Minimum tree measurements should include stem diameters (min 5–7 cm). Ideally the surveying should also include tree locations, total heights (at least on a sample basis), volume/biomass, habitat value and timber quality. Marteloscopes are not different from research plots commonly used in silviculture and growth & yield science. In fact, plots from the latter two subject areas can often be re-used as marteloscopes. What is different are the research objectives and the analysis.

Figure 2 (left) shows a map of the Clocaenog marteloscope in North Wales (UK) including the marks of one test person from 2006: An extraction rack runs through the centre of this Sitka-spruce marteloscope. Black colour highlights frame trees[1], grey the trees to be thinned and the unmarked trees are white. The corresponding stacked empirical diameter distribution is also shown (Figure 2, right). Obviously both frame trees and trees to be thinned were mostly selected from larger diameter classes resulting in a crown thinning.

Table 1 is an example of a typical marking sheet. The design of the marking sheet may vary depending on the purpose of the training session or experiment. For example, it is possible to leave the tree-number column blank and to ask the test persons just to note those trees that they intend to select. Species and stem-diameter information can also be omitted if this serves the experimental purpose.

The design of the marking sheet surely has an influence on the marking behaviour. It is therefore advisable to consider the design carefully and to be creative in order to improve the outcome of the experiment.

Usually basic instructions are given to all 15–30 test persons along with a brief qualitative and quantitative description of the forest stand. The details of these instructions depend on the purpose of the experiment and can even be completely omitted, when testing the test person's intuitive management skills.

It is also good practice to record the test person's names, gender, work affiliation, professional and geographic backgrounds. Any additional information can potentially turn out as useful covariates or for post-stratification and aid the interpretation of the results.

In the data processing, the marking sheets are digitalised. A cross or tick indicating tree selection is converted to a '1'. No selection results in '0', so that a typical test person data column consists of a continuous sequence of 0's and 1's.

Table 1. Design of a typical, basic tree marking sheet for use in marteloscope research. *DBH* is diameter at breast height and measured in centimetres. "Frame" is short for frame tree.

Tree#	Species	*DBH*	Frame	Thin
1	Birch	55.4		X
2	Pine	60.6	X	
3	Pine	61.5		X
4	Birch	33.5		
5	Birch	42.1		
6	Pine	52.3		
7	Birch	15.6		
8	Birch	57.2		
9	Pine	64.3		X
10	Birch	24.2	X	

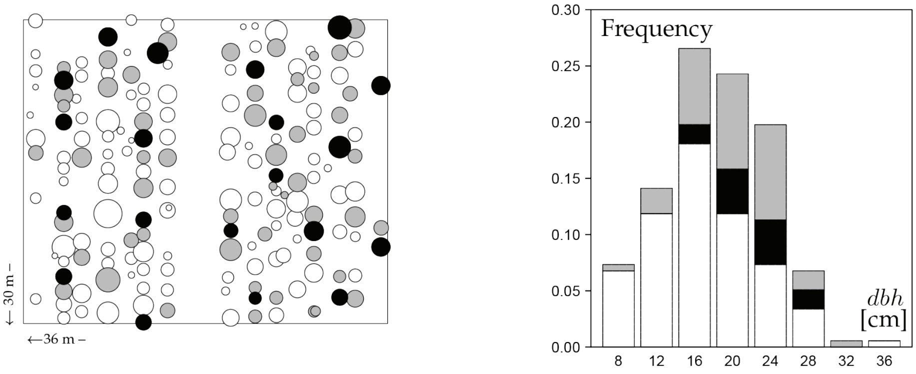

Figure 2. Map and proportions of frame and competitor trees marked by one test person in the Clocaenog marteloscope experiment in North Wales in 2006. Details are provided in the text.

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[1] Frame trees (also referred to as future crop trees) are trees that are selected for their specific characteristics (e.g. economic or conservation value) and retained 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.

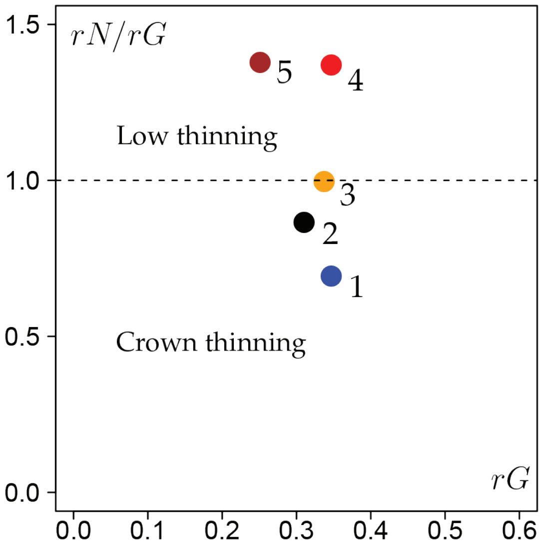

Figure 4. The *NG* ratio of five test persons in the Coed y Brenin marteloscope.

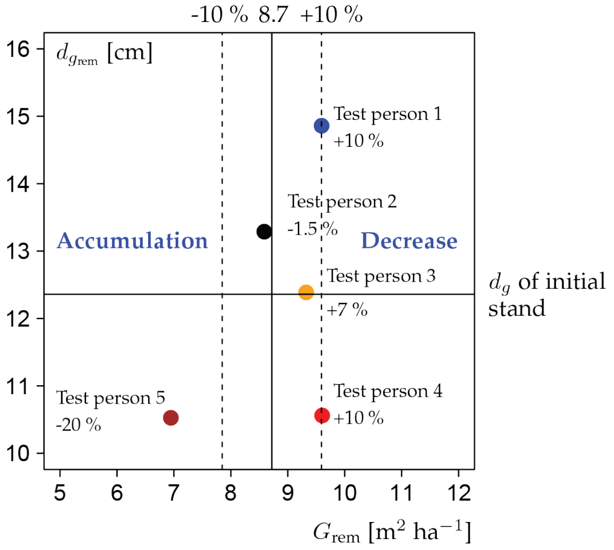

Figure 5. Quadratic mean diameter over basal area of trees marked for thinning by five test persons in the marteloscope experiment at Coed y Brenin. The stand growth rate of 8.7 m^2 ha^{-1} was recorded for the period 2006–2011.

was 13 and this implies that two trees were marked by 13 test persons out of 15. The distribution suggested by the bar chart is reminiscent of a binomial distribution and the shape indicates little agreement.

Fleiss et al. (2003) described measures of agreement used for ratings on categorical scales in psychological and medical research. Among them is a measure κ (kappa) for multiple test persons.

$\kappa = 1$ indicates complete agreement, values close to zero, on the other hand, are almost chance agreements. In contrast to many applications in medicine and psychology, kappa applied to marteloscope experiments usually scores comparatively low indicating poor agreement. For example, in the mixed broadleaved-conifer plantation at Coed y Brenin in Wales, planted in 1985, including 387 trees and 15 test persons, κ was 0.102. Slightly better results were found in an Irish marteloscope including 131 trees and 24 test persons in a pure Sitka spruce plantation with $\kappa = 0.194$. When applied to the selection of frame trees in the same marteloscope κ was 0.310. Apparently it is easier to agree on final crop trees that remain in the forest until final harvesting than on the competitors of these frame trees. The concept of identifying potentially harmful trees for eviction seems to be a highly abstract and difficult one for the human mind. This may explain why the overall results are poor. In recent research, we also found that κ was on average around 0.40 for thinnings from below at nine different marteloscopes across Great Britain and around 0.15 for crown thinnings on the same sites using the same test persons. Thinnings from below have so far been usual practice in Great Britain and the recent introduction of crown thinnings as part of Continuous Cover Forestry possibly inspired confusion in tree selection behaviour.

When moving on to analyse the behaviour of individual test persons, we can for example quantify the thinning type the different test persons have applied. This is very useful, since thinning types, e.g. crown thinning and thinning from below[2], in silviculture have a strong effect on forest development and are often handled as qualitative concepts. In many marteloscope training sessions it even turned out that some test persons were convinced of marking for a crown thinning, however, the statistics, much to their surprise, indicated a thinning from below: The perception of what humans sometimes think they do can be different from what they actually do. A suitable indicator of thinning type is the *NG* ratio (Kassier 1993), defined as the relative number of trees removed divided by the relative basal area removed.

If $NG = 1$, the mean size of the trees marked is near the mean basal-area tree, d_g. This can often be the result of a natural disturbance such as windthrow or snow damage. If $NG < 1$, proportionally less trees were removed than basal area. This typically indicates a crown thinning. Finally, proportionally more trees were removed than basal area if $NG > 1$ indicating a thinning from below. The more an observed *NG* ratio differs from 1, the clearer the thinning-type trend. Figure 4 shows the distribution of the *NG* ratio

"Research in human tree selection behaviour is an inspiring, novel research direction."

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[2] A *crown thinning*, also referred to as *high thinning* or *thinning from above* involves the removal of big, dominant trees to favour trees of roughly the same size. A *thinning from below* or *low thinning* implies the removal of smaller and less dominant trees than those that are favoured and usually dominate the main canopy (after Helms 1998).

of five test persons in the Coed y Brenin marteloscope. We can clearly see that the thinning intensity (measured on the abscissa in relative basal area, *rG*) is almost similar (with the notable exception of test person 5), however, two test persons have marked for a thinning from below, one person for an indifferent and two persons for a crown thinning, although all test persons were briefed to aim at a crown thinning. Using the *NG* ratio as part of a marteloscope experiment in Tikincor Forest (County Tipperary, Ireland) indicated that inexperienced test persons were able to learn and implement new forest management techniques more readily than experts. Interestingly, in the same study, the agreement among experts was larger before rather than after training (Vítková et al. 2015). This was not a totally unexpected outcome, but the finding is crucial for the future design of education and training in forestry.

If growth rates can be calculated from past survey records, it can also be useful to check how much the tree volume or basal area suggested by the test persons in their markings coincides with the increment of the last five or ten years. This provides crucial information about the sustainability of a suggested intervention. Figure 5 depicts the same five test persons as in Figure 4. All test persons above the horizontal line representing the initial quadratic mean diameter performed a tree marking corresponding to a crown thinning. The two participants 4 and 5 below this line made decisions leading to a thinning from below.

The vertical solid line marks the stand increment of the last five years and is accompanied by two dashed vertical lines that give a region of allowance of ±10 %. Assuming that no additional thinning is carried out within the next five years other than the one defined by the test persons, basal-area values smaller than 8.7 m^2 lead to an accumulation of basal area. Values larger than 8.7 m^2 result in a decrease of stand basal area. The marking of test person 2, a university student without forestry education, is closest to the observed stand increment whilst test person 5, a professional forester, has marked trees so that basal area will further accumulate. All others carried out a marking that decreases stand basal area, which makes sense in this very dense forest stand. Interestingly, test persons 1 and 4 both mark trees to amount to 10 % more than the basal area increment of the last five years, however, one of them carries out a crown thinning and the other a thinning from below.

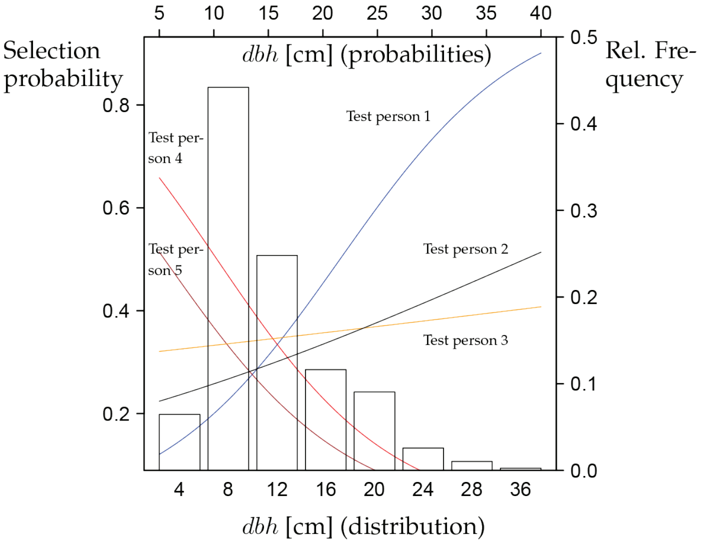

Figure 6. Tree selection probabilities of five test persons participating in a marteloscope experiment at Coed y Brenin and their dependence on *dbh*.

Finally, we can use covariates to learn about factors that may have influenced human decision making. In analysing them we can draw on experience and knowledge from mortality and survival analysis. The technique used to analyse tree selection probabilities is that of logistic regression with binary response. The probability of selection success can now be related to a set of linear predictors. In the simplest case we can start with stem diameter and later involve other covariates to see which of them had the greatest influence on the marking decisions of a particular person.

Figure 6 featuring again the same five test persons as in the previous figures clearly shows that test persons 1, 2, 4 and 5 have been influenced by stem diameter whilst test person 3 has not responded much to *dbh*. For this test person stem diameter has not been an important criterion. With test persons 1 and 2 the selection probability increases with increasing stem diameter. This suggests a tendency towards a crown thinning. Test persons 4 and 5 show a tendency reflecting thinning from below, as the tree selection probability increases with decreasing stem diameters. Interestingly, we also found that the person-specific parameters of the logistic regression model were strongly correlated with the respective *NG* ratios.

Implications and future directions

Research in human tree selection behaviour is an inspiring, novel research direction at the interface between natural sciences, social sciences and ecology. It uses a strictly interdisciplinary approach by combining statistical methods from outside forest science with forestry knowledge. At the same time, the research described in this fact sheet can also be considered as impact analysis contributing to transparency of decision making in forestry and thus to professional credibility. Research in human tree selection behaviour also provides useful information for modelling person-specific thinning and harvesting strategies as well as on their variability to be incorporated in tree and forest simulators. The analysis of human choices in forests helps to predict the consequences of interventions and keeps data up to date. Marteloscope-based research is also citizen science, where frequently non-scientists collect data and make them available to professional researchers for detailed analysis.

Marking exercises and training sessions promote forestry education, life-long learning and continuing professional development. Thus forestry staff can re-confirm skills and knowledge in regular sessions similar to hunters and stalkers who have to train the command of their weapons on a regular basis and acquire new skills. In this sense, marteloscopes are also tools for – as Klaus von Gadow put it – preventive sustainability control and adaptive management. Finally, as part of open-day events at universities and colleges, marking exercises and experiments can be organised to inspire prospective students. In the same way other groups of people outside forestry with a very different professional background can carry out tree markings as team-building events. However, the topic of human tree selection is much bigger and includes the selection of habitat trees in nature conservation, the marking of trees by harvester drivers in forest operations, the virtual removal of trees in simulator software, the selection of trees by indigenous people as opposed to professionals as well as the selection of trees for burial in forest cemeteries or the selection of Christmas trees in a Christmas tree plantation. In all these activities, trees are selected for various different purposes and the selection process is affected by a wide range of different factors, which partly relate to the trees and the forest ecosystem which they are part of and partly to implicitly human factors. Anybody interested in this research or in the practical application of marteloscopes is welcome to contact the authors for advice.


A student from the Estonian University of Life Sciences selecting trees in a marteloscope at Järvselja Forest (Estonia). Photo: Arne Pommerening

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Marteloscope, marking, forest management, agreement, logistic regression.

Read more:

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